Comprehensive Investigation Report and Remedial Alternatives Analysis Swann Park Baltimore, Maryland

Submitted on behalf of

Honeywell

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and

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October 2007

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HONEYWELL SITE#: R35113
DOCUMENT FILE LOC: 4.03.02

Executive Summary

Swann Park is located at the intersection of McComas Street and Race Street, in South Baltimore. The Park opened in the early 1900s and is partially constructed on fill placed along the Middle Branch of the Patapsco River. The park is currently closed, but was historically used by neighborhood residents for recreation and local schools and sports groups hold athletic practices and games at the Park. The Park is adjacent to a former Allied Chemical Race Street plant that was closed and demolished in 1976. Historically, the plant manufactured and blended pesticides and other agricultural chemicals.

On April 24, 2007, the Maryland Department of the Environment (MDE) issued an administrative order to the City of Baltimore (City) and Honeywell International Inc. (Honeywell) to investigate and propose a remedy for Swann Park. Over the last several months, Honeywell and the City have worked expeditiously to meet the requirements of MDE's Order. With the City's assistance, Honeywell has undertaken a thorough investigation of environmental conditions in soil and groundwater at Swann Park, has completed a human health risk evaluation in accordance with MDE and United States EPA guidance, and has evaluated a number of possible approaches to cleaning up the Park. In this report, Honeywell and the City are jointly proposing a cleanup approach that will protect human health and the environment and promptly return the Park to the community for recreational use. The proposed cleanup includes:

- Removing 3,200 cubic yards of contaminated soil;
- Covering the entire park surface with a clean soil layer that is two feet deep to ensure the protection of park users by preventing contact with the remaining soil; and
- Constructing utility corridors to protect utility workers.

This report summarizes the work that has been completed to date, the cleanup options that have been considered, and the cleanup approach being recommended by Honeywell and the City. Under the terms of the Order, MDE will select the final remedy for the Park after soliciting comments from the public.

The Investigation of Environmental Conditions at Swann Park

In April, 2007, at MDE's request, Honeywell collected 46 shallow soil samples from Swann Park. Subsequently, under MDE's Order, Honeywell collected 21 additional discrete and composite surficial soil samples and also collected 36 additional deeper soil samples. All told, Honeywell collected more than 100 soil samples. In addition, Honeywell collected eight groundwater samples from the Park. The samples were analyzed by an independent laboratory for a broad range of potential contaminants, including metals, pesticides, and volatile and semi-volatile organic compounds. The results of those analyses are contained in this report.

Soil Results

The laboratory results demonstrated that arsenic is the only chemical that is consistently detected in soil at the Site at levels that exceed MDE's regulatory screening criteria. In

general, the results also demonstrated that the highest levels of arsenic were found in the northwest corner of the Park and along the northern boundary with the former Race Street plant. Further, the results indicated that arsenic levels in soil generally are higher at the surface and decline with soil depth below the surface, except along the northern property line, suggesting limited downward migration of arsenic from the surface soils to deeper soils

1. Surface Soils—Arsenic detections in surficial soils (0 to 3 inches deep) are fairly widespread across the Park but are highest in the northwest corner of the Site where, at one location, arsenic levels exceed 800 mg/kg. A defined area of arsenic detections that exceed 200 mg/kg is present in surficial soils in the central portion of the Site, and most (but not all) concentration values in surface soils exceed 100 mg/kg across the Site. The volume averaged concentration of arsenic in surface soils across the entire 10.4 acre park was calculated to be approximately 175 mg/kg.

2. Shallow Subsurface Soils—Soils between 9 inches and 2 feet below the surface also contained arsenic, but at levels below those found at the surface except for an area along the northern Park boundary. The majority of soil samples in this depth range contained arsenic below 100 mg/kg although higher concentrations were found along the northern Park boundary and in the northwest corner.

3. Subsurface Soils—At depths between 2 feet and 5 feet below the surface, arsenic concentrations were detected below approximately 50 mg/kg across most of the Site, except for a few locations along the eastern boundary and the northwest corner.

Groundwater and Stormwater Results

Groundwater data demonstrated that arsenic is the only contaminant detected above relevant regulatory criteria. Elevated levels of arsenic in groundwater are limited to the northwestern corner of the site, and appear to be related to the high levels of arsenic found in soil in the same general area. In addition, arsenic is present in a segment of the storm drain system that runs beneath the park. The limited spatial distribution of arsenic concentrations in groundwater, together with the geochemistry of the water, indicates that the elevated arsenic conditions are localized to the northwest corner of the park. Groundwater at Swann Park is not a source of drinking water.

Human Health Risk Evaluation

MDE's Order required the completion of a human health risk evaluation that is used to develop risk-based remediation goals. These goals were developed using site-specific data to the extent such data was available, including:

- Site-specific data regarding the bioavailability of the arsenic at the park and the mineral phases in which it is found were incorporated into the risk evaluation; and

- The amount of time recreational users might spend at the park were based on high school athletic schedules, recreational sports league schedules, and other information regarding actual historic and projected use of Swann Park.

The risk evaluation considered four basic categories of park users: a high-school youth playing sports at the park, an adult playing recreational sports at the park, a child watching

sporting events, and a construction/utility worker. Remedial goals were calculated for each type of Park user to correspond to a hazard index of 1 or an incremental cancer risk of 1 X 10^{-5} (1 in 100,000). Based on the health evaluation, the calculated remedial goals for arsenic were 212 mg/kg for recreational users and 454 mg/kg for construction workers.

Although MDE's order required a human health risk evaluation and the report contains information based on that requirement, the recommended remedy eliminates the potential exposure pathways to the public. As discussed further below, the placement of a minimum of two feet of clean soil over the entire Park surface area ensures the protection of recreators by eliminating their potential for exposure to any soil that is currently at the Park. Utility or construction workers are protected by removal of soils above risk-based concentrations before the clean cover is placed. In addition, utility corridors will be excavated and backfilled with clean soil where primary utilities are to be located.

Screening of Remedial Technologies

The first step in evaluating potential cleanup approaches for Swann Park is to identify and screen those cleanup technologies that have been used elsewhere and are widely accepted as effective means of addressing arsenic contamination. As a result, a wide range of different technologies were initially evaluated including: chemical treatment or solidification of the arsenic-impacted soil, biological treatment, soil mixing, soil removal, institutional controls, and the addition of a clean cover for the Park.

Technologies were initially screened based on the potential for effectiveness, implementability and comparative cost. Several of these technologies were determined to be inappropriate for Swann Park. For example, use of chemical treatment or solidification would likely require several years of pilot studies and the Park would have to remain closed for that period. Biological treatment would involve planting trees and bushes that may well be incompatible with future park use. Biological remediation would also take a long time. Soil mixing (i.e. mixing clean soil with contaminated soil to reduce overall average concentrations) was also rejected as a potential remedy because other remedies were equally or more protective.

Containment remedies using a clean soil cover were retained because they would eliminate the exposure pathway to park users. Excavation of soils that have arsenic concentrations exceeding risk-based levels was also retained for consideration. Excavation of soils with arsenic above background levels or default residential criteria was considered, but eliminated from further evaluation because it was not necessary for compliance with the MDE order. It would also significantly delay reopening of the park, and could present unnecessary risks to the community, construction workers, and motorists during construction. Moreover, other remedies are available that provide equivalent effectiveness, have widespread acceptance and application at other similar sites and can be implemented safely and expeditiously.

Remedial Alternatives Development and Evaluation

The general remedial approaches that were retained for a more thorough analysis include components of soil removal or excavation, the placement of a soil cover, and institutional and engineering controls. Each remedy was first evaluated to confirm that the remedy

would be protective of human health and the environment. Remedies that meet that threshold requirement were then evaluated against a number of other important factors as required by MDE, including: compliance with applicable regulations, short term effectiveness, long term effectiveness and permanence, the degree to which a remedy reduces toxicity, mobility, or volume through treatment, implementability, and cost. In addition, any remedy needed to be consistent with the City's continued use of the property as a Park. The remedies evaluated are presented in the table below:

Number	Alternative	Description
1	No Action	No remediation, Park left as is.
2	Soil Removal, No Cover, and Land-Use Controls	Excavation of soils exceeding site-specific, risk-based values within 24-inches of final grade and land-use controls.
3	Soil Removal, 12 inch Cover, and Land-Use Controls	Excavation of soils exceeding site-specific, risk-based values for a construction worker; construction of a 12-inch clean soil cover to eliminate exposure to park users by preventing direct contact with remaining soils; and land-use controls.
4	Soil Removal, 24 inch Cover, and Land-Use Controls	Excavation of soils exceeding site-specific, risk-based values for a construction worker; construction of a 24-inch clean soil cover to eliminate exposure to park users by preventing direct contact with remaining soils; and land-use controls.
5	Soil Removal to the Groundwater Table and 24 inch Cover	Excavation of soils exceeding site-specific, risk-based values calculated for a park user to the groundwater table and construction of a 24-inch clean soil cover to prevent direct contact with remaining soils; and limited land-use controls.

The "No Action" remedy was included in the evaluation in accordance with MDE guidance as a baseline for comparison to the other remedies. Alternative Remedies 2 through 5 each involve the excavation of certain soils containing arsenic. Because the vast majority of significantly contaminated soil is found in the top two feet below the ground surface, Alternatives 2, 3, and 4 focus on soil removal within that zone. Alternative 2, for example, requires excavation of any soil in the top two feet that exceeds the calculated remedial goal for recreational users. Alternatives 3 and 4 require excavation of soil that exceeds the calculated remedial goal for construction workers who might excavate the soil and installation of clean utility corridors. Those alternatives also provide added protection for recreational users and others through the placement of a clean soil cover to eliminate their exposure to any existing site soils that remain at the Park. Alternative 5 requires excavation of soil above the calculated remedial goal for recreational users all the way down to the water table.

Alternatives 2 through 5 are all protective of human health and the environment, and can all be implemented at the Park. In addition, they all include removal of arsenic "hot spots," particularly in the northwest corner of the Site. Alternatives 3 and 4 are considered to be superior to Alternatives 2 and 5 in effectiveness for the following reasons:

- The clean soil cover eliminates the potential that people playing in the Park will come into contact with soil containing arsenic --even at low levels;

- Implementation of Alternatives 3 and 4 will have significantly less potential impact on the community during their construction, which will take less time than either Alternative 2 or 5; and
- The additional soil added by the cover is consistent with the City's plans for improving the Park, which require the overall grade of the land surface to be raised.

MDE uses cost-effectiveness as a means to select a remedial alternative from those that are determined to be protective of human health and the environment. Alternatives 3 and 4 were determined to be more effective and cost less than Alternatives 2 and 5, making these alternatives the most cost-effective remedies for Swann Park.

Recommended Remedial Alternative

Implementation of Alternative 4 at Swann Park is the joint recommendation of the City and Honeywell. The two feet of clean soil cover that would be placed across the entire park in Alternative 4 will provide additional confidence that the remedy is protective of human health and the environment. The clean soil cover eliminates the potential that people playing in the Park will come into contact with soil containing arsenic --even at low levels. Second, the additional soil added by the cover is consistent with the City's plans for improving the Park. Hot spot removal and the use of engineering controls in utility corridors will ensure that construction workers can work safely in the Park in the future. The estimated cost of Alternative 4 is $3,493,000. This fully protective remedy can also be implemented rapidly with minimal disruption to the community and will ensure timely completion of the City's renovation of the Park and its return to the community for recreational use.

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SECTION 1

Introduction

This Comprehensive Investigation Report and Remedial Alternatives Analysis (CIR-RAA) provides the results of an environmental investigation that was completed at Swann Park (hereafter referred to as "the Site") in June 2007. The investigation results are primarily used to characterize Site conditions and develop and evaluate remedial action alternatives for the Site. The objectives and technical approach for the investigation are presented in the Comprehensive Investigation Work Plan (CIWP), which was submitted on June 6, 2007 and approved by the Maryland Department of Environment (MDE) on June 12, 2007.[1] (CH2M HILL 2007a).

The CIWP was prepared in accordance with the April 24, 2007 MDE Order (the Order) issued jointly to the City of Baltimore and Honeywell International Inc. (Honeywell) (MDE, 2007a). This CIR-RAA has been prepared to satisfy Sections 2 and 3 of the Order. Table 1-1 illustrates how specific requirements of Section 2 of the Order are addressed in this report. Items specified in Section 3 of the Order are addressed in Sections 9 through 12 of this CIR-RAA.

The CIWP and the Order specified that a soil and groundwater information report was to be submitted to MDE within 30 calendar days after CIWP approval. This requirement was met through submission of the Preliminary Draft Soil and Groundwater Data Report (Data Report) to MDE on July 12, 2007 (CH2M HILL, 2007b). The Data Report presented a brief synopsis of the investigation activities and nonvalidated analytical results for the primary Analytes of Interest (AOIs) and supporting analyses. This CIR-RAA provides a detailed investigation summary and validated set of analytical results. Honeywell and the City of Baltimore are submitting this report pursuant to the MDE approval of the Data Report on August 9, 2007 which required the CIR and RAA be submitted by no later than September 14, 2007.

1.1 Organization

This CIR-RAA is organized into 14 sections as outlined below:

Section 1 – Introduction
Section 2 – Site Description
Section 3 – Investigation Methodology
Section 4 – Physical Characterization
Section 5 – Analytical Results
Section 6 – Extent
Section 7 – Fate and Transport
Section 8 – Development of Risk-Based Remedial Goals
Section 9 – Development of ARARs and RAOs

[1] CIWP Approval Letter from Ms. Peggy Smith, MDE CHS Enforcement Division to Mr. Christopher French, Honeywell International Inc. dated June 12, 2007.

Section 10 – Screening of Remedial Technologies
Section 11 – Development of Remedial Alternatives
Section 12 – Detailed Analysis of Remedial Alternatives
Section 13 - Conclusions and Recommendations
Section 14 - References

SECTION 2

Site Description

Swann Park is located in south-central Baltimore City (Figure 2-1). The park property currently consists of approximately 11 acres of athletic fields and associated green space (Figures 2-2). There are eight athletic fields at the park consisting of one baseball field, three softball fields, and four fields used for soccer, football, and other sports (Figure 2-2). There are no buildings on Swann Park and the only structures are associated with the athletic fields (e.g., scoreboards and backstops).

Swann Park is currently owned by the City of Baltimore and has been used as a park since circa-1905 (City of Baltimore, 1905). A stone bulkhead located along the western property boundary was constructed between 1905 and 1912 and a storm drain line that crosses through the park was constructed circa 1912 (City of Baltimore, 1912). Additional details regarding the physical characteristics of the park are presented in Section 4.

2.1 Surrounding Land Use

Swann Park is immediately surrounded by properties that are used primarily for industrial purposes. Specifically, land use on immediately adjacent properties and features consists of the following:

- The Middle Branch of the Patapsco River (Middle Branch) bounds Swann Park to the west.
- The Western Maryland Railroad bounds Swann Park to the south.
- The Schuster Concrete facility bounds Swann Park to the east (south of McComas Street).
- An unoccupied building bounds Swann Park to the east (north of McComas Street).
- The location of a former pesticide manufacturing facility (referred to as the "2000 Race Street Site") bounds Swann Park to the north. This property is currently owned primarily by the City of Baltimore and is now covered with an engineered asphalt and clay cap.

Residential units are located to the east Swann Park. These units, consisting of seven row-houses, lie between McComas Street and the Schuster Concrete facility (Figure 2-2). The westernmost row house is separated from the park boundary by a distance of approximately 90 feet across an open parking area.

2.2 Surrounding Land Use Assessment

An assessment of land use and ownership within a defined buffer zone that surrounds Swann Park was conducted as a part of the comprehensive investigation activities. The buffer zone was defined as a circular area, with a radius of 1,000 feet, positioned on the northeast corner of Swann Park (Figure 2-3). The primary objectives of this assessment were

to further evaluate land use in vicinity of Swann Park, identify listed hazardous waste sites within the buffer zone, and identify areas where environmental investigations have been performed.

Including the adjacent Race Street Site, six hazardous waste sites are located within the defined buffer zone and were identified through the use of EPA's EnviroMapper technology and MDE's Environmental Restoration and Redevelopment Program (ERRP) websites (Figure 2-3). General information regarding these facilities is listed in Table 2-1. Further evaluation of these listed sites is provided in the following sub-sections.

TABLE 2-1
Listed Hazardous Waste Sites within approximately 1000 feet of Swann Park

Facility	Address/Zip Code	Classification
2000 Race Street Site (Former Allied Chemical Agriculture Plant)	2000 Race Street	Former Agricultural Chemical Production Facility
BG&E Spring Gardens	1699 Leadenhall St.	Multi-Activities (Power Transmission)
Middleton and Meads Co Inc	1900 S Hanover St	Hazardous Waste (Automotive Paint and Body Repair)
1800 S Hanover St	1800 S Hanover St	Gasoline Filling Station
Baltimore City General Garage	101 Dickman St	Hazardous Waste (Automotive Repair)
BFI Waste Systems	260 W Dickman St	Air Emissions (Refuse)
240 W Dickman St	240 W Dickman St	CSX Railroad/Lumber Yard

2.2.1 2000 Race Street Site (Former Allied Chemical Agriculture Plant)

The 2000 Race Street Site is the location of a former Allied Signal, Inc. (predecessor to Honeywell) agricultural chemical production and repackaging facility which operated from the 1880s to approximately 1976. Currently, the site is vacant with no buildings or materials present on grade, with the exception of the aboveground support structures associated with overlying spans for Interstate-95. Controlled hazardous substances (CHS) associated with former pesticide and herbicide operations and chromium ore processing residue are contained on the Race Street Site as discussed below and are covered with an engineered asphalt and clay cap. There are no ongoing CHS management activities at the Site; the Site is closed and has not accepted CHS since 1976.

The facility is listed as a non-National Priorities List (NPL) site in EPA's Comprehensive Environmental Response, Compensation and Liability Act Information System (CERCLIS) and the facility status is No Further Remedial Action Planned (NFRAP). Further investigation activities are planned based on a Consent Order between Honeywell, the City of Baltimore, and MDE dated May 23, 2007.

2.2.2 BG&E Spring Gardens

The BG&E Spring Gardens Facility was constructed in 1855 to manufacture gas through the distillation of coal. During the manufactured gas operations period, the facility produced gas by four different methods including water gas, carbureted water gas, oil gas, and coke (USEPA, 1985). Between 1942 and 1966 the facility was converted from manufactured gas to natural gas.

The Spring Gardens facility is currently listed as a natural gas transmission center. The facility maintains a National Pollution Discharge Elimination System (NPDES) permit to discharge a number of substances and the facility is listed by the Resource Conservation and Recovery Act Information System (RCRAInfo) as a handler of hazardous waste. The facility is listed in the CERCLIS database, but as of 1990 the site was archived from the list of active sites. The facility is non-NPL and the facility status is NFRAP.

2.2.3 Middleton and Meads Co

Middleton and Meads is an automotive paint and body repair shop. The facility is a small generator of hazardous waste and is listed by the Maryland-Resource Conservation and Recovery Act (MD-RCRA) program. Middleton and Meads is bounded to the north by the 1800 South Hanover Street site (MDE, 2007b).

2.2.4 1800 South Hanover Street

The property at 1800 South Hanover Street was historically utilized as a gasoline filling station, warehouse, and motor freight station. The property bounds the Middleton and Meads facility to the north. A Phase I Environmental Site Assessment (ESA) conducted on the property identified concentrations of metals and petroleum hydrocarbons in soil. The ESA report was not available for review during preparation of this report. An application to the Voluntary Cleanup Program (VCP) for this property is currently being reviewed by MDE (MDE, 2007b).

2.2.5 Baltimore City Department of Public Works General Garage

The Baltimore City General Garage is an active automotive maintenance facility for fleet vehicles of the Baltimore City Department of Public Works. The facility is listed by RCRA Info. As of May 11, 2005 the facility was accepted into the MDE VCP/Brownfields Division (MDE, 2006A). Phase I and Phase II ESAs have been performed on the property and have identified concentrations of metals, poly-cyclic aromatic hydrocarbons (PAHs) and petroleum compounds in soil (MDE, 2006a). Specific information from these ESAs was not available for review during preparation of this report.

South of the Baltimore City Garage Property and outside of the 1,000-foot buffer zone is the Middle Branch Park Property. Although this Middle Branch Park property is located outside the Swann Park buffer zone, it is noted herein since metals and PAHs were identified in soil and groundwater during ESAs conducted on the property (MDE, 2005). The Middle Branch Park Property was accepted into the VCP in 2003 (MDE, 2005).

2.2.6 BFI Waste Systems

BFI Waste Systems is a subsidiary of Allied Waste, Inc. and the primary function of BFI appears to be the trucking and handling of general refuse. According to EPA Envirofacts, the facility maintains air emissions and/or multi media permits with MDE.

2.2.7 240 West Dickman Street

240 West Dickman Street is an operating lumberyard that encompasses multiple parcels and includes several railroad spurs. The facility appears to have been constructed mainly on land reclamation fill. ESAs conducted on the property have identified concentrations of total chromium, hexavalent chromium, lead, mercury and total petroleum hydrocarbons – diesel range organics (TPH-DRO) in soil and arsenic, cadmium, chromium, lead and mercury in groundwater (MDE, 2006B). The ESA reports were not available for review during preparation of this report. The property was accepted into the MDE Voluntary Cleanup Program as of July 14, 2006 (MDE, 2006b).

2.3 Recent Investigation History

In April 2007, surface soil sampling was performed at Swann Park as requested in an April 12, 2007 letter from MDE to the City of Baltimore and Honeywell International Inc. Soil sampling was completed at 23 sample locations identified as SP-DP-01 through SP-DP-023 (Figure 2-4) (CH2M HILL, 2007c). Two soil samples were collected from each location at depth intervals of 0 to 3 inches below grade and 3 to 9 inches below grade. A total of 46 field samples were collected for laboratory analysis consisting of metals, hexavalent chromium, SVOCs, pesticides (organophosphorus and organochlorine), and herbicides.

The analytical results for this April 2007 sampling event were provided to MDE and the City of Baltimore in three separate transmittals from Honeywell dated April 19, 2007, April 23, 2007, and April 27, 2007 (Honeywell, 2007a; Honeywell, 2007b; Honeywell, 2007c). They were also provided in Appendix A of the CIWP (CH2M HILL, 2007a).

MDE subsequently issued an Order on May 24, 2007 to Honeywell and the City requiring a comprehensive investigation to study and assess contamination of soils and groundwater at the Site (MDE 2007a). The results of the comprehensive investigation contained herein are presented in response to the Order.

SECTION 3

Investigation Methodology

The objective of Section 3 is to describe the methodology employed for the comprehensive investigation activities conducted at Swann Park. The technical approach and methodology for the investigation was originally outlined in the CIWP and, with few exceptions discussed below; the field investigation was conducted as specified in the CIWP. Investigation tasks included a sample location survey, utility clearance, surface soil sampling, subsurface soil sampling, monitoring well installation, slug testing, groundwater sampling, collection of synoptic water level measurements, storm water sampling, elevation surveying, and a closed-circuit television (CCTV) inspection of the storm drain system. All of these tasks were completed between the dates of May 16, 2007 and June 5, 2007. In addition to Honeywell's consultant (CH2M HILL), representatives of the City, Honeywell, and MDE were periodically on-site during field activities. The City's consultant, Environmental Resources Management (ERM), was present for a majority of the on-site fieldwork activities.

3.1 Sample Location Survey

Coordinates for the proposed sample locations at Swann Park were obtained from a geographic information system (GIS) and were uploaded onto a Trimble Pro-XRS® differential global positioning system (GPS). On May 16 and 17, 2007 the GPS was used in the field to locate and mark the proposed sample stations with a wooden stake. With only one exception, all actual sample locations coincided with locations proposed in the CIWP. The only exception involved a slight location adjustment to monitoring well SP-MW-006 due to the proximity of the proposed location to a subsurface utility (City of Baltimore storm water line). The horizontal position and elevation of each monitoring well was later surveyed as outlined in Section 3.8.

3.2 Utility Clearance

After the sample locations were marked and prior to intrusive activities, subsurface utilities were located and marked at Swann Park. The utility clearance was performed on May 18, 2007. Utilities were marked within a 25 foot radius of each proposed borehole location using a GSSI SIR-3000® Ground-Penetrating Radar (GPR) and electrical induction methods.

Identified utilities included an electrical line, a water line, and the storm drain system. A manhole in the central portion of Swann Park was identified during the GPR survey and was buried beneath approximately four inches of soil. With the exception of the above mentioned utilities, subsurface utilities appear to be absent throughout the main portion of the Site.

3.3 Dust Monitoring

In accordance with the Health and Safety plan, MiniRam PDM-3 dust monitors were used to measure the concentration of airborne particulates during all drilling, soil sampling and

other miscellaneous tasks performed during the field investigation. The monitors were zeroed daily and were set to measure and log the concentration of airborne particulates in 10 minute intervals. The data indicates that dust concentrations remained well below the action level (0.9 mg/m^3) throughout the field investigation.

3.4 Surface Soil Sampling

Composite and discrete surface soil samples were collected during the Swann Park investigation. All surface soil samples were collected from a depth interval of 0-3 inches below grade. During the investigation, MDE was provided with a split soil sample at all discrete surface soil sample locations. Prior to collection, all sample locations were photographed in order quantify the fraction of vegetative cover present at each location. The composite surface soil sampling task was completed between the dates of May 21, 2007 and May 25, 2007. Discrete soil sampling was performed in conjunction with the installation of direct push technology (DPT) borings and was completed between the dates of May 22, 2007 and May 31, 2007.

3.4.1 Composite Surface Soil Sampling

Composite surface soil samples were collected from eight locations, defined as Field 1 through Field 8 (Figure 3-1 through 3-8). Within each Field, an equal volume of surface soil was collected from 30 discrete sample locations which had been randomly generated and marked prior to the investigation. The total volume of soil from all discrete locations within a particular Field was then homogenized to create one composite surface soil sample that is representative of conditions at each Field.

Surface soil was collected at each discrete location using a stainless steel hand trowel and/or hand auger. Soil characteristics were classified in accordance with the Unified Soils Classification System (USCS) and to the degree possible, all organic material consisting mainly of turf and grass roots, was removed prior to homogenization. The total volume of soil was then homogenized in stainless steel bowls and/or disposable aluminum pans and placed in laboratory-supplied, glass containers which were labeled in accordance with the analytical schedule (Table 3-1).

3.4.2 Discrete Surface Soil Sampling

Discrete surface soil samples were collected at 13 locations on Swann Park (Figure 3-9). Since many of the proposed sample locations coincided with proposed DPT locations, samples requiring low volume ($\leq$ 4 liters) were collected with a DPT rig. The required sample volume was obtained by advancing an acetate-lined macrocore to a depth of 3 inches in multiple boreholes within 2 to 3 feet of the proposed sample location. Surface soil samples requiring more volume (> 4 liters) were collected with a stainless steel trowel and/or hand auger.

During collection, the soil characteristics were classified in accordance with the USCS and to the degree possible, all organic material was removed. Soil samples were homogenized in stainless steel bowls and/or disposable aluminum pans and then placed in laboratory-supplied glass containers which were labeled in accordance with the analytical schedule (Table 3-1).

3.5 Subsurface Soil Sampling

As proposed in the CIWP, subsurface soil samples were collected from two separate depth intervals and the following text describes the methodology used to collect samples from each interval. During the investigation, MDE was provided with a split soil sample from all discrete shallow subsurface and subsurface soil sample locations. The subsurface soil sampling task was completed between the dates of May 22, 2007 and May 31, 2007.

At each DPT borehole location, an initial borehole was advanced into the subsurface at the proposed sample location. The soil core obtained from this borehole was classified according to the USCS and was screened for volatile organic compounds (VOCs) using a photo-ionization detector (PID). VOC samples were obtained from the depth interval containing the highest PID reading. If VOCs were not field detected, then the VOC sample was collected from a representative portion of the intact soil core. Multiple DPT boreholes were then advanced to the required depth interval in order to collect the requisite sample volume. These additional borings were installed within four feet of the proposed location and were not classified, but any changes in lithology or PID readings were noted by the field geologist. Soil boring logs are presented in Appendix A.

3.5.1 Shallow Subsurface Soil Sampling

Shallow subsurface samples were collected from a depth interval of 9-24 inches below grade at 23 DPT boring locations on Swann Park (Figure 3-10). The shallow subsurface soil samples were collected by advancing a 1.5-inch diameter acetate-lined macrocore to a depth of 24 inches below grade. The upper 9 inches of the soil core was then discarded and the remainder was retained in a stainless steel bowl and/or disposable pan for homogenization. The homogenized sample was placed in laboratory-supplied glass containers which were labeled in accordance with the analytical schedule (Table 3-1).

3.5.2 Subsurface Soil Sampling

Subsurface soil samples were collected from a depth interval of 24-60 inches below grade at 13 boring locations (Figure 3-11). Subsurface soil samples were collected by first advancing a stainless steel drive point to a depth of 24 inches below grade after which, a 1.5-inch diameter acetate-lined macrocore was advanced to a depth of 60 inches below grade for sample collection. A macrocore was used to collect both intervals at locations that required analysis of the 9-24 inch and 24-60 inch intervals. Subsurface soil from each sample locations soil was homogenized in a stainless steel bowl and/or disposable pan and the soil sample was placed in laboratory-supplied glass containers which were labeled in accordance with the analytical schedule (Table 3-1).

3.5.3 X-Ray Fluorescence Screening

During the investigation, all discrete surface and subsurface soil samples were field screened with an Innov-X Model 440 portable X-Ray Fluorescence (XRF) analyzer. In addition, subsurface soil collected during monitoring well installation was also retained for screening. At DPT locations, the 9-24 inch depth interval and the 24-60 inch depth interval were homogenized and screened. Subsurface soil from monitoring well locations was typically collected and screened in 1 to 2 foot depth intervals. Approximately 8-12 ounces (oz) of soil was retained at each interval and placed in a plastic bag for screening.

XRF field screening was typically performed approximately once per day with the analyzer set to soil mode and to a test duration of 30 seconds. Prior to screening, tests were run on factory-created standards of known metals concentration in order to quantify the accuracy of the analysis results. During screening, the window of the analyzer was placed tightly against the plastic bag that contained the soil sample and the test was run. In accordance with manufacturer recommendations, a soil thickness greater that 0.5 inches was maintained between the analyzer and the test stand during testing. Test data was stored in the analyzer until a daily download was performed. Results of the XRF analysis are provided in Appendix B.

3.6 Monitoring Well Installation

The following text outlines the methodology for the installation, construction, and development of monitoring wells SP-MW-001 through SP-MW-008 (Figure 3-12). The installation tasks for SP-MW-001 through SP-MW-007 were completed between the dates of May 21, 2007 and May 24, 2007. Monitoring well SP-MW-008 was installed, constructed, and developed on May 29, 2007.

3.6.1 Borehole Installation

Prior to well construction, the subsurface lithology at each well location was characterized by the classification of samples collected during the installation of a DPT borehole. Soil samples were collected in 4 foot increments with a 1.5-inch diameter, acetate lined macrocore. The recovered soil sample was logged in accordance with USCS and was screened with a PID. Soil samples were not retained for analysis at the well locations but some soil was retained for XRF screening as outlined in Section 3.5.3. Soil boring logs are presented in Appendix A.

The primary purpose of the lithologic characterization was to determine the depth to water and the depth to the top of a silt layer that is present beneath the Site. Both depth parameters were used to determine how the monitoring well was to be constructed. At the completion of lithologic characterization, an 8.25-inch diameter borehole was drilled to the top of the silt using a hollow-stem auger (HSA) drill rig and the well was constructed.

3.6.2 Monitoring Well Construction

All monitoring wells at Swann Park are constructed with 2-inch diameter polyvinyl chloride (PVC) riser and 0.010-inch, factory slotted PVC screen. The CIWP stated that all monitoring wells were to be constructed with 10 foot lengths of screen. Due to the shallow nature of some of the wells and the lithologic characteristics present beneath Swann Park, this specification was not always practical. Screen lengths were adjusted in the field so that the thickness of well seals could be maximized with shorter screens or the full extent of water bearing units could be captured with longer screens. Well construction logs are presented in Appendix A and a summary of monitoring well information is presented in Table 3-2.

The annular space around all monitoring well screens was filled to a height of 1-2 feet above the screen with #1 filter pack (quartz) sand. The sand was then capped with 1-2 feet of bentonite chips which were allowed to hydrate and form a seal prior to placing a cement-bentonite grout seal to ground surface. All monitoring wells were finished at ground surface with a protective steel cover (stick-up) and a 3 foot by 3 foot concrete pad.

3.6.3 Monitoring Well Development

Wells SP-MW-001 through SP-MW-007 were developed on May 24, 2007 and well SP-MW-008 was developed on May 29, 2007. Monitoring wells seals were allowed to cure for approximately 24 hours prior to development with the exception of SP-MW-008 which was developed prior to placement of the grout seal.

All wells were developed with a surge block and whale pump. Where possible, the flow rate of the pump was maintained at a maximum of approximately 2-4 gallons per minute (gpm). Water quality measurements of pH, conductivity, temperature, turbidity, and oxidation-reduction potential (ORP) were collected with a Horiba U-22® as development progressed. Development was halted when the water was relatively free from turbidity as determined by the water quality meter and observations by the field geologist suggested that the water was clear and a sufficient volume of water had been removed from the well. In all but one well, greater than 20 wet casing volumes of water were removed before development was considered complete. Due to low water production in SP-MW-004, approximately 9 well volumes were removed during development.

3.7 Groundwater Sampling

Groundwater samples were collected from monitoring wells SP-MW-001 through SP-MW-008 during the field investigation (Figure 3-12). A minimum of 72 hours was allowed to elapse between the completion of development and the collection of groundwater samples at each well. The groundwater sampling task was completed a between the dates of May 29, 2007 and June 1, 2007.

All monitoring wells were sampled under low-flow conditions. With the exception of SP-MW-004 and SP-MW-008, all wells were purged and sampled using a submersible pump (Grundfos Redi-Flow II). Due to an equipment malfunction on July 1, 2007, the dissolved and VOC samples from SP-MW-004 and all samples from SP-MW-008 were collected with a peristaltic pump. During purging, water quality parameters were measured with a flow-cell and Horiba U-22 until the parameters stabilized within the following limits:

- pH: within 0.1 units
- Conductivity: +/- 3%
- Dissolved Oxygen: +/- 10%
- Turbidity: +/- 10% or as low as practicable given sampling conditions
- ORP: +/-10 millivolts (mV)

Once the water quality parameters stabilized, groundwater samples were collected in laboratory supplied containers that were pre-preserved in accordance with the method of analysis. Dissolved samples were field filtered through a disposable, 0.45 micron filter as the groundwater was placed into the sampling container. Groundwater sample containers were labeled according to the proposed analytical schedule (Table 3-1).

3.8 Slug Testing

Slug tests were performed in monitoring wells SP-MW-002, SP-MW-005, and SP-MW-006 on May 31, 2007 and June 1, 2007. All testing was performed after groundwater samples had been collected at these well locations. Prior to testing, an In-Situ Mini-Troll was set to record

water level change in the wells on a logarithmically decreasing time scale so that rapid change in water levels could be assessed. The troll was then inserted into the well and securely fastened to the casing to minimize disturbance during testing.

Two falling head slug tests and two rising head slug tests were performed at each test location. Falling head tests were performed by recording the water level change after the rapid insertion of a 1.5-inch diameter slug to a depth below the water table. Rising head tests were performed by recording water level change in the well after the slug was rapidly withdrawn from the well. Water levels were allowed to recover to approximate pre-test position prior to the initiation of each test. Where possible, manual water-level measurements were collected before, during, and after testing to confirm stabilization of the water elevation and to assess the accuracy of the data logger during post-processing. Hydrographs of the raw data logger output and analysis results are provided in Appendix C.

3.9 Synoptic Water Level Measurements

Synoptic water level measurements were obtained from all wells at Swann Park and all wells at the Race Street Site on June 1, 2007. The measurements were collected prior to any sampling or slug testing tasks performed on June 1. Water level measurements were recorded with an electronic water level indicator graduated in increments of 0.01 feet. Water depths measurements were read from a measuring point on the north end of each monitoring well casing and were recorded, along with the measurement time, in the field log book. A summary of water elevation data is presented in Table 3-2.

In addition, all wells at Swann Park and the Race Street Site were gauged for the presence of non-aqueous-phase liquid (NAPL) either as light non-aqueous-phase liquid (LNAPL) or dense non-aqueous-phase liquid (DNAPL). These measurements were obtained with an oil/water interface probe graduated in increments of 0.01 feet. Water depth and/or NAPL measurements were read from a measuring point on the north end of each monitoring well casing and were recorded, along with the measurement time, in the field log book.

3.10 Storm Water Sampling

Storm water samples were collected from three sample stations located along the Swann Park storm drain system on May 24 and 25, 2007 and June 4, 2007. Samples collected on May 24 and 25 represent the dry weather samples and samples collected on June 4 represent the wet weather samples as proposed in the CIWP. During each event, samples were collected from the storm drain outfall (SP-SW-001), the manhole located near the center of Swann Park (SP-SW-002) and the manhole located at the intersection of McComas and Race Streets (SP-SW-003) (Figure 3-12).

During each sampling event, storm water samples were collected using a peristaltic pump. One water quality reading, which included measurements of pH, conductivity, turbidity, temperature, and ORP, was obtained from each location prior to sampling. In addition, the approximate depth to water at the time of sampling was noted in the field log book. Storm water samples were collected in laboratory supplied containers that were pre-preserved in accordance with the method of analysis. Dissolved samples were field filtered through a

disposable, 0.45 micron filter as the water was placed into the sampling container. Sample containers were labeled according to the proposed analytical schedule (Table 3-1).

3.11 Equipment Decontamination

All non-disposable sampling equipment used during the investigation was decontaminated according to a four step procedure that included, in order, the following elements:

1. Alconox detergent and tap water rinse
2. 10 % Methanol and tap water rinse
3. Tap water rinse
4. Deionized water rinse.

While not in use, all decontaminated equipment was stored in plastic bags or sealed in aluminum foil. The sampling equipment was decontaminated according to the following schedule:

- Trowels, bowls, and hand augers used in composite surface soil sampling tasks were decontaminated between sampling at each Field location
- Trowels, bowls, and hand augers used in discrete surface and subsurface soil sampling tasks were decontaminated between each sample location
- Steel macrocore holders, drilling stem, and hollow-stem augers were decontaminated between each borehole location and the steel macrocore holders were decontaminated between each sample depth interval
- Groundwater pumps, water level meters and oil/water interface meters were decontaminated between uses at each well location.

3.12 Quality Assurance/Quality Control Sampling

During the Swann Park investigation, Quality Assurance/Quality Control (QA/QC) samples were collected in accordance with the following schedule:

- Field (ambient) blanks were collected once per week
- Equipment (rinsate) blanks were collected once per day per sampling method
- Trip blanks were placed in each cooler that contained VOC samples
- Field duplicates were collected at the rate of one duplicate sample per 10 native samples
- Matrix Spike/Matrix Spike Duplicate (MS/MSD) samples were collected at the rate of one MS/MSD sample per 20 native samples

3.13 Investigation Derived Waste Management

Investigation Derived Waste (IDW) generated during the Swann Park investigation included soil cuttings and drilling spoils, groundwater from purge and development tasks, decontamination water, and miscellaneous waste including personnel protective equipment (PPE), used groundwater tubing and filters, used disposable soil sampling pans. All IDW

was placed in United States Department of Transportation (USDOT) approved, 55-gallon, steel drums. All IDW drums were labeled as outlined in the CIWP and were placed on pallets in a bermed staging area that is located on the 2000 Race Street Site. To the degree possible, the IDW generated at specific locations was kept separate for characterization and disposal purposes.

On June 1, 2007, IDW characterization samples were collected. Three IDW soil samples and three IDW water samples were collected during this event. All samples were analyzed for TCLP, reactivity, corrosivity, ignitability, pesticides (EPA Method 8081) and chlorinated herbicides (EPA Method 8151A).

3.14 Sample Handling

All samples were handled in accordance with industry standard Chain-of-Custody (COC) procedures. Completed samples were labeled in accordance with the proposed analytical schedule and placed on ice immediately after collection. A temperature blank was included in each cooler to ensure that the samples were cooled to a preservation temperature of 4° C. Due to the short holding time (48 hours) for analysis of hexavalent chromium in water samples, all samples were picked up by a courier from Lancaster Laboratories, Inc. at the end of each sampling day.

3.15 Elevation Survey

Elevation surveys were conducted at Swann Park on May 30 and 31, 2007. The elevation survey included a topographic survey of the park and a survey of monitoring well elevations. The horizontal and vertical datum used in the survey was Maryland State Plane, North American Datum [NAD], 1983 and (North American Vertical Datum [NAVD], 1988, respectively. A minimum of three control points were installed prior to the survey and the surveyor installed two elevation bench-marks that can be utilized for future elevation measurements at the park. Each survey element is described in further detail below.

3.15.1 Topographic Survey

The topographic survey included the measurement of elevations across the entire area of Swann Park up to the shoreline at Middle Branch and extending a minimum of 50 feet beyond the remaining property boundary. The topographic survey was conducted on a grid spacing that allowed for the generation of a topographic map with a one foot contour interval.

3.15.2 Monitoring Well Survey

The horizontal position and elevation of all monitoring wells at Swann Park were determined during the elevation survey. The survey at each well included elevation measurements for the top of the PVC casing (TOC), top of the steel protective cover, concrete pad, and ground. A summary of the TOC and ground elevations and horizontal coordinates are provided in Table 3-2 and a full set of monitoring well survey data is provided in Appendix A.

3.16 Storm Drain CCTV Inspection

A CCTV inspection of the storm drain system at Swann Park was conducted on May 29, 2007 and June 5, 2007. The drain system was viewed during inspection through the use of a camera mounted on top of a remotely-operated vehicle. The inspection vehicle traveled through segments of the storm drain pipe from access points at the manhole located on Swann Park and the manhole located at the intersection of Race and McComas Streets. Only limited segments of the system could be fully inspected due to the large amount of debris and sediment that has accumulated in the pipe (Figure 3-13). The full CCTV inspection report and a CD-ROM containing the raw video footage are provided in Appendix D.

SECTION 4

Physical Characterization

The objective of this section is to describe the current physical conditions and identify potential contaminant migration routes and/or exposure pathways at Swann Park. Results of the topographic survey and storm drain CCTV inspection are provided below as well as a description of the geology and hydrogeology beneath the Site as determined by the analysis of data obtained during the field investigation. The implications and potential influence of the physical characteristics of the Site on contaminant migration are discussed in Section 4.5.

4.1 Topography

Swann Park is located in an east to west oriented depression that slopes gently to the west toward Middle Branch (Figure 4-1). Surface elevations range from a maximum of 22 feet above mean seal level (ft-MSL) at the northeast corner of the property to approximately 3 to 4 feet-MSL near Middle Branch. The eastern and western thirds of the property are generally flat and the land surface is mildly steeper towards the central portion of the Site. The ground surface on the eastern third of the property slopes gently to the southwest and toward a shallow swale that runs to the west-northwest along the southern property boundary. Ground surface elevations rise sharply along the northern and southern property boundaries, where the Site abuts the 2000 Race Street Site and the Western Maryland Railroad line, respectively.

Based on the available information, it appears that the general topography of the Site has not been significantly altered since Swann Park was established circa-1905. A 1985 Regrading Plan for Swann Park, a Site Map of the park based on 1982 photography, and a 1912 drawing of the storm drain all depict conditions that are consistent with results of the recent topographic survey (City of Baltimore, 1912; City of Baltimore, 1982; City of Baltimore, 1985).

A comparison of current surface elevations with elevations depicted on the historic drawings appears to indicate that the current elevations are approximately one to two feet less than the historic elevations on the eastern and western portions of the Site (City of Baltimore, 1912; City of Baltimore, 1982). However, no survey datum is referenced on the historic drawings. Since the drawings were produced by the City of Baltimore, the historic survey may be referenced to the Baltimore City Elevation Datum (BCED). The BCED is 1.7 feet higher than NAVD88 and therefore likely accounts for the elevation differences between the historic and current data.

4.2 Utilities

The following utilities were identified during the utility location survey:

- An electrical line is located along the southeastern property boundary. It appears that this line is used to transmit power to a scoreboard that is located in the southeast corner of the Site.

- A water line is located at the central portion of the eastern property boundary. The waste line appears to enter the Site from McComas Street and stops approximately 100 feet west of the eastern property boundary.
- A storm drain is located beneath the central portion of the Site. This drain runs through the Site from McComas Street to an outfall at the Middle Branch.

A drawing provided by the City of Baltimore indicates that subsurface utilities, consisting of an electrical line, gas line, sanitary sewer line, and a water line, were completed in the northeast corner of the Site in support of a comfort station behind the backstop for Field 4 (City of Baltimore, 1966). However, these utilities were not identified during the utility survey.

Of the identified utilities listed above, the storm drain system is of primary interest to this investigation because it has the potential to provide an additional exposure pathway and/or migration route for contaminants. A summary of construction documents, field observations, and inspection results for the storm drain are provided below.

4.2.1 Storm Drain System Construction

A drawing of the storm drain system, dated November 26, 1912, indicates that the drain was specified to be a 42-inch diameter pipe that runs through Swann Park from the intersection of Race Street and McComas Street to an outfall at the Middle Branch (City of Baltimore, 1912). The invert elevation at the outfall is specified on the drawing as -0.5 feet with no datum reference.

The 1912 drawing also shows two manholes. One manhole is located at the intersection of Race Street and McComas Street (McComas Street manhole) and the second is located in the central portion of Swann Park (Swann Park manhole). The drawing shows a straight run of pipe between the McComas Street manhole and the outfall. No laterals or other inlets are depicted on this drawing.

A 1985 drawing shows the storm drain system as described above and specifies the construction of two storm water inlets and associated laterals on Swann Park (City of Baltimore, 1985). One inlet was to have been constructed directly north of the Swann park manhole and the lateral for this inlet was to link directly to this manhole. The second was to have been constructed approximately 120 feet east of the Swann Park manhole and was designed to drain the area located south of the main storm drain. Both laterals were to have been constructed of PVC pipe that is stated in the drawing as being “on hand.”

4.2.2 Storm Drain Inspection Results

Field observations are generally consistent with the reviewed construction drawings with the exception that the storm drain inlets and laterals that were to have been constructed at Swann Park circa 1985 do not appear to be present. The inlets were not identified during the utility survey or the CCTV inspection.

Both the Swann Park and McComas Street manholes are present and are functional. Both manholes are constructed of brick, are approximately 10 feet deep, and have a shallow concrete trough at the bottom. One inlet pipe and one outlet pipe are present at the Swann Park manhole and both are 42-inches in diameter and are constructed of concrete. One

outlet and two inlet pipes are present at the McComas Street manhole. The outlet pipe that routes water through Swann Park and the inlet pipe that approaches the McComas Street manhole from the east are 42 inch diameter concrete pipes. A second inlet approaches the McComas manhole from the northeast and may be tied in to a shallower, apparently newer, drain system located in the vicinity.

The CCTV inspection results indicate that the storm drain system is in fairly poor condition. Circumferential cracks were observed along the inspected length of the system and concrete aggregate is commonly exposed along the base of the pipe. Holes and exposed soil were observed at three locations approximately 25 to 49 feet east of the Swann Park manhole. No obvious signs of groundwater infiltration (wet cracks, mineralization staining, etc.) were observed at the cracked and eroded pipe locations. The pipe also contains miscellaneous debris (concrete, brick, cobbles, and general rubble) and sediment that prevented full inspection of the system. The sediment is as much as 4 inches thick inside the pipe at a distance of approximately 130 feet west of the Swann Park manhole. The storm drain outfall is constructed of steel pipe. A tide gate or other means of controlling tidal inflow into the line was not observed during the inspection. Field observations suggest that the storm drain outfall was at least partially submerged throughout the time period of investigation and that water levels at the outfall appear to fluctuate with the tidal cycle.

Water was observed in the drain system during dry weather conditions despite a sustained period (greater that one week) of dry weather that preceded the dry weather sampling event. Under dry weather conditions (5/24/07 and 5/25/07), approximately 8 to 10 inches of water was present in the Swann Park manhole and approximately 4 to 5 inches of water was present in the McComas Street manhole. Water flow in both manholes was slow to stagnant.

The wet weather event was conducted on a day that followed a period of very heavy rain (6/4/07). Under these conditions, approximately 2 feet of water was present in the Swann Park manhole and approximately 1 foot of water was present in the McComas Street manhole. Water flow in both manholes was slow during the wet weather sampling event.

4.3 Geology

The following sections describe the geological conditions beneath Swann Park. This section is arranged such that it presents a detailed summary of the surface and subsurface soil characteristics and then presents an overall interpretation of subsurface conditions beneath the Site. The primary purpose of this section is to document the extent of various soil types at Swann Park in order to interpret how these soil types may affect groundwater flow and contaminant migration.

4.3.1 Surface Soil

With the exception of exposed soil on the various athletic fields (e.g., infield area of the baseball field), Swann Park is almost wholly covered with a grassy turf. The turf has a root system that extends approximately 1-4 inches into the surface soil.

The field classification of surface soil types at Swann Park vary slightly from silt to sand with most samples collected from the 0 to 3 inch depth interval described as brown to yellowish brown silty sand that contains fine sand, trace gravel, little to some organic

material and is dry to slightly moist. The organic material mentioned in the descriptions appears to be mainly due to the presence of grass roots. In limited areas, the silty sand extends to depths of 1.5 to 2 feet, but the overall depth of this material is generally less than 1 foot below grade.

Grain size distribution curves for composite and discrete surface soil samples show that the surface soil is comprised of approximately equal proportions of silt and sand (Figures 4-2 and 4-3). According to these curves, the sample classifications range from silty sand to sandy silt. Additionally, the curves suggest that surface soil conditions are fairly uniform across the Site.

4.3.2 Subsurface Soil

Shallow subsurface soils are commonly described as heterogeneous mixtures of silt and sand that have mottled coloration, contain varying amounts of gravel and varying proportions of sand grain size, and contain brick fragments or miscellaneous debris. Grain size distribution curves derived from six shallow subsurface sample locations generally support the field classifications and show that show that soils within the shallow subsurface are classified as silty sand, sandy silt and silt (Figure 4-4).

The base of the heterogeneous soils appears to be shallow (<2 feet) on the eastern portion of Swann Park and gradually increase in depth toward the western property boundary. Heterogeneous soils encountered at monitoring well locations SP-MW-001, SP-MW-002 and SP-MW-003 extend to depths of 12-16 feet and are comprised of black, very loose, poorly-graded fine to medium sand that is interlayered with black, very soft silt with varying amounts of clay. Fragments of porcelain and other trash were identified at 12 feet in boring SP-MW-001.

Soils that underlie the heterogeneous soils are also described in the field as silt or sand which may grade locally to silty sand or clayey sand. Grain size distribution curves from five subsurface soil samples show that soils within the 24 to 60 inch depth interval are classified as sandy silt to silt (Figure 4-5). However, these grain size distribution curves were derived from samples that included the entire 24 to 60 inch depth interval regardless of whether lithologic contacts were observed within that interval. Soil stratification is apparent the deeper subsurface and therefore the curves are not necessarily representative of the silt or sand lithology, but likely include portions of both.

The sand is comprised of more homogeneous layers of yellowish brown to brown, poorly-graded fine to medium sand that may contain trace gravel. The sand is also described as well-graded at few locations. Shallow silt layers tend to be pale brown to brownish gray, soft to medium stiff and may contain little to some clay. Deeper silt layers tend to be black, gray or bluish gray may contain some clay, are soft to stiff, and contain coarse-silt to sand size flecks of mica. Soil boring data also suggests that the silt may grade vertically to sand or contain thin interbeds or lenses of silty sand and/or sand.

4.3.3 Geologic Interpretations

Based on the soil descriptions presented above, there appear to be two identifiable soil units beneath Swann Park:

1. Fill that is comprised of heterogeneous silt and sand
2. Alluvium that is comprised of stratified silt and sand layers

Geologic cross-sections developed for the Site depict the stratigraphic relationship of these soil units in the subsurface (Figures 4-6, 4-7 and 4-8).

The fill materials include the surface soil and heterogeneous portions of subsurface soil (Figures 4-7 and 4-8). Surface soil is interpreted as fill material based on the fact that definite fill materials (e.g. brick fragments, heterogeneous soils, debris) are commonly present in the shallow subsurface. The fill unit also includes the heterogeneous soils identified to depths of 12-16 feet along the western property boundary (Figure 4-7). The fill materials thicken to the west, which is consistent with the interpretation that the western portion of the park is constructed on reclaimed land (Tricil Environmental Response and Hygenetics/GCL, 1991).

The soils that underlie the fill materials are presumably native alluvial deposits. The grain size, sorting characteristics, and interlayered nature of the alluvial deposits are generally consistent with soil types that are typically found in fluvial environments and the alluvium is likely to be a product of deposition along the banks of the Middle Branch. Although there appear to be some minor lateral variation in soil lithology, the individual silt and sand units appear to be laterally continuous beneath much of Swann Park (Figures 4-7 and 4-8).

Data from the adjacent Race Street Site suggest that the deep silt layer at Swann Park is also encountered at the 2000 Race Street Site. The top of the silt was the target for the placement of monitoring wells at Swann Park (Figure 4-7). However, a similar silt lithology may be present at shallower depths along the eastern portion of the Site (Figure 4-8). The thickness of the silt beneath Swann Park is unknown. However, borings completed on the adjacent Race Street Site suggest that the silt thickness ranges from 15 to 45 feet.

4.4 Hydrogeology

The primary focus of the hydrogeologic characterization presented in this report is on shallow groundwater that is present within the fill materials and alluvium that underlie Swann Park. All monitoring wells at the Site are screened above a silt that is considered to act as a confining unit based on observations and data from the adjacent 2000 Race Street Site (Figures 4-7 and 4-8) (O'Brien and Gere, 2003). Hydraulic conductivity tests were performed on samples of the semi-confining and confining units during recent investigation activities at the 2000 Race Street Site. The hydraulic conductivity values obtained from these tests range from 3.28×10^{-6} cm/sec (semi-impervious to impervious) to 5.37×10^{-8} (impervious).

4.4.1 Synoptic Groundwater Elevations

Static groundwater depths at Swann Park measured on June 1, 2007 ranged from approximately 2 feet below ground surface along the western edge of the property to 6 to 8 feet below ground surface in the central and eastern portions of the Site (Table 3-1). These groundwater depths correspond to an elevation range of 0.84 ft-MSL (SP-MW-001) to 12.25 feet MSL (SP-MW-006). Groundwater depths were also measured in wells near the Middle Branch at times that corresponded to the predicted high and low tide. The measurements indicate that groundwater elevations are not tidally influenced.

Groundwater elevation contours indicate that the shallow groundwater flows generally to the west, toward the Middle Branch, and a fairly distinct groundwater gradient break is present in the vicinity of monitoring well SP-MW-008 (Figure 4-9). East of SP-MW-008, a relatively steep gradient of 0.02 ft/ft exists. To the west of SP-MW-008, the gradient shallows to approximately 0.004 ft/ft. This gradient break is believed to coincide with the approximate limits of the deeper fill material that is present along the western boundary of the site. The relatively shallow gradient in the fill suggests that the fill is likely more hydraulically conductive than the alluvium.

The storm drain is positioned at least partially below the shallow groundwater table along much of its length through the Site (Figure 4-8). Although cross-section A-A' is essentially parallel to the storm drain, the drain system is not depicted because it would obscure some of the geologic details of the Site and the characteristics of the soils that directly surround the drain are unknown. Note that the groundwater contours do not indicate a component of flow toward the drain. However, it is not likely that the coarse spacing of the monitoring well network would detect small flow perturbations near the drain.

Monitoring wells at Swann Park were also gauged for the presence of LNAPL and DNAPL. False positive results were initially obtained with the NAPL probe at monitoring well locations SP-MW-001, SP-MW-002, and SP-MW-003. These locations were further investigated by pumping water from the well and observing the water in a clear container. These observations, coupled with the analytical results presented in Section 5, indicate that NAPL is not present in any of the Swann Park monitoring wells.

4.4.2 Slug Test Results

The slug tests that were conducted in monitoring wells SP-MW-002, SM-MW-005 and SP-MW-006 generally support the interpretation that the conductivity of the fill material is higher than the alluvium. Hydraulic conductivity estimates were derived through analysis of the slug test data in AQTESOLV® for Windows Version 3.5 using the method of Bouwer-Rice, 1976. At the time of testing, the water table was present within the filter pack interval of all monitoring wells, which appears to have caused a concave upward curvature of the slug test data. This behavior, when plotted on a displacement-time graph, is termed a double straight line effect and is caused by rapid draining of the filter pack followed by a slower response curve that is controlled by the formation (Bouwer, 1989).

Due to the apparent presence of the double straight line effect and attempt was made to estimate hydraulic conductivity through the analysis of the second portion of the response curve. The first portion of the response curve often yielded results that were unreasonable given the soil type and observations made during development and sampling. Choosing the second portion of the response curve was ambiguous in some of the individual test data (e.g. SP-MW-006) and different sections of the curve often yielded very different results. Tests in SP-MW-005 showed that this well recovered very slowly and was not fully recovered in three of the four tests and two tests were not analyzed in SP-MW-006 due to noise in the data.

Despite the analysis difficulties outlined above, at least one test from SP-MW-005 and SP-MW-006 and all tests from SP-MW-002 yielded reasonable estimates given the soil type and other field observations. The additional tests at SP-MW-005 and SP-MW-006 were then re-analyzed and it was found that in ambiguous cases one of the straight line segments of

the response curve did produce very similar hydraulic conductivity estimates (Table 4-1). Average hydraulic conductivities of 11.56 feet/day, 0.33 feet/day and 3.60 feet/day were calculated in wells SP-MW-002, SP-MW-005, and SP-MW-006, respectively (Table 4-1). Results of each slug test analysis are provided in Appendix C.

4.5 Physical Controls on Contaminant Migration

Contaminant migration is strongly dependant on the type and characteristics of the specific contaminant(s) that are detected at a particular site. However, contaminant migration is definitely influenced by the physical and chemical conditions present in the contaminated media. The following text is a summary of the physical characteristics of Swann Park that may exert some influence on contaminant migration:

- A shallow, alluvial silt layer appears to underlie the eastern and central portions of the Site and a deep silt layer appears to underlie the majority of the Site. These silt layers likely inhibit the vertical migration of soil and/or groundwater contaminants based on hydraulic conductivity estimates of alluvial silt samples collected from the adjacent 2000 Race Street Site.
- Contaminants would be expected to migrate vertically more rapidly and to deeper depths on the western portion of the Site, which is underlain by fill material to depths of 12 to 16 feet. This fill is coarser and more hydraulically conductive than the alluvium. The fill materials are in turn, underlain by the deep silt, which would act as a barrier to vertical migration as outlined above.
- Groundwater contaminants would be expected to migrate to the west, parallel to the groundwater flow direction, across the Site. Based on data presented above, the horizontal migration of groundwater contaminants would be expected to occur more rapidly where deep fill materials are encountered (e.g., western third of the Site).
- Given the poor condition and depth of the storm drain and the fact that water was observed during the dry weather event, it is likely that groundwater is infiltrating the drain system.

SECTION 5

Analytical Results

This section presents: the results of laboratory analyses of soil, groundwater, and storm water samples collected during the Swann Park investigation; the methods that were used to perform the analyses; the validation process that was applied to the analytical data received from the laboratories; and a brief discussion of locations where analytes were detected and any apparent trends in these data. The nature and extent of analyte presence is presented in Section 6.

As described in the CIWP, the list of analytes discussed herein fall into two categories:

- Primary Analytes of Interest (AOIs):
  - Soil: Heavy Metals (arsenic, barium, cadmium, chromium (total and hexavalent), mercury, lead, selenium, silver, and vanadium), Semi-Volatile Organic Compounds (SVOCs), Volatile Organic Compounds (VOCs), Pesticides. Analyses for metals, pesticides, and SVOCs were performed according to a multi-incremental and sub-sampling approach as described in Section 5.2.
  - Groundwater and Storm Water: Heavy Metals (Arsenic, barium, cadmium, chromium (total and hexavalent), mercury, lead, selenium, silver, and vanadium), SVOCs, VOCs, Pesticides. Both total and dissolved fractions of Metals, SVOCs and Pesticides, were analyzed.
- Supporting Analyses:
  - Soil: Grain Size, Total Organic Carbon (TOC), Synthetic Precipitation Leaching Procedure (SPLP), Toxicity Characteristic Leachate Program (TCLP), arsenic bioaccessibility procedure, and arsenic mineralogy.
  - Groundwater: Total organic carbon (TOC), major cations (calcium, magnesium, potassium, sodium), major anions (bromide, chloride, fluoride, nitrate, nitrite, orthophosphate, sulfate), alkalinity, and total phosphorous.

Analytical results for the primary AOIs detected in soil, groundwater and storm water are discussed in Sections 5.4 through 5.7, Section 5.8, and Section 5.9, respectively. A discussion of the supporting analyses, which includes results for TCLP, SPLP, and Arsenic Bioaccessibility and Mineralogy, is presented in Sections 5.10, 5.11 and 5.12, respectively.

5.1 Analytical Methodology

For soil samples, the primary AOIs were analyzed after the sample was prepared in the laboratory according to a multi-incremental and sub-sampling procedure. This approach was used for the analysis of all primary AOIs with the exception of VOCs. All secondary analyses were performed on the total fraction of sample (i.e. the multi-incremental and sub-sampling approach was not used prior to analysis).

Prior to sub-sampling, the samples scheduled for analysis of AOI metals underwent additional preparation steps. The metals samples were first oven-dried at 40° C and then sieved through a 250 µm mesh screen. This sieve size was chosen because the soil fraction finer than 250 µm is most likely to adhere to hands and become airborne and inhaled. Only the material passing through the 250 µm sieve was retained for sub-sampling and subsequent analysis. Oven drying and sieving were not performed on SVOC and pesticide samples.

The sub-sampling procedure outlined below applies to the sieved fraction of AOI metals samples and to the total fraction of SVOC and pesticide samples. In this procedure, the sample was spread evenly over a pan to create an even depth. The pan was then positioned over a 50-section grid guide. The lab then used a volume-specific scoop to collect an increment of soil near the center of each grid section and through the entire depth of soil in the pan. After completion of the incremental scooping, the sub-sample increments were composited and analyzed according to the methods presented in Section 5.2.

5.2 Analytical Methods

Samples collected during the comprehensive investigation were analyzed as specified on Table 3-1. For all media types, the primary AOIs were analyzed in accordance with the following laboratory methods:

- Heavy Metals
  - EPA SW-846 6010B - Arsenic, barium, cadmium, chromium (total), lead, selenium, and silver
  - EPA SW-846 7199 – chromium (hexavalent)
  - EPA SW-846 7470A/7471B - mercury
- EPA SW-846 8081A - Pesticides (organochlorine pesticides and kepone)
- EPA SW-846 8260B - VOCs
- EPA SW-846 8270C – SVOCs

Secondary and supporting analyses were performed in accordance with the following laboratory methods:

- ASTM D422 - Grain Size (sieve and hydrometer)
- MCAWW 415.2 [2] - Total Organic Carbon (TOC)
- SW-846 1312/6010B - Synthetic Precipitation Leaching Procedure (SPLP) followed by analysis for arsenic
- SW-846 6010B - Major Cations (calcium, magnesium, potassium, sodium)
- MCAWW 300 series - Major Anions (bromide, chloride, fluoride, nitrate, nitrite, orthophosphate, sulfate)

[2] Based on Methods for Chemical Analysis of Water and Wastes (MCAWW), EPA-600/4-79/020, Revised March 1983.

- MCAWW 310.1 – Alkalinity
- SW-846 6010B – Iron and manganese
- MCAWW 365.2 – Total phosphorus
- Arsenic Relative Bioaccessibility Procedure – Consists of analysis of arsenic using the Relative Bioaccessibility Procedure to estimate bioaccessible mass of arsenic based on research performed by U.S. Environmental Protection Agency Region VIII (http://www.epa.gov/unix0008/r8risk/hh_rba.html) and the alternative extraction methodology provided by the University of Colorado (http://www.colorado.edu/geolsci/legs/invitro1.html).
- Arsenic Mineralogy –The arsenic mineralogy of selected soil samples was determined by electron microprobe analysis (EMPA), conducted in accordance with the standard operating procedure of Dr. John Drexler of the University of Colorado presented in http://www.colorado.edu/geolsci/legs/speciation1.html. The mineral forms of arsenic in soil influence the relative bioavailability of the soil arsenic (Kelley et al. 2002, DoD 2003).
- In addition, TCLP was performed on four soil samples in order to assist in evaluation of remedial alternatives. The TCLP and associated waste characterization analyses included the following:
- SW-846 311/8260B - TCLP VOCs
- SW-846 1311/8270C - TCLP SVOCs
- SW-846 1311/8081 - TCLP Pesticides
- SW-846 1311/8082 - TCLP PCBs
- SW-846 1311/8151 - TCLP Herbicides
- SW-846 1311/6010B - TCLP Metals
- SW-846 1311/7470A - TCLP Mercury
- SW-846 1030 - Ignitability/Flashpoint
- SW-846 9045C – pH (corrosivity)
- SW-846 9034 - Reactive sulfide
- SW-846 9012 - Reactive cyanide

5.3 Data Validation

In accordance with the CIWP, data validation was performed by a third party on the AOIs listed in Section 5.2. Level III validation was performed on 100 percent of the samples and Level IV validation was performed for the following analytes: arsenic, hexavalent chromium, mercury, kepone, dieldrin, p,p-DDE, p,p-DDT, and benzo(a)pyrene. Data validation flags are presented along with the analytical data on Tables 5-1 through 5-6.

5.4 Composite Surface Soil Results

The primary AOIs detected in composite surface soil (0-3 inches) samples are discussed below. Validated analytical data for the composite surface soil samples are presented in Tables 5-1A through 5-1C. Supporting analyses for the composite surface soil samples are presented in Table 5-1D and are discussed in Section 7.

5.4.1 Metals

All of the primary AOI metals were detected in the composite surface soil (0-3") samples (Table 5-1A). Arsenic, barium and lead were detected at the highest range (i.e. levels consistently exceed 100 mg/kg at most locations.). Arsenic concentrations ranged from 77.2 mg/kg (Field 2) to 810 mg/kg (Field 5), barium concentrations ranged from 70.9 mg/kg (Field 2) to 157 mg/kg (Field 5), and lead concentrations ranged from 163 mg/kg (Field 2) to 930 mg/kg (Field 5). Mercury was detected at a concentration range of 0.222 to 1.94 mg/kg and similarly, the remaining AOI metals were detected at relatively lower levels ($\leq$100 mg/kg). Similar to the pattern observed for arsenic, barium, and lead, samples from Field 5 also contained the maximum detected concentrations of chromium, mercury, selenium, silver and vanadium and samples from Field 2 contained the lowest (or nearly so where non-detect) concentrations of chromium, mercury and selenium.

5.4.2 Pesticides

Detected pesticides in the composite surface soil samples include 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, Alpha Chlordane, Dieldrin, Delta BHC, and Heptachlor Epoxide. 4,4'-DDD, 4,4'-DDE, 4,4'-DDT were detected at all composite surface soil locations at a concentration range of 0.035 mg/kg to 3.5 mg/kg (Table 5-1B). These three compounds were detected at the highest concentrations in samples from Field 5, Field 6, Field 7 and Field 8.

Alpha Chlordane was only detected at Field 4, Dieldrin was detected at all sample locations with the exception of Field 3, Delta BHC was only detected at Field 3, and Heptachlor Epoxide was detected at all sample locations except Fields 3 and 4. The maximum detected concentration of these last three constituents is 0.099 mg/kg.

5.4.3 VOCs

Composite surface soil samples were not analyzed for VOCs in accordance with the CIWP. VOC results for discrete surface soil samples are discussed in Section 5.3.3.

5.4.4 SVOCs

Nineteen SVOCs were detected in the composite surface soil samples (Table 5-1C). The compounds Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(g,h,i)perylene, Benzo(k)fluoranthene, Chrysene, Flouoranthene, Indeno(1,2,3-cd)pyrene, Phenanthrene and Pyrene were detected at all sample locations. The maximum detected concentration of all of these components is 0.92 mg/kg (Fluoranthene in Field 6). With one exception, the concentration of SVOCs that were not detected at all sample locations generally does not exceed 0.1 mg/kg and many of these concentrations are laboratory estimated values ("J"-qualified values).

5.5 Discrete Surface Soil Results

The primary AOIs detected in discrete surface soil (0-3 inches) samples are discussed below. Validated analytical data for the discrete surface soil samples are presented in Tables 5-2A through 5-2D. Supporting analyses for the discrete surface soil samples are presented in Table 5-2E and are discussed in Section 7.

5.5.1 Metals

The full suite of primary AOI metals were analyzed in 5 of the 15 discrete surface soil samples (Table 5-2A). The remaining locations were analyzed for arsenic only or were only analyzed for pesticides (SP-DP-015, SP-DP-016 and SP-DP-017). Like the composite surface soil samples, arsenic, barium, and lead were detected at the highest concentrations in all discrete surface soil samples. Arsenic concentrations in the discrete surface soil samples ranged from 41 mg/kg to 1,930, mg/kg, barium concentrations ranged from 78.8 mg/kg to 217 mg/kg, and lead concentrations ranged from 158 mg/kg to 1,250 mg/kg. The maximum detected concentrations for all three analytes were present in the sample from SP-DP-023. Additionally, the maximum concentration of the remaining AOI metals, including mercury at a concentration of 5.63 mg/kg, was detected in this sample.

5.5.2 Pesticides

Concentrations of 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, Alpha Chlordane, Dieldrin, Endosulfan II, Endosulfan Sulfate, Endrin Aldeyde, Heptachlor Epoxide, and Methoxychlor were detected in the discrete surface soil samples (Table 5-2B). 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, and Dieldrin were detected at all sample locations. The maximum concentration of these constituents was detected in samples from locations SP-DP-017 and SP-DP-023. The maximum concentration of the remaining pesticides, with the exception of Methoxychlor, were also detected the sample from location SP-DP-017. The maximum concentration of the remaining constituents is 0.16 mg/kg Heptachlor Epoxide.

5.5.3 VOCs

VOCs were analyzed at five discrete surface soil locations (Table 5-2C). Concentrations of 2-Butanone, Acetone, Methyl Acetate, and Methylene Chloride were detected in these samples, but no single VOC was detected at all locations. Acetone was detected at the highest concentration range of 0.045 mg/kg to 0.15 J mg/kg. All other constituents were detected at levels less than 0.075 mg/kg.

5.5.4 SVOCs

Twenty SVOCs were detected in the discrete surface soil samples (Table 5-2D). The compounds Acenaphthylene, Anthracene, Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(g,h,i)perylene, Benzo(k)fluoranthene, Chrysene, Flouoranthene, Indeno(1,2,3-cd)pyrene, Phenanthrene, and Pyrene were detected at all sample locations. With the exception of Acenaphthylene, the maximum concentrations of all of these constituents were present in the sample from location SP-DP-022. With the exception of Fluoranthene (maximum concentration = 1.3 mg/kg) and Pyrene (maximum concentration = 1.2 mg/kg), all other concentrations of SVOCs were detected at levels of less than 1 mg/kg.

5.6 Shallow Subsurface Soil Results

The primary AOIs detected in discrete shallow subsurface soil (9-24 inches) samples are discussed below. Validated analytical data for the shallow subsurface soil samples are presented in Tables 5-3A through 5-3D. Supporting analyses for the shallow subsurface soil samples are presented in Table 5-3E and are discussed in Section 7.

5.6.1 Metals

The primary AOI metals were analyzed at 10 shallow subsurface sample locations (Table 5-3A). Concentrations of arsenic, barium, and lead again represent the highest concentrations of AOI metals that were consistently detected. Arsenic concentrations ranged from 3.53 mg/kg (SP-DP-008) to 2,410 mg/kg (SP-DP-023), barium concentrations ranged from 46 mg/kg (SP-DP-012) to 675 mg/kg (SP-DP-023), and lead concentrations ranged from 50.6 mg/kg (SP-DP-012) to 888 mg/kg (SP-DP-023). Other AOI metals that are frequently detected in the shallow subsurface samples include chromium (19.6 K mg/kg - 72.5 mg/kg), mercury (0.0548 J mg/kg – 2.71 mg/kg), vanadium (0.0346 mg/kg – 42 mg/kg), and hexavalent chromium (0.56 J mg/kg – 4.6 J mg/kg).

5.6.2 Pesticides

Concentrations of 4,4′-DDD, 4,4′-DDE, 4,4′-DDT, Alpha Chlordane, Dieldrin, Delta BHC, Endosulfan II, Endosulfan Sulfate, Endrin Aldeyde, Endrin Ketone, Heptachlor, Heptachlor Epoxide, and Methoxychlor were detected in the shallow subsurface soil samples (Table 5-3B). 4,4′-DDE and 4,4′-DDT were detected at all sample locations and 4,4′-DDD was present at all but one location. The maximum concentration of these constituents was detected in the sample from SP-DP-021.

The remaining pesticide compounds were detected at levels less than 0.093 J mg/kg. Seven of the ten compounds were detected at location SP-DP-023 and eight of the ten compounds were detected at location SP-DP-007. However, two of the pesticide compounds detected in the native sample at SP-DP-007 were not present in the duplicate sample.

5.6.3 VOCs

Four VOCs, 2-Butanone, Acetone, Methyl Acetate, and Methylene Chloride, were detected in the shallow subsurface soil samples (Table 5-3C). Acetone was detected in six of ten sample locations at a concentration range of 0.007 mg/kg to 0.05 mg/kg. Methylene Chloride was detected in four of the ten samples at a concentration range of 0.003 J mg/kg to 0.056 mg/kg. The maximum concentration of both constituents was detected in the sample from SP-DP-011. 2-Butanone and Methyl Acetate were detected in one out of the ten samples at concentrations of 0.005 J mg/kg and 0.006 mg/kg, respectively.

5.6.4 SVOCs

Twenty-one SVOCs were detected in the shallow subsurface soil samples (Table 5-3D). None of the compounds were detected in all ten samples. Eleven compounds were detected in all samples with the exception of the sample from SP-DP-012. The maximum concentrations of the SVOCs were detected in samples from SP-DP-007 and SP-DP-019. The highest concentration of any one SVOC analyte is 5.2 mg/kg Fluoranthene and the majority of the SVOC concentrations do not exceed 1 mg/kg.

5.7 Subsurface Soil Results

The primary AOIs detected in discrete subsurface soil (24-60") samples are discussed below. Validated analytical data for the discrete surface soil samples are presented in Tables 5-4A through 5-4D. Supporting analyses for the subsurface soil samples are presented in Table 5-4E and are discussed in Section 7.

5.7.1 Metals

The primary AOI metals were analyzed at 13 subsurface sample locations (Table 5-4A). Concentrations of arsenic, barium and lead again represent the highest concentrations of AOI metals that were consistently detected. Arsenic concentrations ranged from 4.74 mg/kg (SP-DP-011) to 3,970 mg/kg (SP-DP-023), barium concentrations ranged from 22.4 mg/kg (SP-DP-012) to 336 mg/kg (SP-DP-028), and lead concentrations ranged from 9.73 mg/kg (SP-DP-011) to 1,590 mg/kg (SP-DP-018). Other AOI metals that are present in the subsurface samples include chromium (13.3 mg/kg – 47.1 mg/kg), mercury (0.0241 J mg/kg – 168 mg/kg), silver (0.415 J mg/kg – 0.681 mg/kg), vanadium (18.4 mg/kg – 37.8 mg/kg), and hexavalent chromium (0.68 J mg/kg – 2.1 J mg/kg).

5.7.2 Pesticides

Concentrations of 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, Aldrin, Alpha Chlordane, Delta BHC, Dieldrin, Endrin Ketone, and Heptachlor Epoxide were detected in the subsurface soil samples (Table 5-4B). 4,4'-DDE and 4,4'-DDT were detected at all locations and the maximum concentration of these constituents was 0.16 J mg/kg 4,4'-DDE at location SP-DP-024. The concentrations of all other detected pesticide compounds are less than 0.071 mg/kg.

5.7.3 VOCs

Five VOCs, 2-Butanone, Acetone, Benzene, Methylene Chloride, and Toluene, were detected in the subsurface soil samples (Table 5-4C). Detections for 2-Butanone, Benzene, and Toluene occurred in single instances and the concentrations of these constituents only slightly exceed the maximum detection limit (MDL) as indicated by other samples. Acetone was detected in six of the seven samples at a concentration range of 0.012 J mg/kg to 0.056 mg/kg and Methylene Chloride was detected at two locations at a concentration range of 0.003 J mg/kg to 0.044 mg/kg.

5.7.4 SVOCs

Twenty SVOC compounds were detected in the subsurface soil samples (Table 5-4D). The maximum concentrations for a majority of these constituents were detected in the sample from location SP-DP-028 and most of the SVOCs were present in samples from locations SP-DP-018, SP-DP-023, SP-DP-024 and SP-DP-028. With the exception of the sample from SP-DP-028, the majority of the SVOC detections do not exceed 1 mg/kg. Bis(2-Ethylhexyl)phthalate was the only constituent present at all sample locations and was the only constituent present at sample locations SP-DP-011 and SP-DP-012.

5.8 Groundwater Results

The primary AOIs detected in groundwater samples collected from monitoring wells SP-MW-001 through SP-MW-008 are discussed below. The validated groundwater analytical data is presented in Table 5-5A through 5-5F. The groundwater supporting analyses are presented in Table 5-5G and are discussed in Section 7.

5.8.1 Metals

Five AOI metals, arsenic, barium, chromium, lead, and vanadium, were detected in the groundwater samples (Table 5-5A). Arsenic was detected at four locations at a concentration range of 27.7 µg/L to 7,420 µg/L and the maximum concentration of arsenic was detected in the sample from SP-MW-001. All five AOI metals were detected in samples from SP-MW-005 and SP-MW-006 and these wells were the only locations where lead was present. Barium was the only constituent detected in all groundwater samples. Chromium was detected in 5 samples and vanadium was detected in 6 samples. Cadmium, mercury, selenium, silver and hexavalent chromium were not detected.

The AOI metals arsenic, barium, chromium, mercury, and vanadium were detected in the dissolved samples (Table 5-5A). Dissolved arsenic was detected at 6 well locations at a concentration range of 10.7 B µg/L to 6,590 µg/L and the maximum concentration was present in SP-MW-001. Dissolved chromium, mercury and vanadium were present in one, two, and four samples, respectively and dissolved barium was detected in all 8 samples.

5.8.2 Pesticides

Pesticides were detected in 4 groundwater samples (Table 5-5B). 4,4′-DDD, 4,4′-DDE and 4,4′-DDT were all detected in a sample from SP-MW-008 and 4,4′-DDE was also detected in samples from SP-MW-005 and SP-MW-006. All detections for these constituents were less than 0.071 µg/L. Dieldrin and Kepone were detected in SP-MW-006 and Toxaphene was detected in samples from SP-MW-004 and SP-MW-005.

One pesticide compound, 4,4′-DDD, was detected in the dissolved sample from monitoring well SP-MW-007 at a concentration of 0.0047 J µg/L (Table 5-5C). Note that no pesticides were detected in the total sample from this location. No other pesticide compounds were detected in the dissolved samples.

5.8.3 VOCs

Groundwater samples from Swann Park were analyzed for 48 different VOCs and none of these compounds were detected (Table 5-5D).

5.8.4 SVOCs

A total of 65 SVOCs were included in the analysis and thirteen of these compounds were detected in one groundwater sample from monitoring well SP-MW-008 (Table 5-5E). The maximum concentration of the detected SVOCs in SP-MW-008 is 20 µg/L Phenanthrene.

65 compounds were also included in the analysis for dissolved SVOCs (Table 5-5F). One compound, Caprolactam, was detected at locations SP-MW-005 and SP-MW-006 at a maximum concentration of 30 µg/L and Acenaphthene was detected at a concentration of 2 J µg/L at SP-MW-008. No other dissolved SVOCs were detected.

5.9 Storm Water Results

The primary AOIs detected in storm water samples collected from sample stations SP-SW-001, SP-SW-002 and SP-SW-003, are discussed below. The validated storm water analytical data is presented in Tables 5-6A thorough 5-6F.

5.9.1 Metals

The AOI metals arsenic, barium, chromium, lead, and vanadium were detected in the storm water samples (Table 5-6A). Arsenic was detected at locations SP-SW-001 and SP-SW-002 during both the wet and dry weather events at concentrations ranging from 17.1 J µg/L to 230 J µg/L. The maximum total arsenic detection occurred at station SP-SW-001 during the dry weather sampling event. Barium was detected at all sample stations during both sampling events. Chromium was detected at all three stations during the wet weather event, but was only detected as a B flagged result during the dry weather event at station SP-SW-002. Similarly, vanadium was detected at all three stations during the wet weather event, but was only detected as a B flagged result during the dry weather event at station SP-SW-001. Lead was detected at a concentration of 9.1 J µg/L during the wet weather event at station SP-SW-003. The remaining AOI metals, cadmium, mercury, selenium, silver, and hexavalent chromium, were not detected.

Dissolved concentrations of three AOI metals, arsenic, barium, and chromium, were detected in the storm water samples (Table 5-6A). Dissolved arsenic was detected during both the dry and wet weather events at station SP-SW-001 and was only detected during the wet weather event at station SP-SW-002. Dissolved arsenic concentrations ranged from 987 J µg/L to 15.8 J µg/L and the maximum concentration was detected at station SP-SW-001 during the dry weather event. Dissolved chromium was only detected at station SP-SW-002 during the wet weather event. The remaining AOI dissolved metals, cadmium, lead, mercury, selenium, silver, and hexavalent chromium, were not detected.

5.9.2 Pesticides

Eight pesticide compounds, 4,4'-DDD, 4,4'-DDT, Aldrin, Alpha BHC, Alpha Chlordane, Dieldrin, Gamma BHC – Lindane, and Heptachlor, were detected in the storm water samples (Table 5-6B). The majority of the pesticide detections appear to correlate with the wet weather sampling event and most of the compounds were detected in samples collected from station SP-SW-002. However, all but one of the pesticide concentrations are estimated values and none of the concentrations exceed the non-estimated value of 0.023 µg/L.

Six pesticide compounds, 4,4'-DDT, Aldrin, Alpha BHC, Beta BHC, Gamma BHC-Lindane, and Heptachlor, were detected in the dissolved fraction of the storm water samples (Table 5-6C). All of these compounds were detected only once and of the concentrations are estimated. None of the concentrations exceed a value of 0.015 J µg/L, which was the detected value for Beta BHC at SP-SW-001 during the dry weather event.

5.9.3 VOCs

Storm water samples from Swann Park were analyzed for 48 different VOCs and none of these compounds were detected (Table 5-6D).

5.9.4 SVOCs

Storm water samples from Swann Park were analyzed for 65 different SVOCs and two compounds, bis (2-Ethylhexyl)phthalate and Di-n-octylphthalate, are listed as detected (Table 5-6E). Both compounds were present in the wet weather event native sample and/or field duplicate at station SP-ST-002. However, all three concentrations are estimated. The concentration of bis(2-Ethylhexyl)phthalate (2 J µg/L) detected in the duplicate sample is exactly the same as the maximum detection limit (MDL) listed for the native sample. Di-n-octylphthalate was present in the native and duplicate sample at a concentration of 3 J µg/L, which is only 1 µg/L higher than the MDL listed for the other samples.

Storm water samples from Swann Park were analyzed for 65 different dissolved SVOCs and only one compound, Caprolactam, was detected in the wet weather native sample from station SP-SW-002 (Table 5-6F). However, this compound was not detected in the corresponding duplicate sample. No other dissolved SVOCs were present in any of the samples.

5.10 TCLP Results

Results for TCLP soil analyses are presented on Tables 5-7A through 5-7E. TCLP VOCs, SVOC and Herbicides were not detected in any of these samples. One pesticide, Heptachlor, and six TCLP metals, were detected at relatively low concentrations in these samples. TCLP arsenic concentrations ranged from 0.0194 J milligrams/Liter (mg/L) to 2.21 mg/L.

The TCLP sampling locations were chosen based on sampling results from April 2007, which indicated that elevated arsenic concentrations existed in the vicinity of these locations and results from May 2007, presented above, appear to verify the presence of elevated arsenic concentrations at these locations. To further define the soil conditions at Swann Park, the TCLP results were compared with hazardous waste criteria as defined in 40 Code of Federal Regulations (CFR) 261.24. This comparison revealed that soils at Swann Park do not have the contaminant levels or waste characteristics representative of a characteristic hazardous waste.

5.11 SPLP Results

Results for the SPLP analyses are presented on Table 5-8. SPLP sample locations were chosen to represent conditions at various depths across the entire area of Swann Park and include locations SP-DP-0012 and SP-DP-023 where elevated arsenic concentrations have been detected. The SPLP results show that, under the conditions defined by the analytical method (EPA Method SW-846 1312/6010B), 0.1 to 1 percent of arsenic is released from the soil samples.

5.12 Arsenic Bioaccessibility and Mineralogy

The toxicity of arsenic has been assessed based on epidemiological studies of populations exposed to high concentrations of arsenic naturally present in drinking water. It is a fundamental principle of toxicology that chemicals such as arsenic must be absorbed into the body to cause systemic toxicity. The measure of the degree to which a chemical is absorbed into the body is referred to as bioavailability. Absolute bioavailability is the

fraction of the dose of a chemical that is absorbed and enters the body after being ingested (Kelley et al. 2002).

When arsenic is ingested from solid materials such as soil, absorption may be decreased compared the absorption from water. Less soluble forms of arsenic are reported to be one-half to one-tenth as bioavailable as the more soluble forms of arsenic (DoD 2003). Relative bioavailability is a measure of the difference in absorption between different forms of a chemical (e.g., arsenic in water, food, or soil). Site-specific relative bioavailability data can be used to adjust the default bioavailability assumptions in exposure models and derive risk estimates that more accurately represent actual exposures. In order for ingested arsenic to be absorbed into the body, it generally must first dissolve in the gastrointestinal tract. Consequently, studies of the dissolution of materials containing arsenic under conditions that mimic those of the gastrointestinal tract can help predict the degree to which the arsenic will be absorbed.

Numerous *in vivo* studies (i.e., studies in animal models) or *in vitro* studies (i.e., non-animal, 'test tube' studies) have evaluated the relative bioavailability of arsenic in soil and other solid materials. The relative bioavailability of arsenic in various soils and waste materials has been measured using rats, swine, rabbits, dogs, and monkeys (Casteel et al. 1997; Casteel et al. 2003; Freeman et al. 1993; Freeman et al. 1995; Groen et al. 1994; Ng et al. 1998; Roberts et al. 2002; Roberts et al. 2007). A number of USEPA regions and states have relied upon these studies, allowing adjustments of default bioavailability assumptions for arsenic based on the study results. Scientists in USEPA Region 8 have overseen *in vivo* bioavailability studies of arsenic from a variety of different environmental media (i.e., soils and mining tailings) using juvenile swine as the animal model (USEPA 2005c). For 29 materials tested, 26 yielded reliable estimates of relative bioavailability that ranged from 8 to 61 percent. Three materials with arsenic concentrations of 16, 17 and 67 mg/kg had concentrations that were too low to provide reliable estimates.

The primate studies have generally shown arsenic relative bioavailability to be less than 30 percent. Roberts et al. (2002) measured the relative bioavailability of arsenic in soil from five different sites through measurement of urinary arsenic excretion in monkeys. Results varied with soil sample characteristics, ranging from 11 to 25 percent. In a subsequent study with a different species of monkeys, Roberts et al. (2007) tested 14 soil samples from 12 sites, including three samples from near a former arsenic pesticide manufacturing facility. The relative bioavailability of arsenic in these samples ranged from 5 to 31 percent.

The *in vitro* procedures that have also been developed provide a faster and less costly alternative for estimating the relative bioavailability of arsenic and metals in soil (Kelley et al. 2002; Ruby et al. 1996, 1999; Ruby 2004). The *in vitro* methods are based on the concept that the rate and/or extent of metal solubilization in the gastrointestinal fluid are important determinants of relative bioavailability in vivo. As such, most *in vitro* tests are designed to measure the rate or extent of metal solubilization in an extraction solvent that mimics physiological conditions in the human gastrointestinal tract (Kelley et al. 2002; Ruby et al. 1996, 1999; Ruby 2004). The fraction of a metal that solubilizes in an *in vitro* system is referred to as bioaccessibility. Thus, bioaccessibility is the measurement of the fraction of a metal that is soluble and available for absorption.

It has been determined that *in vitro* procedures for lead correlate well with results from *in vivo* studies and therefore can be used to estimate the relative bioavailability of lead from soil (Ruby et al. 1999; NAS 2003; USEPA 2004a). For arsenic, the correlations have been weaker, but consistently demonstrate reduced relative bioavailability for most soils (Rodriguez et al. 1999; USEPA 2005c). For 23 materials tested by USEPA Region 8, bioaccessibility ranged from 9 to 68 percent. USEPA (2005c) notes that there is measurement error in both the *in vivo* and *in vitro* estimates of relative bioavailability, thus the lack of correlation is not due solely to limitations in the *in vitro* method.

Studies of the mineralogy of the metal species present in soil and other solid materials may provide many insights regarding the nature of the metal minerals present and their physical location within particles. Such studies are useful in interpreting bioavailability study results (NAS 2003; Ruby 2004; USEPA 2005c). The trivalent and pentavalent forms of arsenic are most common in soil. Ionic forms that can bind to soil particles and less soluble mineral forms of arsenic tend to be less soluble and less bioavailable than more soluble forms such as sodium arsenate and arsenic trioxide. Less soluble forms of arsenic include sulfide minerals, complex oxides, and mineral forms bound with iron, manganese, and phosphate (Kelley et al. 2002). As with other chemicals, adsorption of arsenic to soil particles is likely to increase with time, resulting in reduced solubility and lower relative bioavailability in aged arsenic in soil (Yang et al. 2002; Datta and Sarkar 2005c).

5.12.1 *In Vitro* Bioaccessibility

To assess the bioavailability of arsenic in soil at the Site, 22 soils samples collected from the park were evaluated by *in vitro* testing (Table 5-9). Each of the surface (0-3 inches) composite samples from the eight athletic fields at the Site were evaluated via *in vitro* testing. In addition, fourteen of the discrete samples were selected for testing, including samples from various locations at the Site and from all three of the sample depth ranges—surface (0-3 inches), shallow subsurface (9 inches to 2 feet), and subsurface (2 to 5 feet).

The *in vitro* extraction testing was performed by Columbia Analytical Services. Briefly, the apparatus used is a Plexiglas block containing a 37°C water bath with a flywheel that drives a rotor holding a series of bottles containing the extraction fluid and sample. The extraction fluid is maintained at a pH of 1.5, buffered with 0.4 M glycine. One hundred milliliters of the extraction fluid and 1 gram of test substrate are added to each bottle and the bottles are rotated end over end for 1 hour. After extraction, a sample is taken directly from the bottle with a syringe. A 0.45-µm cellulose acetate disk filter (25-mm diameter) is attached to the syringe, and the extract is filtered into a sample vial for analysis. Filtered samples are stored in a refrigerator at 4°C until they are analyzed for arsenic.

The results of the *in vitro* tests indicate that arsenic bioaccessibility of the soil samples ranges from 30 percent to 84 percent, with a mean of 56 percent (Table 5-10). Below 1,000 mg/kg total arsenic, arsenic bioaccessibility is weakly correlated to total arsenic concentration (Figure 5-1); with a correlation coefficient of 0.45. Above 1,000 mg/kg, there is no correlation between total arsenic and bioaccessibility. The soil samples with the highest bioaccessibility values (>65%) were collected from northwest areas of the site. No trend in arsenic bioaccessibility is readily apparent with depth of the soil sample; however, there are limited data available to make this assessment.

5.12.2 Arsenic Mineralogy Analysis

A subset of 15 of the samples tested for bioaccessibility were also submitted for mineralogy analysis to assess the relationship between arsenic bioaccessibility and the forms of arsenic present in arsenic-bearing phases characteristic of the samples. The samples selected for this testing included all of the surface soil composite samples from the athletic fields and seven of the discrete samples representing a range of bioaccessibility and sample depths (Table 5-9). Samples selected were those with the arsenic concentrations higher than 100 mg/kg because samples with lower arsenic concentrations have too few arsenic-bearing particles for accurate mineralogic characterization.

The arsenic mineralogy was determined by electron microprobe analysis (EMPA), conducted in accordance with the standard operating procedure presented in the Work Plan. EMPA was performed by Dr. John Drexler at Laboratory for Environmental and Geological Studies, University of Colorado at Boulder. EMPA involves mounting the sample in an epoxy matrix, polishing a flat surface on this soil/epoxy "puck," and scanning across this surface with a focused electron beam. A low-energy beam can be focused on a wide area (e.g., a few hundred micrometers across) to generate picture-like black-and-white images of the samples ("photomicrographs"), where the brightness of individual mineral grains is approximately proportional to the molecular weight of the elements in the minerals. For more quantitative analysis, a high-energy narrow electron beam can be focused on individual grains (e.g., as small as ~1 μm), providing quantitative estimates for the concentration of elements in this sample from the intensity and frequency of the energy emitted from the target.

The EMPA for this project used a "point counting" sampling method to determine the dominant arsenic-bearing mineral phases in each sample. Specifically, point counting involves overlaying a regular grid across each soil sample, and then measuring the composition of the individual mineral grains at each point in the grid. By analyzing a large number of grains in each sample (typically more than 100 in each sample), sufficient arsenic-bearing phases are encountered to identify the dominant minerals hosting these metals and the concentrations of metals in each phase. In interpreting EMPA results, it is important to understand that, on a mass basis, only a tiny fraction of the total sample is evaluated and there is thus moderate uncertainty as to whether the results are truly representative of the sample as a whole.

Interpretation of the EMPA point-count benefits from an explanation of the reported parameters, specifically, the "frequency of occurrence" and "relative mass" for specific mineral phases.

> *Frequency of Occurrence* is the fraction (based on dimension) that a particular arsenic-bearing mineral phase contributes to the total of all of arsenic-bearing mineral phases. This is calculated for each sample by summing the longest dimension of all the grains of a specific mineral phase that contained measurable arsenic, then dividing by the total length of all grains in the sample with measurable arsenic. The frequency of occurrence is thus illustrative of which arsenic-bearing phase(s) are the most commonly observed in the sample or the relative volume of each arsenic-bearing phase.

> *Relative mass* is the mass fraction of the total arsenic in a sample that resides in a particular phase. This is calculated by summing the estimated mass of arsenic in all the grains of a particular phase, and then dividing by the estimated total mass of arsenic in all grains with detectable arsenic. The calculation considers the arsenic concentration and specific gravity of the mineral phase. The relative mass provides insight to the arsenic-bearing phase(s) in a sample is likely to control the total bulk concentration for arsenic. A mineral phase may be relatively abundant based on the frequency of occurrence, but insignificant in terms of total arsenic mass due to the low arsenic content and/or low specific gravity of the phase.

Although the precise phase stoichiometry can be determined through EMPA, doing so is often time- and cost-prohibitive. Further, arsenic in soil is often adsorbed onto other mineral particles or present in mixture of amorphous or metastable mineral phases and, as a result, arsenic is often not associated with a pure mineral phase. During EMPA analyses, the general mineralogy of arsenic-bearing particles typically can be assigned to the general phase types: oxide, carbonate, sulfide, sulfate, or phosphate. For the first four types, the major cation associated with the phase is identified (e.g., Fe-sulfate, Fe-OOH, PbAsO, etc.). Although some of these phases could represent a stoichiometric mineral form, most are likely to be metastable and/or amorphous and have some quantity of arsenic sorbed to their surface. The phosphate ion (PO_4) is the only common dominant ion of the "phosphate" phase. This phase might include minerals that contain mixtures of phosphate and arsenate such as walentaite $(Ca,Mn,Fe)Fe_3(AsO_4,PO_4)_4\text{-}7H_2O$, morelandite $(Ba,Ca,Pb)_5Cl[AsO_4,PO_4]_3$, or turneaureite $Ca_5(Cl)[(AsO_4, PO_4)_3]$, but most likely represent arsenic adsorbed onto other phosphate-containing particles.

The results of the EMPA are summarized in Table 5-11. For reference, Table 5-11 also includes total soil arsenic concentration and arsenic bioaccessibility for each sample. Figure 5-2 summarizes the overall mineral speciation results for the Site soil samples. Based on frequency of occurrence, fly ash and ferrous oxyhydroxide (FeOOH) are the most abundant arsenic-bearing minerals identified in the samples. However, based on relative arsenic mass, the dominant arsenic-bearing phases in the samples are arsenic-ferrous oxyhydroxide (AsFeOOH), FeOOH, and lead arsenic oxide (PbAsO). The relative arsenic mass data demonstrate that fly ash, which is characterized by low arsenic concentration, is a relatively unimportant arsenic-bearing phase in the Site soils. Other commonly occurring, but less dominant arsenic-bearing phases include phosphate, iron sulfate ($FeSO_4$), manganese oxyhydroxide (MnOOH), and calcium chromate ($CaCrO_4$).

The PbAsO phase identified in many of the soil samples is consistent with the composition of lead arsenate (PbHAsO), a commonly used pesticide until the 1940's. The PbAsO phase is generally more abundant in the soil samples that were collected from the northwest area of the park, while the dominant arsenic-bearing phases in soils collected in other areas tend to be AsFeOOH and FeOOH. This distribution is consistent with that anticipated as a result of weathering. As lead arsenate weathers, liberated arsenic can be expected to become associated with iron oxide minerals in the soil matrix, as these oxides are dominant sorbents for arsenic in natural systems. There is no readily apparent association between the dominant arsenic-bearing mineral phase (based on frequency of occurrence or relative arsenic mass) and the arsenic bioaccessibility. These results suggest that the weathering

process and subsequent oxidation of lead arsenate, does not result in increased arsenic bioaccessibility in the soils.

SECTION 6

Extent of Contamination

The following section presents a discussion of the horizontal and vertical extent of analytes detected in soil, groundwater, and storm water samples collected from Swann Park. The analytical results discussed in Section 5 indicate that a number of the primary AOIs, including metals, pesticides, VOCs, and SVOCs, were detected; however, the discussion presented below is focused primarily on the extent of arsenic concentrations in all media types. The extent of contamination discussion is focused on arsenic based on the following rationale:

- A preliminary screening of analyte concentrations presented in Section 5 reveals that arsenic is the only AOI at the Site that is consistently detected at levels that exceed the default, non-site specific, MDE Cleanup Soil Standards for Residential and non-Residential land use (MDE, 2001).
- Arsenic is identified as the only AOI identified above the Agency for Toxic Substances Disease Registry (ATSDR) environmental guideline for soil based on the ATSDR Health Consultation dated June 13, 2007.
- As discussed in Section 8.7 (Development of Risk-Based Remedial Goals), arsenic has been identified as the only chemical of concern detected at the Site based on the application of risk-based screening levels (RBSLs), the calculation of remedial goal options (RGOs), and associated comparisons of analytical data against these values.
- An April 19, 2007 letter from MDE to the Baltimore City Commissioner of Health requested that Swann Park be closed to public access based on the concentrations of arsenic that were detected at the Site.
- The Order states that the April 2007 sampling results indicate that significant concentrations of arsenic are present in soils at the Site (MDE, 2007a). The Order additionally states that the maximum arsenic concentrations and 95 percent Upper Confidence Limit (UCL) concentrations of arsenic detected in soil exceed the EPA emergency removal concentration levels for both residential and industrial properties.

It should be noted that the discussion presented below is provided without consideration of, or comparison to, background concentrations of arsenic from anthropogenic and natural sources. An appropriate background data set representing the urbanized and industrialized nature of the area around the Site was not available for comparison during the development of this report. Therefore, the contribution of background to the overall arsenic concentration detected on-site has not been assessed.

Within Section 8 (Human Health Risk Assessment), a simplified comparison of Site soil data is performed against the Anticipated Typical Concentrations (ATCs) for Eastern Maryland based on MDE Guidance (MDE, 2001) as a screening step within the risk assessment; however, the sample population used to represent the area of Eastern Maryland do not include any locations within the urbanized area of Baltimore City and therefore do not

necessarily provide a representative background concentration for this urbanized and industrialized area. It is possible that background levels of arsenic in the vicinity of the Site are greater than the ATCs for Eastern Maryland.

6.1 Extent of Arsenic in Soil

A map of arsenic concentrations and isoconcentration contours shows that arsenic detections in surface soil are fairly widespread across the Site (Figure 6-1). Note that the arsenic data presented on this map was supplemented with surface soil (0-3 inch) data gathered during the April 2007 sampling event. Arsenic concentrations are highest in the northwest corner of the Site and exceed 800 mg/kg in the vicinity of sample location SP-DP-012. A broad area of arsenic detections that exceed 200 mg/kg is present in the central portion of the Site and most concentration values in surface soil samples exceed 100 mg/kg across the Site.

Arsenic detections are fairly widespread across the Site in the 9 to 24 inch depth interval (Figure 6-2). However, the majority of the concentrations were detected below 100 mg/kg across most of the southern and central portion of the Site. Arsenic detections that exceed 200 mg/kg are generally limited to the northern Site boundary and the maximum arsenic concentrations are found in the northwest corner of the Site.

Within the 24 to 60 inch depth interval, the arsenic concentrations were detected below approximately 50 mg/kg across most of the Site (Figure 6-3). Arsenic concentrations in excess of 100 mg/kg were detected at two locations, SP-DP-026 and SP-DP-027, along the eastern Site boundary. As with the shallower soil depths the maximum arsenic concentrations were detected in subsurface soil samples that were collected from the northwest corner of the Site.

6.1.1 Additional Extent Constraints

Additional constraints on the extent of arsenic in soils at Swann Park are provided by results of the XRF field screening. The XRF data appears to correlate moderately well with laboratory determined arsenic concentrations (Figure 6-4). A table of arsenic concentrations determined by XRF screening is provided in Appendix B and a summary of the XRF results is provided below:

- The spatial distribution of arsenic concentrations determined by XRF data reveals similar concentration patterns as determined by the laboratory analytical results.
- XRF results from discrete surface soil locations show that elevated (658 mg/kg – 1,374 mg/kg) arsenic concentrations are present in the northwest corner (SP-DP-017, SP-DP-023 and SP-MW-001) and central portion of the Site (SP-DP-031).
- XRF results in the shallow subsurface show elevated (421 mg/kg – 870 mg/kg) arsenic concentrations along the northern property boundary. Arsenic concentrations detected across the remaining portions of the site are less than 214 mg/kg.
- XRF results from the 24 to 60 inch depth interval at subsurface sample and monitoring well locations show that elevated arsenic concentrations are present in soils located along the northern property boundary and in the northwest corner of the Site. Across

the remainder of the Site, the XRF arsenic concentrations were below the instrument detection limit or were below 50 mg/kg.

XRF data from the monitoring well locations provide additional depth constraints on subsurface arsenic concentrations that are not available in the analytical data set. These results are summarized below:

- Arsenic was not detected by the XRF in any depth interval at monitoring well locations SP-MW-002 and SP-MW-003. Samples from both well locations were screened in 2-4 foot intervals to depths of 24 to 25 feet.
- Arsenic was not detected below a depth of 6 feet at SP-MW-004 and below a depth of 4 feet at SP-MW-008.
- Arsenic was only detected in the 10 to 11 foot depth interval at SP-MW-005 (9.02 mg/kg) and the 11 to 12 foot depth interval at SP-MW-007 (9.68 mg/kg).
- Arsenic was detected in all samples down to a depth of 12 feet at monitoring well locations SP-MW-001 (22.84 mg/kg – 87.96 mg/kg) and SP-MW-006 (13.64 mg/kg – 27.07 mg/kg).

6.1.2 Volume Averaged Arsenic Concentrations in Surface Soil

In order to support the development of risk-based remedial goals presented in Section 8, the average arsenic concentration was calculated for surface soil at Swann Park. The average arsenic concentrations were calculated from a numerical 3D solid model created using the C-Tech's Environmental Visualization System. Input data for the model included validated field sampling results from 82 analytical samples collected from the ground surface to depths of approximately 5 feet bgs. The 3D arsenic concentration distribution was calculated using a geologically robust algorithm called Kriging.

The modeled layer on which the volumetric average was calculated was assumed to be coincident with the 0 to 3 inch sample depth. The arsenic concentrations within the layer were assumed to be log-normally distributed with an anisotropy ratio of 10:1. The model grid was automatically selected by the Kriging algorithm based on the number and density of field samples and thickness of the geologic layer. The outer boundaries of the solid model are chosen by the algorithm to ensure high confidence in the calculations and are beyond the park boundary. However, the average arsenic concentration for surface soil was calculated only for the surface soil layer that exists within the park boundary. The volume averaged concentration in surface soil at the Site is 175 mg/kg (Table 6-1).

TABLE 6-1
Volume Averaged Arsenic Concentration in Surface Soil

Depth Interval (inches)	Approximate Volume (1000 cubic yards)	Average Arsenic Concentration (mg/kg)
0 - 3	4.15	175

6.2 Extent of Arsenic in Groundwater

Elevated levels of arsenic in groundwater appear to be limited to the northwestern corner of Swann Park (Figure 6-5). At this location, total arsenic was detected at a concentration of 7,420 µg/L and dissolved arsenic was detected at a concentration of 6,510 µg/L. Relatively lower concentrations of total arsenic (<101 µg/L) and dissolved arsenic (<32.4 B µg/L) were detected in monitoring wells SP-MW-002, SP-MW-005, SP-MW-006 and SP-MW-008. Note that the concentrations of dissolved arsenic in groundwater at these locations are B flagged, meaning that arsenic detections were less than levels detected in the rinse blank associated with these samples. With the exception of a relatively low, B flagged detection for dissolved arsenic at SP-MW-003, arsenic was not detected in monitoring wells located along the southern property boundary.

6.3 Extent of Arsenic in Storm Water

Storm water samples collected from Swann Park indicate that total and dissolved arsenic is present in the segment of the storm drain system that runs beneath the park (Figure 6-5). Total and dissolved arsenic were not detected in samples collected during the dry or wet weather sampling events at the McComas Street manhole. Total arsenic was detected in the Swann Park manhole during the dry and wet weather sampling events at approximately the same concentration. Dissolved arsenic was not detected at the Swann Park manhole during the dry weather event, but was present during the wet weather sampling event.

Concentrations of total and dissolved arsenic were detected at the storm drain outfall (SP-SW-001) during the dry and wet weather events. These samples represent the maximum concentrations of total and dissolved arsenic in the storm water samples. The outfall pipe face was ½ to ¾ submerged during both sampling events, so the outfall samples are not wholly representative of actual storm water discharging from the pipe. Total arsenic concentrations were less than the dissolved arsenic concentrations in this set of samples. This discrepancy has been investigated and the cause has not been identified but may be related to laboratory methods. Other total and dissolved metals results indicated the anticipated relationship of dissolved concentrations lower than total concentrations.

6.4 Summary and Interpretations

At the surface of Swann Park, arsenic concentrations in excess of the ATCs are widespread across most of the park area and increase near the central and northwest portions of the Site. Arsenic detections at a depth of two feet below grade are still fairly widespread across the park; however the bulk of the elevated (>800 mg/kg) arsenic detections are concentrated along the northern property boundary and northwest corner of the Site. Arsenic concentrations decrease substantially at depths below two feet across most of the park area, but elevated concentrations are still present in the northwest portion of the Site. XRF data suggests that elevated arsenic concentrations dramatically decrease below a depth of five feet in the northwest corner of the Site.

The distribution of arsenic concentrations in groundwater suggests a spatial relationship between elevated arsenic in groundwater and elevated arsenic in soil. This is likely due to the fact that the shallow groundwater is in contact with impacted soil, especially in the

northwest corner of the Site where elevated arsenic extends to five feet below grade and groundwater was encountered at less than two feet below grade. The limited extent of the elevated arsenic concentrations in groundwater is consistent with the west-directed groundwater flow pattern that is present at the Site.

The absence of arsenic in the upstream McComas Street manhole suggests that arsenic detected in groundwater at the Site is likely the source of arsenic in the storm water samples. The poor condition of the storm drain system combined with the fact that water flow was present during dry weather conditions suggests that groundwater is infiltrating the storm drain system. The infiltration is likely occurring somewhere upstream of the Swann Park manhole since arsenic was detected in samples from the manhole and the arsenic concentrations at this location are comparable to arsenic concentrations in groundwater samples from monitoring well SP-MW-005.

SECTION 7

Fate and Transport

The fate and transport of arsenic under most natural soil conditions is primarily controlled by the availability and stability of iron oxyhydroxide that readily adsorbs and retains arsenic when the pH is between about 4 and 8 under aerobic and oxidizing conditions. Iron oxyhydroxide ubiquitously coats soil particles and imparts a characteristic yellow-brown, brown, and orange color to the soil. Conditions that destabilize the iron oxyhydroxide coating include a pH less than about 4 and anaerobic/reducing conditions (ORP $\leq$ -150 mV). These conditions would individually promote the dissolution of iron oxyhydroxide and thereby release and mobilize arsenic. In addition, elevated orthophosphate concentrations and pH values above about 7.5 increasingly compete with adsorbed arsenic and may also cause arsenic desorption from iron oxyhydroxide. Therefore, the pH, ORP, and orthophosphate concentrations in water and iron concentrations in soils are parameters to be considered when the fate and transport of arsenic is being investigated. The following sections summarize and interpret the geochemical conditions that may influence the fate and transport of arsenic at Swann Park.

7.1 Distribution of Arsenic in Swann Park Soil

The arsenic distribution maps presented for the three sample depth intervals indicate that, except for the surface soil, the lateral mobilization of arsenic appears to be very limited and that arsenic is not mobilized vertically from the surface soils of Swann Park except in the vicinity of SP-DP-023 (Figures 6-1 through 6-3). The median arsenic concentration for all soil samples with depth decreases from 107 mg/kg in the surface soils to 98 mg/kg in the shallow subsurface and finally to 25 mg/kg in the subsurface soil. These relationships indicate that arsenic is not being transported to depth except in the northwest corner of the Site where data from SP-DP-023 indicates that arsenic concentration systematically increases with depth.

The arsenic distribution in the shallow subsurface generally supports this conclusion except along the northern boundary of the park where arsenic concentrations are greater in the 9-24 inch depth interval than in the surface soils. This may be an indication of a shallow soil remedy that was reportedly completed at the Site in the late 1970's..

7.2 Arsenic-bearing Mineral Phases in the Soil

The lack of arsenic mobility suggests that there are mineral phases within the soil that restrict arsenic mobility. As discussed in Section 5.12.2, fourteen soil samples and one duplicate were analyzed to determine the mineral phases in the soils. The full arsenic mineralogy report is provided in Appendix E and Figure 5-2 summarizes the significant mineral phases containing arsenic in the soil samples as well as their frequency of occurrence and relative mass of arsenic in each mineral phase.

Combustion products labeled as fly ash is the most common mineral phase in the soils. The second most common mineral phase is iron oxyhydroxide at a significantly lower frequency.

These two mineral phases account for over 80 percent of the frequency of particle occurrence (total volume) in the soils. Unlike arsenic, the iron concentration in the soil has a relatively constant range between 1.6 and 1.7 percent regardless of depth.

The mineralogy analysis indicates that nearly 65 percent of the arsenic is adsorbed to two iron oxyhydroxide phases (AsFeOOH and FeOOH) that have an arsenic concentration of approximately 25 percent. The AsFeOOH and FeOOH phases represent 56 to 80 percent of the arsenic mass in the composite soil samples from Fields 1 through 4, 6 and 7. Discrete soil samples from the three depth intervals at SP-DP-023 contain 19.3 to 39.7 percent arsenic and these two mineral phases represent 79 to 94 percent of the total arsenic mass in the soils at this location (Table 5-11). These results suggest that arsenic is being strongly attenuated and immobilized by adsorption to iron oxyhydroxide coating or other mineral phases in the soil samples. The average and median soil pH values are circa neutral and range from 6.8 to 7.5 regardless of depth. Therefore, unless the soil approaches or is under reducing conditions, these two iron oxyhydroxide phases are stable.

The lead arsenic (PbAsO) mineral phase represents slightly more than 20 percent of the arsenic mass in the soil samples. It has a low frequency of occurrence but it contains about 20 percent arsenic. This lead phosphate phase does not dominate any of the arsenic mass in the discrete soil samples but it dominates the Field 4 (47.6 percent) and Field 8 (70.1 percent) composite soil samples. Unlike arsenic, the median lead concentration tends to be slightly higher in the 9 to 24 inch soil than the surface or deeper soil. Lead arsenate is only very slightly soluble in cold water (Lead Arsenate EPA Pesticide Fact Sheet 12/86) and was historically extensively used as a pesticide across the US and is a documented elevated arsenic source in orchard soils (Adriano, 1986). Lead arsenate very slowly weathers to dissolved lead and arsenate both of which are readily attenuated by adsorption to the iron oxyhydroxide that ubiquitously coats soil particles. Magalhaes (2002) describes the precipitation of lead-arsenate-chloride, the mineral mimetite ($Pb_5(AsO_4)_3Cl$), as a method used to remove dissolved arsenic concentrations to less than 0.2 micrograms per liter. The lead arsenic phase reported above may include mimetite.

An orthophosphate mineral phase (phosphate) is the third mineral phase containing about six percent of the arsenic mass in the soil samples. It has a slightly lower frequency of occurrence than the lead arsenate and is reported to contain 7.4 percent arsenic. The median total phosphorus concentration is about the same in the 0 to 3 and 9 to 24 inch depth intervals but higher in the 24 to 60 inch interval. The phosphate phase is the dominant phase in the 9 to 24 depth interval at location SP-DP-021 with 42.9 percent of the total arsenic mass in the soil sample from this location. There are a number of phosphate minerals that can incorporate arsenate into their structure during precipitation of the mineral suite collectively called apatite.

In summary, three mineral phases comprise over 90 percent of the arsenic in the soils. All three of these phases are typically considered relatively insoluble. As expected iron oxyhydroxide is by far the most important mineral phase containing arsenic. This phase is adsorbed to soil particles and is considered irreversibly adsorbed under aerobic/oxidized soils. Lead arsenate is the second most important mineral phase and is also generally considered relatively insoluble. Orthophosphate mineral phases represent the third most important phase and minerals in this phase are also generally considered insoluble. Since

the most important phase is dependent on the oxidation state of the soils, the water chemistry becomes important.

7.3 Arsenic in Groundwater

Groundwater chemistry is available from eight monitoring wells distributed across the Site (Figure 4-9). Similar to the soils, the pH of all except one groundwater sample is circa neutral and ranges from 6.55 to 7.69 (Table 7-1). The exception is groundwater from SP-MW-005 which is located in the vicinity of the highest concentrations of arsenic in surface soils. Even though the soils contain more than 600 mg/kg arsenic in the vicinity of this well, the dissolved arsenic concentration in groundwater is only 20.3 µg/l probably because arsenic adsorption to iron oxyhydroxide is most effective at this pH.

The oxidation-reduction potential (ORP) is considerably variable ranging from oxidized plus 156 mV to an almost reducing minus 196 mV (Table 7-1). The ORP readings have to have about 220 mV added to the value to convert the reference electrode to a hydrogen reference electrode and thereby convert the reading to Eh. An Eh of zero is the value between oxidizing (plus Eh values) and reducing conditions (negative Eh) values. Iron oxyhydroxide becomes increasingly unstable and tends to dissolve as the Eh becomes less oxidizing than an Eh of about plus 100 mV at the pH of these groundwaters. When iron oxyhydroxide becomes unstable and dissolves the adsorbed arsenic becomes dissolved as well.

The acidic and highly oxidized condition of groundwater at the SP-MW-005 well location are probably responsible for the both the elevated arsenic concentration in the soil and the very low arsenic concentration in the groundwater. The elevated dissolved arsenic concentration in the groundwater from SP-MW-001 is likely related to the elevated concentration in the soils (increasing with depth) as a source but there are many more reasons for the elevated dissolved arsenic concentration at this location.

The ORP value of essentially minus 200 mV of the groundwater from SP-MW-001 means that iron oxyhydroxide, the major mineral phase in the vicinity of this well location, is unstable. Arsenic in the vicinity of SP-MW-001 is being desorbed partially by hydroxide (highest pH of 7.69) and dominantly by dissolved orthophosphate in groundwater at this location. The total phosphorus concentration in this groundwater is 1.3 mg/L and the orthophosphate concentration is between 0.3 and 0.4 mg/L. This means that there is almost one mg/L of dissolved organic phosphorus in this groundwater. This concentration of organic phosphorus coupled with the elevated total organic carbon (TOC) of 4.1 and near reducing ORP suggests a healthy microbial population at this well location. The organic phosphorus probably slowly oxidizes to form the dissolved orthophosphate.

The second highest concentration of arsenic in groundwater was detected in SP-MW-008. The groundwater from this location also has a relatively elevated orthophosphate concentration (0.44 mg/l) and a elevated turbidity (70.7 NTU). The orthophosphate concentration of 0.031 mg/L will cause some arsenic to become desorbed from iron oxyhydroxide. However, the elevated turbidity suggests that a significant portion of the "dissolved" arsenic is adsorbed to the iron oxyhydroxide causing the elevated turbidity. Iron oxyhydroxide is probably precipitating near the well location and likely is adsorbing

arsenic. The precipitated colloidal iron oxyhydroxide can easily pass through a 0.45 micron filter and cause an elevated dissolved arsenic concentration to be reported by the laboratory.

The spatial distribution of arsenic concentrations in groundwater, coupled with the geochemical evidence presented above, does not indicate that an arsenic groundwater plume exists across the site. Dissolved arsenic is elevated in groundwater from monitoring well SP-MW-001 where elevated arsenic concentrations are also found in the soil. Data presented above and in Section 6 also indicates the conditions present in the northwest corner of the Site are very localized. The dissolved arsenic concentration detected at SP-MW-001 is two orders of magnitude higher than the next highest dissolved arsenic concentration and is likely caused by the near reducing conditions and dissolved orthophosphate detected in this portion of the Site. Arsenic concentrations detected in groundwater from the northeast and north central portions of the Site are likely related to a combination of the arsenic in soils and groundwater conditions at each well location. Elevated arsenic concentrations were not detected in monitoring wells located along the southern and southwestern central boundaries of the Site.

SECTION 8

Human Health Risk Evaluation

This section presents the development of risk-based remediation goals for Swann Park. The use of risk-based concentrations (in conjunction with background levels) as remediation goals is consistent with MDE guidance. Risk-based remediation goals are used when identifying and screening remedies. It should be noted, however, that the remedial alternatives that include clean soil covers do not rely upon the calculated risk based remediation goals for recreational users. Those remedies exceed the risk based standards by eliminating the exposure pathway for recreational users.

The general approach used when identifying applicable risk-based remediation goals is consistent with the MDE-approved CIWP (CH2M HILL, 2007). The remediation goals are identified to address Sections 2(m) and 2(n) of the MDE Order requiring that environmental pathways and exposure routes at Swann Park be identified and a risk evaluation be performed to assess potential impacts of controlled hazard substances (CHS). The remediation goals are established with a substantial margin of safety, assuming reasonable maximum exposures (RMEs) that might occur and using toxicity values that are expected to overestimate actual risks.

The overall approach for developing the remediation goals presented below follows U.S. Environmental Protection Agency (USEPA) Risk Assessment Guidance for Superfund (RAGS), Part A (USEPA, 1989), Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (USEPA, 2002), and RAGS Part B - Development of Preliminary Remediation Goals (USEPA, 1991a).

In this section, the results of the recent Agency for Toxic Substances and Disease Registry (ATSDR) draft Health Consultation for Swann Park (ATSDR, 2007) are summarized, remedial goal options (RGOs) are developed, and the major uncertainties associated with the calculated remediation goals are described. The four-step process used in calculating the remediation goals is summarized as follows:

Step 1 – **Identification of Preliminary COPCs** - Identify the analytes detected in environmental media, identify applicable RBSLs and background concentrations, and compare analytical data to RBSLs and background levels to identify preliminary COPCs.

Step 2 – **Evaluation of Exposure Scenarios** - Identify potential current and future realistic receptors, exposure routes, and exposure factors.

Step 3 – **Identification of Toxicity Values** - Identify conservative USEPA-approved toxicity values for preliminary COPCs.

Step 4 – **Risk Characterization** – Select appropriate carcinogenic and non-carcinogenic target risk levels and calculate RGOs for preliminary COPCs (identified in Step 1) based on appropriate exposure scenarios and toxicity values (identified in Steps 2 and 3).

A range of human health risk-based remedial goals (termed "remedial goal options" [RGOs]) is developed for preliminary Chemicals of Potential Concern (COPCs) identified in soil and shallow groundwater at Swann Park. As noted below, the ATSDR Health Consultation identified arsenic as the only chemical consistently above risk-based levels based on April 2007 analytical data. However, for completeness, RGOs are developed in this section for all chemicals in soil with maximum detected concentrations above conservative residential risk-based screening levels (RBSLs) based on samples collected in April 2007 and May 2007.

Swann Park is currently closed for regular activities, and signs are posted indicating that the park is closed until further notice. Current exposures (if any) are minimal and not contact-intensive. Therefore, the remedial goals presented in Section 8.4 are intended to be protective of potential future exposures by the receptors identified in Section 8.2.

All chemicals with maximum detected concentrations above conservative residential RBSLs are retained as preliminary COPCs in soil. Maximum detected concentrations of all chemicals detected in groundwater samples collected in May 2007 are compared to conservative groundwater concentrations protective of construction workers. As discussed in Section 8.4, maximum detected concentrations of all preliminary COPCs except arsenic in soil are lower than RGOs and therefore arsenic is the only chemical of concern based on the analytical results from April and May 2007. There are no chemicals of concern in groundwater.

8.1 Summary of ATSDR Health Consultation

On June 14, 2007, the ATSDR released its draft Health Consultation for Swann Park (ATSDR, 2007). Based on analytical data from soil samples collected by CH2M HILL in April 2007 and concerns raised by community members, ATSDR evaluated potential exposures for the following receptors and exposure frequencies/durations:

- Youth (teen) athletes (such as baseball, football, and other sports) – daily for 4 years;
- Park workers – daily for 30 years
- Adult athletic coaches – daily for 20 years
- Adult park visitors and spectators – daily for 4 years
- Children playing at the park – daily for 6 years
- Pica children (children intentionally ingesting soil) – one day

ATSDR compared existing (April 2007) data against risk-based concentrations ("Minimal Risk Levels") and identified arsenic as the only chemical consistently exceeding guidelines. In addition, because kepone was historically processed at the adjacent Race Street site, kepone is also included in the risk estimates. Potential chemical intakes are calculated and both cancer and non-cancer risks are estimated for potential exposures to park soils. The Health Consultation concluded that normal park activities (e.g., field sports and park maintenance) are unlikely to pose adverse health effects. However, children with pica behavior could experience temporary illnesses. For all receptors evaluated, long-term adverse health effects (including cancer) are concluded to be unlikely. The report indicated that the draft conclusions will be re-evaluated when additional analytical data become available from Swann Park.

8.2 Identification of Preliminary COPCs

The purpose of identifying preliminary COPCs is to identify the chemicals that have the greatest potential to pose unacceptable risks to people who might come into contact with site media. The preliminary COPCs are identified for soil and shallow groundwater at Swann Park using a screening process that compared maximum detected concentrations to (1) RBSLs and (2) background concentrations. In addition, chemicals that are essential nutrients (calcium, magnesium, potassium, and sodium) are not selected as preliminary COPCs in soil or groundwater.

8.2.1 Data Used for Identifying Preliminary COPCs

In identifying preliminary COPCs, the maximum detected concentrations in each environmental matrix (i.e., soil or shallow groundwater) are used for comparison to the RBSLs and background concentrations. The data used for preliminary COPC selection are described below.

Soil

Three types of soil samples are available from the investigation activities performed on-site in April and May 2007: (1) multi-incremental surface soil samples (collected 0-3 inches below grade at each of 8 existing athletic fields); (2) discrete surface soil samples (collected 0-3 inches below grade); and (3) discrete subsurface soil samples (collected at various depth intervals, ranging from 3 inches to 5 ft below ground surface [bgs]). Samples collected in May 2007, including Quality Control (QC) samples (i.e., field duplicate samples), were sieved with a 250-micron sieve to evaluate the fine portion of the soil which is most likely to adhere to hands and become airborne and inhaled. Both “normal” and “duplicate” samples are used to identify preliminary COPCs in soil regardless of sample depth.

Groundwater

Shallow groundwater samples were collected from eight monitoring wells (i.e., SP-MW-001 through SP-MW-008) installed on-site. The depth to shallow site groundwater ranged from approximately 2 to 8 feet below grade. All samples, including the field duplicate sample, are used for identifying preliminary COPCs in groundwater.

8.2.2 Comparison to Screening Levels

The first step in identifying preliminary COPCs is to compare maximum detected concentrations with human health RBSLs. Based on the applicable exposure scenarios identified during development of the Conceptual Exposure Model (CEM) described in Section 2, the following RBSLs are used for the comparison.

Soil

For each chemical detected in soil, the RBSL is identified using two sources: USEPA Region 3 residential soil Risk-Based Concentrations (RBCs; USEPA Region 3, 2007) and Maryland Department of the Environment (MDE) Residential Cleanup Standards for Soil (MDE, 2001). USEPA Region 3 RBCs are adjusted for a target non-cancer hazard quotient (HQ) of 0.1 to account for potential cumulative effects from multiple chemicals. The lower of the adjusted RBC and MDE Residential Cleanup Standard is used as the soil RBSL. When a RBSL is unavailable from both sources, the USEPA Region 9 Preliminary Remediation Goal (PRG;

USEPA Region 9, 2004) adjusted for a target non-cancer HQ of 0.1 is used as the RBSL. The soil RBSLs are presented in Table 8-1.

Groundwater

Similarly, for each chemical detected in shallow groundwater, the RBSL is identified using the dermal contact component of the MDE Cleanup Standards for Groundwater (MDE, 2001). The RBSLs are calculated using conservative exposure factor values and Equations 21 and 23 presented in *Cleanup Standards for Soil and Groundwater* (MDE, 2001). Groundwater RBSL calculations are presented in Table 8-2.

Use of Surrogate Chemicals for Unavailable Screening Values

If a screening level for a detected chemical is unavailable from the sources listed above, the RBSL for a structurally similar compound or class of compounds is used. Because surrogates are selected that are expected to have greater toxicity than the chemical of interest, the surrogate RBSLs are expected to be conservative.

8.2.3 Comparison to Background Levels

The second step in selecting preliminary COPCs is a comparison of site concentrations to background levels. Chemicals with site concentrations that are not distinguishable from background levels are not included as preliminary COPCs. The following background levels are used for the comparison.

Soil

No background soil samples are available from the area near the Site. Therefore, *Anticipated Typical Concentrations for Metals for Eastern Maryland* as provided by MDE (MDE, 2001) is used to represent background metal concentrations. No maximum detected concentrations are below mean background levels, and therefore no metals are excluded as preliminary soil COPCs on the basis of background.

Groundwater

One monitoring well located hydraulically upgradient of the park (SP-MW-007) is identified as representing background groundwater quality. No maximum detected concentrations are below the background concentrations detected in SP-MW-007, and therefore no chemicals are excluded as preliminary groundwater COPCs on the basis of background.

8.2.4 Preliminary COPCs in Soil and Groundwater

The preliminary COPCs that are identified for soil and groundwater are presented below and are provided in Table 8-3 (soil) and Table 8-4 (groundwater).

Soil

The preliminary COPCs in soil consisted of 9 metals (aluminum, antimony, arsenic, barium, iron, manganese, mercury, thallium, and vanadium), six pesticides/ herbicides and their metabolites (4,4′-DDD, 4,4′-DDE, 4,4′-DDT, dieldrin, heptachlor epoxide, and MCPA), and five polycyclic aromatic hydrocarbons (PAHs) (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene) (Table 8-3).

Groundwater

Arsenic is the only preliminary COPC identified for shallow groundwater (Table 8-4). It should be noted that arsenic is only slightly above its conservative RBSL (i.e., the maximum detected concentration is 7.42 mg/L, whereas the conservative RBSL is 7.41 mg/L).

8.2.5 Evaluation of Detection Limits

An evaluation of the analytical detection limits achieved by the laboratory for the April and May sampling events are described in the following paragraphs.

Soil

The range of detection limits provided by the laboratory for each analyte detected in soil samples is presented in Table 8-3. As shown, with the exception of three analytes (arsenic, thallium, and benzo[a]pyrene), all maximum detection limits are less than screening criteria. For the three analytes mentioned above, some detection limits exceed screening criteria. However, because maximum detected concentrations are used to select COPCs and these three analytes are selected as COPCs, the elevated detection limits for some soil samples does not affect the results of this risk assessment.

Groundwater

The range of detection limits provided by the laboratory for each analyte detected in groundwater samples is presented in Table 8-4. As shown, all maximum detection limits are less than screening criteria. Therefore, the detection limits are suitable for risk assessment purposes.

8.3 Evaluation of Exposure Scenarios

The sources of information used to identify potential future receptors, exposure scenarios, and exposure assumptions are the ATSDR Health Consultation (ATSDR, 2007) and the CIWP.

Land Use

Swann Park is closed, park closure signs are posted, access is limited by fencing, and currently there are no activities at the park. When the park is reopened in the future, the land use will continue to be recreational (i.e., athletic fields). As mentioned during a May 24, 2007 conference call with MDE, the City of Baltimore, and Honeywell and the Swann Park Master Plan dated June 1, 2007, the planned future use of the Site is as a municipal park (Mahan Rykiel Associates, Inc., 2007).

Potential Receptors and Exposure Routes

As indicated in the ATSDR Health Consultation, Swann Park was historically used for recreational activities for team sports. Digital Harbor High School used the park for football and baseball, and local adult sports leagues used the fields for softball, baseball, lacrosse, and kickball. The following receptors are also identified in the Health Consultation: park workers, adult athletic coaches, adult park visitors and spectators, children playing at the park, and pica children. In addition, storm drain workers (involved in repairing and maintaining the buried storm drain at the site) may occasionally be present at the site.

Assuming that park development or regrading occurs in the future, construction workers would also be realistic receptors.

Based on the future realistic receptors identified above, RGOs are calculated for four receptor types that are expected to have the highest relative exposure for their age group and receptor type:

- Youth (high school age) – recreator;
- Adult – recreator;
- Child (ages 2-6) – spectator; and
- Construction worker.

The RGOs developed for these receptor types will be protective of the additional receptor types identified in the ATSDR Health Consultation and the storm drain worker. The RGOs developed for adult recreators are protective of park workers, adult athletic coaches, adult park visitors, and adult spectators. The RGOs calculated for construction workers are protective of workers accessing subsurface utilities.

The soil RGOs must be protective of incidental ingestion and dermal contact with soil, and inhalation of fugitive dust in ambient air. The groundwater RGOs for arsenic must be protective of direct contact exposures. A summary of the receptor types and exposure pathways that should be incorporated into site remedial goals is provided in Table 8-5**.** RGOs are not calculated for pica children (who have single-event exposures) since RGOs are intended to be protective of long-term exposures at the park.

Exposure Factor Assumptions

It is necessary to identify appropriate exposure assumptions when calculating RGOs. Site-specific exposure factor values are used when available. When a site-specific value is not available, a USEPA default exposure assumption is typically used. It should be noted that there are no USEPA default exposure values for recreational scenarios. The primary sources for default exposure assumption values are:

- *Supplemental Guidance to RAGS: Dermal Risk Assessment* (USEPA, 2004)
- *Exposure Factors Handbook* (USEPA, 1997a)
- *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (USEPA, 2002)
- *Standard Default Exposure Factors* (USEPA, 1991b)

The ATSDR Health Consultation is used to obtain exposure factor values for some parameters. In addition, values supported by scientific literature are used. When values are not available in the sources identified above, best professional judgment is used to develop exposure factor values. The exposure factor values used in developing RGOs are presented in Table 8-6 and are briefly described below.

It is expected that the park is not used for athletic activities on days when it is raining or when it is below freezing (i.e., below 32 degrees F). Therefore, for use with the recreator exposure scenarios, a site-specific number of "fair weather days" is calculated based on the number of days in Baltimore when it is not raining and it is above freezing (it is assumed

that snow is not present). Based on annual data at the Baltimore Airport for the years 1986 – 1990, the value ranges from 158 to 197 days/year; the average is 187 days/year (USDOC and USDOE, 2007). It is assumed that on one-half of the fair weather days (94 days), the same individual may be present at the park.

Based on the most recent athletic schedules available on-line for Digital Harbor High School, available at http://www.viewmyschedule.com/lmpublic/calendar.asp?school_id=4672, the baseball and football teams are the only school teams that use Swann Park, and these teams are expected to use Swann Park for games in the 2007-2008 school year. The following information is obtained from the website:

- Varsity Baseball - During the 2006-2007 Season, games were to be held from March 14, 2007 to May 9, 2007, with 9 games at Swann Park for a period of 2 hours per game.
- Varsity Football - For the upcoming 2007-2008 Season, games were to be played from September 7, 2007 to November 9, 2007, with 3 games played at Swann Park.
- Junior Varsity Football - For the upcoming 2007-2008 Season, games were to be played from September 13, 2007 to November 8, 2007, with 5 games played at Swann Park.

Based on the reasonable assumption that practice for the sport season begins approximately one month prior to the first game, the assumption that 5 practices are held per week at the Park during the school day, an athlete would be at the Park for a maximum of 65 days per year (5 days/wk x 13 weeks). Based on the annual data at the Baltimore Airport for the years 1986 – 1990 (USDOC and USDOE, 2007), it rains an average of 29 days between February 15 (one month before the first baseball game) and May 15 (a few days after the last scheduled baseball game). Assuming that 5/7 of those days (21 days) are school days, it is estimated that school baseball players may be outdoors at Swann Park only 44 days per year (65-21 = 44 days). Similarly, based on the annual data at the Baltimore Airport for the years 1986 – 1990 (USDOC and USDOE, 2007), it rains an average of 25 days between August 15 (one month before the first football game) and November 15 (a few days after the last scheduled baseball game). Assuming that 5/7 of those days (18 days) are school days, it is estimated that school football players may be outdoors at Swann Park only 47 days per year (65-18 = 47 days). Therefore, if an individual student participates in both football and baseball, they may be at the park for a total of 91 days/year (44 days playing baseball and 47 days playing football). A frequency of 91 days/year is a value similar to one-half of the number of fair weather days for the Baltimore area.

Site-specific bioaccessibility factors (BAFs) for arsenic are measured (via laboratory analysis) at each of eight existing athletic fields at the park and at selected areas along the sewer line and perimeter of the park. The average measured BAF (59%) for surface soil (collected from the 0-3 inch interval) is used for the recreational and spectator receptors. The average measured BAF (56%) for all soils (surface and subsurface) is used for the construction worker. Bioaccessibility measurements are summarized in Table 8-7.

For use in estimating potential ambient air impacts from soil, site-specific particulate emission factors (PEFs) are calculated for each of eight existing athletic fields at the park based on the measured particle size distribution and the extent of surface cover (turf or other) on each field. The average of the site-specific PEFs calculated for the 8 fields is used

for the recreational and spectator scenarios. Appendix F includes a detailed discussion of the approach used to calculate the site-specific PEFs.

Dermal absorption factors for most chemicals are obtained from RAGS Part E (USEPA, 2004). However, scientific literature indicates that studies of arsenic in soil from nearby a former arsenical pesticide manufacturing facility had negligible dermal absorption. Consequently, use of a value of 0.3 percent for dermal absorption, rather than USEPA's default value of 3 percent, will yield a more accurate estimate of exposure to arsenic via skin contact (Lowney et al, 2005).

For the youth recreator, the site-specific exposure assumptions that are used are an age group of 14 – 17 years old (i.e., a high school team will use the park for organized sports), an exposure frequency of half the "fair weather days" (187/2 = 94 days, which is higher than the number of days [74] expected at the Park during the sport season), a four-year exposure duration (i.e., all four years of high school), an exposure time of two hours per visit (during practice or a game), and an arsenic BAF of 59 percent.

The site-specific exposures assumptions for the adult recreator are an exposure frequency of half the "fair weather days" (187/2 = 94 days), a 10-year exposure duration (i.e., a value slightly above the average number of years [9] that a person in the United States lives in the same house) (USEPA, 1997a), an exposure time of two hours per visit (during practice or a game), and an arsenic BAF of 59 percent.

For the child spectator, the site-specific exposure assumptions that are used are for an age range of 2 – 6 years old, an exposure frequency of 2 days per week over a period of 26 weeks (52 days/year), when they would be watching a family member participating in a sport at the Park), a four -year exposure duration, an exposure time of two hours per visit (during a game), and an arsenic BAF of 59 percent. Although 0-1 year old children may be brought to the Park, children of this young age group would have infrequent contact with soil since they are not very mobile.

The site-specific exposure assumptions for the construction worker are an exposure frequency of 90 days over a one-year period (i.e., park upgrading or redevelopment would require 90 days of construction), a workday of 8 hours, and an arsenic BAF of 56 percent.

The remaining exposure factor values needed to calculate remedial goals are standard USEPA default values for RME, as presented in Table 8-6.

8.4 Identification of Toxicity Values

Toxicity values are used to calculate risk-based cleanup goals. The toxicity values provide an estimate of the relationship between the magnitude of exposure to a chemical and the likelihood and/or severity of adverse health effects. It should be noted that there is a high level of conservatism in the derivation of toxicity values. For example, the RfD is a dose with a safety factor between 3 and 10, and the CSF is an upper-bound estimate of the dose-response curve; these toxicity values are expected to be overestimates of chemical toxicity and actual toxicities could be lower.

Remedial goals are calculated for all preliminary COPCs using oral cancer slope factors (CSFs), inhalation unit risk factors (URFs), oral reference doses (RfDs), and inhalation

reference concentrations (RfCs) obtained from the following sources (in order of USEPA's preferred hierarchy):

- Integrated Risk Information System (IRIS) (USEPA, 2007)
- Provisional Peer-Reviewed Toxicity Values (PPRTVs; as presented in USEPA Region 3, 2007)
- Other peer-reviewed sources (e.g., National Center for Environmental Assessment [NCEA; as presented in USEPA Region 3, 2007], Health Effects Assessment Summary Tables [HEAST; USEPA, 1997b]), Agency for Toxic Substances and Disease Registry [ATSDR] Minimal Risk Levels [MRLs], as presented in USEPA Region 3, 2007)

Tables 8-8 through 8-11 summarize the toxicity values used to calculate the remedial goals. It should be noted that chronic toxicity values are intended to be used to evaluate chronic exposures (those of a 7-year duration or greater), whereas subchronic toxicity values are intended to be used to evaluate subchronic exposures (durations less than 1/10th of a lifetime or 7 years). However, as an extra conservative measure, chronic toxicity values are used in developing remedial goals based on child spectator and youth athlete exposures. Subchronic toxicity values are used to calculate remedial goals for construction workers.

8.5 Remedial Goal Options

Based on the identified preliminary COPCs in soil and groundwater (Section 8.1), the receptors, exposure pathways, and exposure factors identified in Section 8.2, the toxicity values identified in Section 8.3, and target risk levels established by MDE and USEPA, a range of RGOs are calculated. The RGOs are calculated based on a target excess lifetime cancer risk (ELCR) of $1x10^{-5}$ and a target non-cancer Hazard Index (HI) of 1.0 (unity). For soils, RGO equations are based on three exposure routes: incidental ingestion of soil, dermal contact with soil, and inhalation of dust in ambient air as a result of particulate emissions from soil (in accordance with the soil-to-air relationship presented in RAGS Part B (USEPA, 1991a).

For carcinogens, soil RGOs are estimated using the following equation:

$$C = \frac{TR \times BW \times ATc}{EF \times ED \times \left[\left(\frac{IRS \times BAF \times CSFo}{CF}\right) + \left(\frac{SA \times AF \times ABS \times CSFo}{CF}\right) + \left(\frac{IRA \times ET \times CSFi}{PEF}\right)\right]}$$

where:

C = Cleanup concentration of chemical in soil (mg/kg)
TR = Target Risk (unitless)
BW = Body weight (kg)
ATc = Averaging time - cancer (days)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
IRS = Ingestion rate of soil (mg/day)
BAF = Bioaccessibility Factor
CSF = Cancer slope factor (o – oral; i – inhalation) ([mg/kg-day]$^{-1}$)

CF = Conversion factor (10^6 mg/kg)
SA = Skin surface area (cm^2)
AF = Adherence factor – soil-to-skin (mg/cm^2-day)
ABS = Absorption factor (unitless)
IRA = Inhalation rate (m^3/hr)
ET = Exposure time (hr/day)
PEF = Particulate emission factor (kg/m^3)

For non-carcinogens, soil RGOs are estimated using the following equation:

$$C = \frac{TQH \times BW \times ATn}{EF \times ED \times \left[\left(\frac{1}{RfDo} \times \frac{IRS \times BAF}{CF}\right) + \left(\frac{1}{RfDo} \times \frac{SA \times AF \times ABS}{CF}\right) + \left(\frac{1}{RfDi} \times \frac{IRA}{PEF}\right)\right]}$$

where:

TQH = Target Hazard Index
AT_n = Averaging time – non-cancer (days)
RfD = Reference Factor (o – oral; i – inhalation) (mg/kg-day)
(other exposure terms are identified above)

The detailed calculations for the soil RGOs for each preliminary COPC for recreational youth, recreational adult, spectator child, and construction worker receptors are presented in Appendix G. For each receptor, RGOs are calculated based on a target ELCR of $1x10^{-5}$ and a target HI of 1.0. A summary of the lowest calculated remedial goals for the field surface (protective of youth and adult recreators) is provided in Table 8-12. In addition, a summary of the lowest calculated remedial goals for the park perimeter (protective of child spectators) and soil within the depth of future excavation (protective of construction workers) is provided on Table 8-12. However, as shown on Table 8-12, maximum detected concentrations of all preliminary COPCs except arsenic are lower than RGOs; therefore, arsenic is the only chemical of concern in soil.

The RGO equations for groundwater are based on dermal contact only. The equations used to calculate the RGOs are presented on Table 8-6. The lowest calculated remedial goal for arsenic in shallow groundwater (protective of construction workers) is presented in Table 8-13. As shown on Table 8-13, the maximum detected concentration of arsenic is lower than the RGO; therefore, arsenic is not a chemical of concern in groundwater.

The calculated remedial goals for arsenic are presented in the table below:

Location	Remedial Goal (ELCR = $1x10^{-5}$)	Remedial Goal (Hazard Index = 1)
Soil on field surfaces	212 mg/kg	1,180 mg/kg
Soil at park perimeter	222 mg/kg	571 mg/kg
Soil to the depth of excavation	706 mg/kg	454 mg/kg

8.6 Uncertainties Associated with RGOs

As in all risk-based evaluations and calculations, the assumptions used to calculate RGOs introduces uncertainty in the remedial goals. While it is theoretically possible that this leads to higher calculated remedial goals, the use of numerous upper-bound Reasonable Maximum Exposure (RME) assumptions is expected to result in conservative remedial goals with a substantial margin of safety. Any individual's potential exposure and subsequent potential risk are influenced by their individual exposure and chemical sensitivity and varies on a person-by-person basis.

Three major sources of uncertainty in the calculated RGOs are exposure factors used for recreators and child spectators, the site-specific arsenic bioaccessibility factors, and toxicity values used for youth athletes and child spectators.

Recreator and Spectator Exposure Factors

Significant uncertainty exists in the exposure assumptions (e.g., rate of soil ingestion, frequency and duration of exposure) used to calculate RGOs for the recreational user and child spectator scenarios. For instance, the child spectator is assumed to ingest and dermally contact impacted soil at Swann Park for 2 days per week for 26 weeks every year from the ages of 2-6. In addition, the adult is assumed to be involved in sports activities for 94 days per year for a period of 10 years. For these potential receptors, actual contact with soil is unlikely to occur at those frequencies over such a long period of time and at the assumed intensity (e.g., ingestion rate). Therefore, the calculated RGOs for these potential receptors are expected to be conservative.

The exposure frequency and duration for any individual within a population may be higher or lower than the values assumed in the risk evaluation and used to calculate RGOs. Assumptions about exposure frequency and exposure duration directly affect the calculated RGOs. As the exposure frequency or exposure duration for a receptor increases, the calculated RGO for that receptor decreases proportionately.

There may be a small group of children, youth, or adults who use the park at a higher exposure frequency or for a longer duration than that assumed in the RGO calculations. This HHRE provides RGOs based on a youth or adult recreator using the Park for 94 days per year. If a Recreator were to use the Park more often, the RGO would be lower. For example, the average number of "fair weather days" in Baltimore when it is not raining and above freezing is approximately 188 days/year. If the recreator uses the Park twice as often (188 days per year) as that assumed in the HHRE, the RGO would be reduced by one-half (212 mg/kg ÷ 2 = 106 mg/kg).

On the other hand, if a Park recreator has a lower exposure intensity at the park (e.g., engages in light activities such as walking a dog), their soil ingestion rate would be lower than that assumed for an adult/youth athlete engaged in a more physically-demanding recreational activity. Therefore, the calculated risk-based RGO for a lower-intensity activity would be higher than that presented in the HHRE.

A soil exposure frequency of 365 days per year at the Park is not a RME assumption for soil contact. There will be days when the ground is snow-covered, it is below freezing (and the ground is frozen or receptors would wear gloves), or the receptor will be away from home.

The RGOs calculated for all receptors are expected to be protective (at target risk levels) of reasonable maximum exposures (RME). However, as in all risk assessments, there may be a small proportion of the population with high-end exposures or maximally exposed individuals, (e.g., maximally exposed individuals with high-end exposure frequencies and/or ingestion rates). The RGOs were not developed based on high-end exposures but rather on the RME population using site-specific exposure assumptions. The RGOs are expected to be conservative and protective of the RME scenario for recreators. As stated on page 6-19 in USEPA RAGS Part A:

> Each intake variable in the equation has a range of values. For Superfund exposure assessments, intake variable values for a given pathway should be selected so that the combination of all intake variables results in an estimate of the reasonable maximum exposure for that pathway. As defined previously, the reasonable maximum exposure (RME) is the maximum exposure that is reasonably expected to occur at a site. Under this approach, some intake variables may not be at their individual maximum values but when in combination with other variables will result in estimates of the RME.

Arsenic Bioaccessibility

The arsenic relative bioavailability leaching procedure (i.e., in-vitro bioaccessibility [IVBA] procedure) is used to estimate site-specific bioaccessibility of arsenic in soil. As described in Section 7, it has been determined that the correlations between *in vitro* and *in vivo* results for arsenic have been weaker than those for lead, but nevertheless, have consistently demonstrate reduced relative bioavailability for most soils (Rodriguez et al. 1999; USEPA 2005c). In the bioaccessibility tests, arsenic in Swann Park soils demonstrated only a modest reduction in bioavailability compared to soluble arsenic. As described in Section 7, the mineralogy of selected soil samples is also evaluated and compared with the bioaccessibility results. The mineral forms of arsenic in soil influence the relative bioavailability, with more soluble forms being more highly bioavailable (Kelley et al., 2002 and DoD, 2003). The primary mineral phases of arsenic in the soil samples exhibit moderate to high solubility, consistent with the results of the bioaccessibility analyses. There is a substantial likelihood that the actual relative bioavailability of arsenic in these soils is less than the values estimated based on the bioaccessibility results. Uncertainty introduced to the calculated RGOs based on the use of site-specific arsenic bioaccessibility data is relatively small compared with other sources of uncertainty, such as soil ingestion rates or the dose-response analysis for arsenic-induced cancer.

Toxicity Values Used for Youth and Child Exposures

Chronic toxicity values are used when calculating the RGOs for youth athletes and child spectators. However, subchronic toxicity values are more appropriate for durations less than 1/10th of a lifetime (i.e., less than 7 years). Subchronic toxicity values are less toxic than chronic toxicity values because higher doses can be tolerated for shorter exposure durations. Therefore, the RGOs based on long-term exposures may be overly conservative for youth athletes and child spectators who have shorter exposure durations.

8.7 Summary and Conclusions

Soil and shallow groundwater samples were collected in April and May 2007. Twenty one preliminary COPCs are identified for soil and one preliminary COPC (arsenic) is identified for shallow groundwater based on a comparison of maximum detected concentrations to

conservative RBSLs and background levels. Subsequently, potential future receptors, exposure scenarios, exposure factors, and toxicity values are identified, and a range of RGOs are calculated for four receptor types: youth recreator, adult recreator, child spectator, and construction worker. RGOs are calculated based on a target risk level of $1x10^{-5}$ and a target non-cancer HI of 1.0.

The final remedial goals are presented in Tables 8-12 and 8-13. Based on samples collected in April 2007 and May 2007, maximum detected concentrations of all preliminary COPCs except arsenic in soil are lower than RGOs; therefore, arsenic is the only chemical of concern in soil. Because the maximum detected concentration of arsenic in groundwater is lower than the RGO, there are no chemicals of concern in groundwater. As indicated in Section 6, the current average arsenic concentration in soil within the 0-3" depth interval across the Park is 175 mg/kg, which is less than the risk-based remedial goal for arsenic at the Park surface (212 mg/kg). The conclusions presented in this section are consistent with the Health Consultation prepared by ATSDR in June 2007.

It should be noted that there is a high level of conservatism in the derivation of toxicity values. For example, the RfD is a dose with a safety factor between 3 and 10, and the CSF is an upper-bound estimate of the dose-response curve; these toxicity values are expected to be overestimates of chemical toxicity and actual toxicities could be lower.

SECTION 9

Development of ARARs and RAOs

9.1 Remedial Action Objectives

Site-specific remedial action objectives (RAOs) were developed to eliminate or reduce the current and potential future risks to human health and the environment from constituents present at the Site. The following RAOs were developed for the Site:

- Prevention of human exposure, through contact, ingestion, or inhalation to contaminated soil that presents an unacceptable risk (i.e., HI greater than 1 or ELCR greater than $1x10^{-5}$); and
- Prevention of erosion and offsite transport of soils contaminated at concentrations posing unacceptable risk (i.e., HI greater than 1 or ELCR greater than $1x10^{-5}$).

Prevent Human Exposure through Contact, Ingestion, or Inhalation. Exposure to contaminated soil through direct contact and ingestion may occur given the Site is a recreational park. This RAO is intended to prevent unacceptable risks to park and construction workers, recreators (adult and youth), and children (spectator).

Prevent Erosion and Offsite Transport. Possible erosion of surficial soils could result in the offsite migration of COPCs at concentrations posing unacceptable risks through direct contact and ingestion. This RAO is intended to prevent unacceptable risks as a result of exposure to contaminated soils.

9.2 Applicable or Relevant and Appropriate Requirements

This section identifies and summarizes the federal and state laws, regulations, and guidance that affect remediation activities at the Site. The definitions of ARARs below are from USEPA guidance (USEPA, 1988).

- "Applicable requirements" are standards and other environmental protection requirements of federal or Maryland law dealing with a hazardous substance, pollutant, or contaminant and its remedial action.
- "Relevant and appropriate requirements" are standards and environmental protection criteria associated with federal or Maryland law that, although not "applicable" to a hazardous substance or remedial action, apply to situations sufficiently similar to those at the site that use of these requirements is suitable.
- A requirement may be "relevant" to a particular situation but not "appropriate" because of differences in the duration of the regulated activity or the physical characteristics of the affected media.
- A requirement that is relevant and appropriate must be met as if it were applicable. Relevant and appropriate requirements that are more stringent than applicable

requirements take precedence. However, judging the relevancy and appropriateness of these requirements inherently is a subjective process.

There are three classifications of ARARs: chemical-specific, location-specific, and action specific. Potential chemical-, location-, and action-specific ARARs for the Site are presented below. The remedial action alternatives described in this RAA report were analyzed for compliance with the potential federal and Maryland ARARs. The analysis involved identifying potential requirements for each of the alternatives, evaluating the applicability or relevance and appropriateness, and evaluating whether these can achieve the ARARs.

Chemical-specific ARARs are health or risk management-based numbers or methodologies that result in the establishment of numerical values for chemical concentrations for given media that would meet the NCP "threshold criterion" of overall protection of human health and the environment. These requirements generally set protective cleanup concentrations for COCs in the designated media, or set safe concentrations of discharge from remedial activity. Federal and Maryland chemical-specific ARARs are summarized in Appendix H, Table H-5.

Location-specific ARARs restrict activities based on the characteristics of the surrounding environments. Location-specific ARARs may include restrictions on actions within wetlands or floodplains, near locations of known endangered species, or on protected waterways. Federal and Maryland location-specific ARARs that have been reviewed are summarized in Appendix H, Tables H-3 and H-4.

Action-specific ARARs are requirements that define acceptable procedures related specifically to the type of activity being performed. Federal and Maryland action-specific ARARs that may affect the development and conceptual arrangement of removal action alternatives are summarized in Appendix H, Tables H-1 and H-2.

Target Cleanup Goals

s are summarized in Table 9-1. Cleanup levels must conform to the requirements of COMAR 26.14.02.06(E)(2) and Environment Article 7-508.b., and are selected from:

- Federal or State maximum contaminant levels (MCLs);
- Site-specific Risk Evaluations;
- Background levels; or
- Other federal or State standards that may be appropriate or relevant.

Guidance for the development of cleanup levels, conducting environmental assessments, and identifying remedial actions in compliance with COMAR and Maryland Environmental Articles 7-508 (the Voluntary Cleanup Program Act) and 7-208 (Controlled Hazardous Substances Act) has been developed by MDE (MDE, 2001). The guidance provides soil and groundwater standards derived from conservative residential and non-residential (commercial and industrial) exposure scenarios. The guidance does not provide standards which reflect exposure scenarios for a park or recreational site and indicates a preference for the development of site-specific cleanup standards in situations where property conditions or exposure scenarios differ significantly from the assumptions used to derive the residential and non-residential cleanup standards. Accordingly, the site-specific, risk-based cleanup levels for arsenic in site soils presented in Section 8 have been selected as the Target

Cleanup Levels because they are based on site-specific exposure scenarios for Swann Park and the method used for their development complies with applicable Maryland regulations and MDE guidance. Arsenic target cleanup goals that were developed based on the site-specific risk evaluation are summarized in Table 9-1.

The City and Honeywell recognize that the site-specific risk assessment completed for the park does not account for all individual exposure scenarios for potential park users Accordingly, the City and Honeywell have developed, screened, and evaluated specific remedies that are fully protective of any citizen of Baltimore that may visit, use, or participate in recreational activities at the park. As will be presented in subsequent sections of this report, the City and Honeywell are recommending a remedy that is fully protective of any citizen, despite their age, weight, health, occupation, frequency of park use, or any other predictive exposure scenario.

Soil Volume Estimation

Contaminated soil volumes were estimated for the most likely future land use at Swann Park based on exceedance of the risk based target cleanup goals. The following general assumptions were made for the estimation of soil volumes for Swann Park:

- Arsenic concentrations and excavation volumes were calculated for the Site from a numerical 3D solid model created using the C-Tech's Environmental Visualization System (EVS). The 3D arsenic concentration distribution was calculated using EVS's Kriging expert system. Kriging is an interpolation method based on sound mathematical and statistical concepts which ensures that the interpolated results accurately honor measured sample data.
- The model grid was selected by the expert system based on the number and density of field samples and thickness of the geologic layers. The outer boundaries of the solid model were chosen by the expert system to ensure high confidence in the calculations and are beyond the park boundary. Calculated excavation volumes were limited to within the park boundary.
- Input data for the model included validated field sampling results from 82 analytical samples collected from 32 boreholes from the ground surface to depths of approximately 5 feet below ground surface (bgs). The arsenic concentrations in soil are approximately log-normally distributed and were modeled with a horizontal to vertical anisotropy ratio of 10:1. Geologic layers were assumed to be coincident with sample depths: 0 to 3-inches bgs; 3 to 9-inches bgs, 9 to 24-inches bgs; and 24 to 60-inches bgs.
- Excavation volumes include soil overlying excessively contaminated soil (overburden) and a selected amount of over-excavation. The estimate includes overburden excavated with a an approximate 2 horizontal:1 vertical excavation slope.
- Excavation volume was limited vertically to the groundwater table. The water table was modeled using water level measurements collected in May 2007 from site monitoring wells. These measurements are believed to represent low water table conditions due to the dry weather conditions prior to this monitoring event.

Soil excavation volume estimates were based on exceedances of the risk based cleanup criteria for arsenic for the adult recreator and construction worker. Figures 9-1 and 9-2 show the approximate extent of arsenic in soil at Swann Park at concentrations greater than 212 and 454 mg/kg, respectively. The total volume of impacted soil located above the groundwater table for concentrations 212 and 454 mg/kg is 16,500 and 4,500 cubic yards, respectively.

SECTION 10

Screening of Remedial Technologies

10.1 General Response Actions

Identifying general response actions is the first step in the remedial alternatives analysis process; the general response actions are basic actions that might be undertaken to remediate a site. For each general response action, several possible remedial technologies may exist. They can be further broken down into a number of process options. These technologies and process options are then screened based on several criteria. Those technologies and process options remaining for Swann Park after screening are assembled into alternatives in Section 11.0. After the RAOs and PRGs were developed, general response actions consistent with these objectives were identified. The general response actions that may be applicable to the Site include:

- No action;
- Institutional controls;
- Containment;
- In situ treatment; and
- Excavation/disposal.

Each general response action for soil is discussed in the following paragraphs along with an overview of some of the technologies that are representative of the response action.

No Action. The no action response action would not satisfy the RAO of eliminating contact with the contaminated soil or preventing erosion; therefore, this action is not feasible. The no action alternative is retained through the RAA process as a basis of comparison.

Institutional Controls. Institutional controls for soil consist of restricting access to contaminated soil through fencing or land use restrictions (such as Deed Notices). The property is currently fenced to limit human contact to site soil.

Containment. Containment is used to minimize the risk of contaminant migration as well as prevent direct contact exposures. Soil capping or construction of an impermeable cap are applicable remedial technologies that could be used to eliminate exposure to contaminated soils and to help prevent contaminant migration offsite. Surface controls such as grading and revegetating can be used to reduce infiltration of precipitation through contaminated soil and prevent erosion and offsite transport of contaminated soil.

In Situ Treatment. In situ stabilization/solidification involves chemical reactions that physically bind or reduce the mobility of inorganic contaminants.

Excavation/ Disposal. Excavation involves removal of impacted soils (including historic fill) for either offsite or onsite disposal. Physical, chemical, or thermal treatment technologies are used once soil is excavated, as necessary. Physical processes include excavating the contaminated soil and transferring it to an approved onsite or offsite disposal area.

10.2 Technology Screening Methodology

In this section, the technology types and process options available for remediation of soil and groundwater are presented and screened. Screening begins with development of an inventory of technology types and process options based on professional experience, published sources, computer databases, and other available documentation for the general response actions identified in Section 10.1.

Technology types and process options are screened in an evaluation process based on effectiveness, implementability, and cost. Effectiveness is considered the ability of the process option to perform as part of a comprehensive remedial plan to meet RAOs under the conditions and limitations present. Implementability refers to the relative degree of difficulty anticipated in implementing a particular process option under regulatory, technical, and schedule constraints posed at the site. At this point, the cost criterion is comparative only, and similar to the effectiveness criterion, it is used to preclude further evaluation of process options that are very costly if there are other choices that perform similar functions with similar effectiveness at a lower cost. The cost criterion includes costs of construction and any long-term costs to operate and maintain technologies that are part of an alternative.

The technology types and process options identified in the following sections are those offering at least theoretical applicability to remediation of the media of concern at the site. This list of options should be considered dynamic, flexible, and subject to revision based on further investigation findings, results of treatability studies, or technological developments.

10.3 Technologies

Table 10-1 presents a wide range of potentially applicable technology types and process options for soil remediation at the Site. Arsenic treatment technologies considered for use at the Site included, but were not limited to, those presented in *Arsenic Treatment Technologies for Soil, Waste, and Water,* U.S. EPA2002. Screening comments are provided to highlight items of interest or concern for each option. This approach highlights differences within a remedial technology group to allow the best process within each group to be identified and selected.

The remedial technologies that were identified and screened include: land-use controls; containment by a soil cover or RCRA Subtitle D cap; *in situ* treatment by encapsulation (vitrification), chemical treatment (solidification/stabilization), and biological treatment (phytoremediation); and removal by excavation, physical treatment (soil mixing and soil washing), and landfill disposal. As presented in Table 10-1, vitrification was not retained due to the high cost, potential for toxicity of off-gases, and compatibility issues with future site uses. Solidification and stabilization was not retained due to the potential for treated material to weather and release into the environment and the need for extensive pilot and leachability tests to verify effectiveness. Although applicable, soil mixing was not retained because of potential difficulty in achieving thorough blending in large soil volume and the depth of soils that may need to be mixed. Phytoremediation was not retained because of compatibility with the end-use of the park, the limited treatment depth, climatic conditions that may interfere or inhibit plant growth, relatively slow remediation time, and the length

of the treatment period. Plant type was also limited to grasses to facilitate continued use of the site as an athletic recreational facility.

Select excavation of soils that exceed the site-specific, risk-based cleanup levels was developed, evaluated, screened and retained for further consideration. In addition, removal of soils that have concentrations of arsenic above background levels and MDE default cleanup standards was developed for consideration. Removal of soils that exceed background arsenic concentrations or default standards was not retained for further evaluation for the following reasons:

- nearly 4 thousand truckloads would be needed to remove the soil from the site and replace it with fill which would present unnecessary increased risks to the community, construction workers, truck drivers transporting soil to and from the park, and motorists as well as a significant increase in particulate and greenhouse gas emissions;
- construction would take over a year to complete which would postpone the reopening of the park; and
- removal of soils to background would cost over fifteen million dollars, five times greater than other available remedies that provide equivalent effectiveness, have widespread acceptance and application at other similar sites and can be implemented safely and expeditiously.

In summary, the response actions and associated technologies that were retained following screening include:

- No further action;
- Land Use Controls (LUC);
- Containment by soil and vegetative cover; and
- Selective excavation of the soil followed by offsite disposal.

The retained response actions and technologies were assembled into remedial alternatives and subjected to detailed evaluation as discussed in Sections 11 and 12 of this report.

SECTION 11

Development of Remedial Alternatives

The remedial technologies that remain after screening were assembled into a range of alternatives. The specific details of the remedial components discussed for each alternative are intended to serve as representative examples to allow development of comparative cost estimates. The following sections provide a detailed description of each alternative.

Aside from the no-action alternative, all of the remaining alternatives that were developed include an excavation component and some include placement of a soil cover to ensure that the exposure pathway for recreators is incomplete, thereby eliminating their risk of exposure to existing site soils. Therefore, the alternatives that include a soil cover would be independent of RGOs that were calculated for the recreator as part of the Human Health Risk Evaluation. In developing alternatives that include excavation, the RGOs for the recreator and the construction worker were used to determine the scope of excavation necessary to achieve the RGOs in surface soils (for protection of the recreator) and subsurface soils (for protection of the construction worker).

The calculated RGOs are values which are protective of chronic (long-term) soil exposures at the Site. As such, the RGOs represent a long-term, average concentration to which a receptor can be exposed over their assumed exposure duration. To achieve the RGO value in site soil by excavation, a remedial alternative would need to include removal of soils to an extent that would result in the average concentration of remaining soils be below the RGO value. In recognition of the difficulty in identifying the location and volume of soils that would need to be removed to create an average remaining arsenic concentration below the RGO values and to provide an additional margin of remedy protectiveness, excavation remedies were developed to remove all soils that exceed the RGO value. Application of this criterion to the alternatives that include excavation will result in average concentrations of arsenic in remaining site soils far below the RGOs. As identified in the remedial alternatives below, certain alternatives rely on excavation to achieve the RGO for the recreator and for the construction worker. Other alternatives rely on a soil cover to eliminate risk of exposure to the recreator and select excavation of soils to achieve the RGO for the construction worker.

Remedial alternatives were also developed to consider the existing plans of the City to redevelop Swann Park. The redevelopment plan includes rather significant changes in site grading to improve the utility of the park's athletic fields. Honeywell and the City have discussed the redevelopment plan in detail and the grade changes have been fully considered and included in development of remedial alternatives. In the discussion of alternatives below, excavation is framed in the context of "final grade" which has been defined as the final surface contour of the park and its elevation as determined by the City's redevelopment plan for Swann Park.

11.1 Alternative 1 – No Action

The no-action alternative is the baseline against which the effectiveness of other remedial alternatives can be compared. Under this alternative, no control or remediation would take place at the site. CERCLA (Section 121(c)), as amended by SARA, requires that the site be reviewed every 5 years to assess whether the risk to human or ecological receptors has changed.

11.2 Alternative 2 – Soil Removal, No Cover

This alternative provides a 24-inch depth of surface soils that are below the calculated RGO for a typical park recreator and provides utility corridors that are below the RGO for a construction worker. Implementation of this remedy includes:

- Excavation and offsite disposal of 10,300 cubic yards of soil with concentrations greater than the RGO for the recreator that are located within 2-feet below final grade.
- Excavation and offsite disposal of 1,040 cubic yards of soil within assumed primary utility corridors. The corridors would be a minimum of one foot wider than the utility line on each side and bottom of the line, would be lined with an MDE-approved marker fabric and backfilled with clean soil in accordance with MDE guidance (MDE, 2001). In certain areas, the utility corridors would be located and designed to be suitable for planting trees and other landscaping improvements to the park.
- Replacement of the 42-inch storm sewer including excavation and offsite disposal of 1,640 cubic yards of soil. The new stormdrain line would be placed in a clean fill corridor that is a minimum of one foot wider on each side of the line and a minimum of one foot deeper than the line in accordance with MDE guidance (MDE, 2001). The corridor would be lined with an MDE-approved marker fabric material.
- Regrading of remaining site soils to meet the City's redevelopment profile and evenly placing 12,980 cubic yards of imported clean fill to replace excavated soil and to meet final grade.
- Establishing vegetative cover by planting sod to minimize erosion.
- Establishing land use controls in the form of restrictions on excavation and groundwater use as needed.

A depiction of this alternative is shown in cross-sectional view in Figure 11-1 and the extent of excavation is shown in Figure 11-2.

11.3 Alternative 3 – Soil Removal, 12-Inch Cover

This alternative includes excavation of soils that exceed the calculated RGO for a construction worker and installation of a minimum 12-inch clean soil cover to protect the park recreator based on the site-specific risk evaluation and any other park user that was not included in the risk evaluation. Implementation of this remedy includes:

- Excavation and offsite disposal of 3,200 cubic yards of soils with concentrations greater than the RGO for the construction worker that are located within 4-feet of final grade

This essentially results in removing soils greater than the RGO for a construction worker to the depth of groundwater table.

- Excavation and offsite disposal of 520 cubic yards of soil within assumed primary utility corridors. The corridors would be a minimum of one foot wider than the utility line on each side and bottom of the line, would be lined with an MDE-approved marker fabric and backfilled with clean soil in accordance with MDE guidance (MDE, 2001).
- In areas where tree planting is planned as part of the park redevelopment, a minimum three foot thick soil cover will be provided.
- Replacement of the 42-inch storm sewer including excavation and offsite disposal of 1,420 cubic yards of soil. The new stormdrain line would be placed in a clean fill corridor that is a minimum of one foot wider on each side of the line and a minimum of one foot deeper than the line in accordance with MDE guidance (MDE, 2001). The corridor would be lined with an MDE-approved marker fabric material.
- Regrading of remaining site soils to meet the City's redevelopment profile.
- Importing and even placement of 18,000 cubic yards of clean fill to create a minimum 12-inch clean soil cover and to meet the final grade.
- Establishing vegetative cover by planting sod to minimize erosion.
- Establishing land use controls in the form of restrictions on excavation and groundwater use as needed.

A depiction of this alternative is shown in cross-sectional view in Figure 11-3 and the extent of excavation is shown in Figure 11-4.

11.4 Alternative 4 – Soil Removal and 24-Inch Cover

This alternative includes excavation of soils that exceed the calculated RGO for a construction worker and installation of a minimum 24-inch clean soil cover to protect the park recreator based on the site-specific risk evaluation and any other park user that was not included in the risk evaluation. Implementation of this remedy includes:

- Excavation and offsite disposal of 3,200 cubic yards of soil with concentrations greater than the RGO for the construction worker that are located within 5-feet of final grade. This essentially results in removing soils greater than the RGO for a construction worker to the depth of groundwater table.
- Excavation and offsite disposal of 520 cubic yards of soil within assumed primary utility corridors. The corridors would be a minimum of one foot wider than the utility line on each side and bottom of the line, would be lined with an MDE-approved marker fabric and backfilled with clean soil in accordance with MDE guidance (MDE, 2001).
- In areas where tree planting is planned as part of the park redevelopment, a minimum three foot thick soil cover will be provided.
- Replacement of the 42-inch storm sewer including excavation and offsite disposal of 1,420 cubic yards of soil. The new stormdrain line would be placed in a clean fill corridor

that is a minimum of one foot wider on each side of the line and a minimum of one foot deeper than the line in accordance with MDE guidance (MDE, 2001). The corridor would be lined with an MDE-approved marker fabric material.

- Regrading of remaining site soils to meet the City's redevelopment profile.
- Importing and evenly placing 36,000 cubic yards of clean fill to create a minimum 24-inch clean soil cover and to meet the final grade.
- Establishing vegetative cover by planting sod to minimize erosion.
- Establishing land use controls in the form of restrictions on excavation and groundwater use as needed.

A depiction of this alternative is shown in cross-sectional view in Figure 11-5 and the extent of excavation is shown in Figure 11-6.

11.5 Alternative 5 – Soil Removal to the Groundwater Table, 24-Inch Cover

This alternative includes removal of all soils above the groundwater table at the site that exceed the RGO for the park recreator or construction worker. This alternative was developed to present a remedy that has limited land-use controls. Select removal of soils to the groundwater table that exceed the RGO for the recreator would avoid the need for any controls on excavation or site regrading in the future. This alternative also includes a minimum 24-inch clean fill cover across the site surface. No controls or maintenance on the soil cover would be part of this alternative. It would remain protective until such time, if any, that site use changed or exposure parameters were significantly different than currently envisioned. Implementation of this remedy includes:

- Excavation and offsite disposal of 16,500 cubic yards of soil with concentrations greater than the RGO for the park recreator.
- Replacement of the 42-inch storm sewer including excavation and offsite disposal of 1,270 cubic yards of soil. The new stormdrain line would be placed in a clean fill corridor that is a minimum of one foot wider on each side of the line and a minimum of one foot deeper than the line in accordance with MDE guidance (MDE, 2001). The corridor would be lined with an MDE-approved marker fabric material.
- Regrading of site soils to meet the City's redevelopment profile.
- Importing and evenly placing 36,000 cubic yards of clean fill to create a 24-inch layer of clean soil and to meet the final grade.
- Establishing vegetative cover by planting sod to minimize erosion.
- Restrictions on groundwater use may be imposed, restrictions on any excavation below water table will be required.

A depiction of this alternative is shown in cross-sectional view in Figure 11-7 and the extents of excavation are shown in Figure 11-8.

SECTION 12

Detailed Analysis of Remedial Alternatives

The detailed analysis of alternatives presents an evaluation of remedial alternatives for soil relative to each other and against the established evaluation criteria. The detailed analysis of alternatives consists of the following components:

- A detailed evaluation of each alternative against evaluation criteria established in the MDE Order
- A comparative evaluation to facilitate remedy selection

The detailed evaluation is presented in table format. The comparative evaluation is presented in text and highlights the most important factors that distinguish alternatives from each other.

12.1 Evaluation Criteria

MDE's Order lists six criteria by which each remedial unit alternative must be evaluated. These criteria provide grounds for comparison of the relative performance of the alternatives and identify their advantages and disadvantages. This approach is intended to provide sufficient information to adequately compare the alternatives and to select the most appropriate and cost-effective alternative for implementation at the site as a remedial action. The evaluation criteria are:

- Compliance with ARARs
- Short-term Effectiveness
- Long-term Effectiveness and Permanence
- Reduction of Toxicity, Mobility, or Volume through Treatment
- Implementability
- Cost

In addition to the evaluation criteria in the MDE Order, the alternatives were also evaluated for integration with site end-use and schedule to re-open park.

The criteria are divided into two groups: threshold, and balancing criteria. The single threshold criterion is compliance with ARARs. The threshold criterion must be met by a particular alternative for it to be eligible for selection as a remedial action. There is little flexibility in meeting the threshold criterion, unless it is waived by MDE—either it is met by a particular alternative, or that alternative is not considered acceptable.

The six balancing criteria include: (1) long-term effectiveness and permanence, (2) reduction of toxicity, mobility, or volume through treatment, (3) short-term effectiveness, (4) implementability, (5) cost, and (6) integration with site end-use and schedule to re-open the park.

The six balancing criteria weigh the trade-offs between alternatives. A low rating on one balancing criterion can be compensated by a high rating on another. The threshold and balancing criteria evaluated in this document are briefly described below.

Although the process and criteria MDE will apply to select the remedy for Swann Park is not identified in the Order, typically the remedy selected must meet the threshold criteria and be cost-effective. Cost-effectiveness is determined by weighing overall effectiveness (which is a cumulative assessment of balancing criteria 1, 2 and 3 above) of a remedy with its cost. Section 13 provides recommendations for remedy selection based on this typical methodology.

12.1.1 Threshold Criteria

To be eligible for selection, an alternative must meet the threshold criteria described below.

Compliance with ARARs

ARARs are cleanup standards, standards of control, and other substantive environmental statutes or regulations which are either "applicable" or "relevant and appropriate" to the cleanup action. Applicable requirements address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances at the site. Relevant and appropriate requirements are those that, while not applicable, address problems or situations sufficiently similar to those encountered at the site such that their use is well suited to environmental or technical factors at the site. The assessment against this criterion describes how the alternative complies with ARARs or presents the rationale for waiving an ARAR.

12.1.2 Balancing Criteria

The six criteria listed below are used to weigh the trade-offs between alternatives.

Short-term Effectiveness

This criterion addresses short-term impacts of the alternatives. The assessment against this criterion examines the effectiveness of alternatives in protecting human health and the environment during the construction and implementation of a remedy until the response objectives have been met.

Long-term Effectiveness and Permanence

This criterion reflects an emphasis on implementing remedies that will ensure protection of human health and the environment in the long term, as well as in the short term. The assessment of alternatives against this criterion evaluates the residual risks at a site after completing a remedial action or enacting a no action alternative and includes evaluation of the adequacy and reliability of controls.

Reduction of Toxicity, Mobility, or Volume through Treatment

The assessment against this criterion evaluates the anticipated performance of the specific treatment technologies an alternative may employ. The criterion is specific to evaluating only how treatment reduces toxicity, mobility, or volume.

Implementability

The assessment against this criterion evaluates the technical and administrative feasibility of the alternative and the availability of the goods and services needed to implement it.

Cost

Cost encompasses engineering, construction, and operations and maintenance (O&M) costs incurred over the life of the project. The assessment against this criterion is based on the estimated present worth of these costs for each alternative. These estimated costs are expected to provide an accuracy of plus 50 percent to minus 30 percent.

Integration with Site End-Use and Schedule to Re-Open Park

The assessment against this criterion evaluates whether the alternative is consistent with the City's plans for park improvements and the desire to re-open the park as soon as possible.

12.2 Detailed Analysis of Soil Remedial Alternatives

The following alternatives were developed and described in Section 11:

Number	Alternative	Description
1	No Action	No remediation, Park left as is.
2	Soil Removal, No Cover	Excavation of soils exceeding site-specific, risk-based values within 24-inches of final grade and land-use controls.
3	Soil Removal, 12 inch Cover	Excavation of soils exceeding site-specific, risk-based values for a construction worker; construction of a 12-inch clean soil cover to eliminate exposure to park users by preventing direct contact with remaining soils and prevent erosion; and limited land-use controls.
4	Soil Removal, 24 inch Cover	Excavation of soils exceeding site-specific, risk-based values for a construction worker; construction of a 24-inch clean soil cover to eliminate exposure to park users by preventing direct contact with remaining soils and prevent erosion; and limited land-use controls.
5	Soil Removal to the Groundwater Table, 24 inch Cover	Excavation of soils exceeding site-specific, risk-based values to the groundwater table and construction of a 24-inch clean soil cover to prevent direct contact with remaining soils and prevent erosion; and limited land use controls for soils below water table.

Table 12-1 presents detailed evaluations for these soil media alternatives using the seven evaluation criteria described in Section 12.1.

12.3 Comparative Analysis of Remedial Alternatives

12.3.1 Compliance with ARARs

All alternatives other than Alternative 1, No Action, are expected to comply with ARARs, but by different means as discussed below.

Alternatives 3 and 4 comply with ARARs for the recreator by eliminating the exposure pathway through a soil cover and land-use controls to ensure that the cover is maintained. Alternatives 3 and 4 comply with ARARs for the construction worker by the multiple means

of selective excavation of soils that exceed the HHRE-derived RGO, utility corridors and land-use controls that would provide ARAR compliance independently of the calculated RGO.

Alternative 2 complies with ARARs for the recreator by removing soils at the surface that exceed the HHRE-derived RGO coupled with land-use controls to ensure that the two-feet of surface soils which are below the RGO are maintained. Alternative 2 complies with ARARs for the construction worker by installation of utility corridors for the currently anticipated utility locations and land-use controls.

Alternative 5 complies with ARARs for the recreator by eliminating the exposure pathway through a soil cover. There are no land-use controls to ensure the maintenance of the soil cover, but rather excavation of remaining soils above the water table that exceed the HHRE-derived RGO for the recreator. Alternative 5 complies with ARARs for the construction worker by excavation of soils that exceed the HHRE-derived RGO, but no land use controls.

12.3.2 Short-term Effectiveness

The short-term effectiveness of the alternatives can be broken down into: (1) protectiveness of workers and the community during implementation, and (2) the time to complete the remedial alternative, which varies, largely as a result of the soil volumes excavated and ability to establish a ground cover (sod) immediately following excavation and regrading activities. Generally, alternatives that include excavation and disposal of arsenic-impacted soil are less protective of workers and the community than soil alternatives that do not disturb the soil. All alternatives other than the No Action Alternative include excavation; however, these alternatives will meet RAOs and the No Action Alternative will not.

When considering protection of workers and the community during implementation, Alternatives 2 through 5 have the potential for adverse impacts to both workers and the community during construction related to fugitive dust emissions and truck traffic hauling impacted soil. The site soils that are targeted in these excavation alternatives would require health and safety measures to ensure worker protection. Air monitoring would also be required for all of the excavation alternatives to protect workers and the local community (i.e., residential homes, which are within 0.25 mile of the site to the east). Alternative 3 has the lowest potential impact to the workers and community during construction due to the smallest excavation volume. The greater imported fill quantity in Alternative 4 results in a greater potential impact to the workers and community due to the increased truck traffic to and from the site. Alternative 5 results in the disturbance of the largest volume of site soil and therefore has the greatest potential for fugitive dust emissions and exposure to truck traffic.

When comparing the soil alternatives related to the time to complete remedial actions, the alternatives that require less excavation can be completed sooner than the large-scale excavation alternatives. The excavation and imported fill quantities drive the construction schedule since the other features of the remedial alternatives are common to all. Alternative 3 would take the shortest time to implement, estimated at just under 6 months. Alternative 2 is estimated at 6 months to complete and Alternative 4 is estimated to take nearly 7 months to complete. Alternative 5 is estimated to take at least 8 months to complete due to the largest excavation quantities and imported borrow material required for the 24-inch soil cover. Each of these durations includes an assumed 6 weeks for design and 8 weeks for bid

preparation, bid review, and contracting. Because of these construction schedules, Alternative 3 would take the shortest time to meet RAOs and Alternative 5 would take the longest time to meet RAOs.

12.3.3 Long-term Effectiveness and Permanence

The long-term effectiveness and permanence of the alternatives vary, largely as a result of the placement of a soil cover and, to a lesser extent, the degree of excavation achieved. Alternatives 3, 4 and 5 would be more effective than Alternative 2 because these alternatives include a soil cover on remaining unexcavated soil and would eliminate the exposure path, and thereby risk, to recreators and would be independent of any uncertainties in the calculated RGO for the recreator. Alternatives 3 and 4 include land-use controls to maintain the soil cover and for protection of the construction worker (in addition to select excavation and utility corridors) providing greater long-term effectiveness and permanence than the other alternatives. Alternative 5 has no land-use controls to maintain the soil cover and relies solely on the HHRE-derived RGO to provide long-term effectiveness and permanence.

12.3.4 Reduction of Toxicity, Mobility, or Volume

Alternatives 2 through 5 provide various degrees of contaminant reduction by excavation and disposal of arsenic impacted soils at an offsite disposal facility. Alternatives 3, 4, and 5 also provide a degree of containment with the construction of a clean soil cover to limit direct contact with soils and prevent erosion.

Alternatives 3 and 4 provide the least volume reduction with the excavation and offsite disposal of approximately 3,200 cubic yards of soil that exceed the RGO for the construction worker. Alternative 2 removes approximately 10,300 cubic yard of soil with arsenic concentrations that exceed the RGO for the recreator. Alternative 5 provides the greatest volume reduction with the removal of 16,500 cubic yard of soil with arsenic concentrations that exceed the RGO for the recreator above the water table.

Alternatives 2, 3, 4, and 5 include the excavation of soil containing the most elevated levels of arsenic in the northwest and northern boundary of the Site. Removing these soils will significantly reduce the average concentration of arsenic that remains at the Site to a level that is far below the RGOs.

12.3.5 Implementability

Alternatives involving excavation would be more difficult to implement than institutional controls because of the health and safety measures, potential for air emissions and truck traffic in the community as discussed previously. However, based on prior sampling and analytical results, it is anticipated that disposal of excavated soil would be managed as a non-hazardous waste, thus no additional health and safety considerations, treatment permit requirements, and shipping considerations would be required. In general, as the excavation and imported fill quantities increase, the implementability decreases with a longer construction schedule and more truck traffic transporting the material to and from the site.

Alternatives 3 and 4 are the easiest to implement since the area of excavation is relatively small (approximately 3,200 cubic yards) and construction time is relatively short. In addition to excavation quantities, Alternative 3 also requires 18,000 cubic yards of imported borrow material to construct a 12-inch soil cover. Alternative 4 is somewhat more difficult to

implement than Alternative 3 because of the additional 18,000 cubic yards of imported borrow material required to construct a 24-inch soil cover (total of 36,000 cubic yards of imported borrow material). Alternative 2 is more difficult to implement than Alternatives 3 and 4 because of the additional excavation required. Although Alternative 2 does not have a soil cover, 12,980 cubic yards of borrow material must still be imported to replace the excavated soils. Alternative 5 would be the most difficult to implement because of the large volume of soil that must be excavated (16,500 cubic yards) and 36,000 cubic yards of imported borrow material for the 24-inch soil cover. Therefore, Alternative 3, which has the lowest excavation and imported fill quantity, ranks highest and Alternative 5 ranks lowest in implementability.

12.3.6 Cost

Cost estimates for each alternative are presented in Appendix I. A summary of present worth costs for each alternative that includes annual operating and maintenance costs is presented in Table 12-2. Costs presented represent an accuracy of accuracy of +50 to -30 percent. Actual costs will depend on the final scope and design of the selected remedial action, the volume of soil actually removed for offsite disposal, the schedule of implementation, competitive market conditions, and other variables.

Alternative 1, the no action alternative, has the lowest present worth cost, at $0. The lowest cost alternative, excluding the no action alternative, is Alternative 3 at $2,947,000. This alternative has the least excavation quantity and a constructed soil cover of 12-inches. Alternative 4 is the next highest cost alternative at $3,493,000 followed by Alternative 2 at $4,217,000, and then Alternative 5 at $5,774,000.

12.3.7 Integration with Site End-Use and Schedule to Re-Open Park

Alternatives 2, 3, 4, and 5 are all in alignment with the City's plan for park improvements. The final grade elevations achieved in each alternative vary in order to optimize imported fill and cover soil requirements with the grade achieved following excavation. Alternatives 2 and 3 would take the least time to implement and offer the greatest potential for the park to re-open in Spring 2008, but would likely require construction to be performed throughout the winter months and a sod field in lieu of grass from seed to establish the vegetative cover in time for Spring use. Alternatives 4 and 5 would take the longest time to implement and with construction being performed in the winter months, the park still may not be ready until late spring or summer 2008. As indicated previously, a sod field in lieu of grass from seed would be required to establish the vegetative cover.

Excavation of soils and placement of soil cover will alter the final grade of the park. Alternatives 2 and 3 result in a final grade that is closer to the City's redevelopment plan. Alternatives 4 and 5 will require rather significant increases to the final grade in order to accommodate the 24-inch soil cover. There may be additional measures that must be undertaken to interface the raised grade with bordering properties. Therefore, Alternatives 2 and 3 rank the highest with respect to integration with the park reconstruction process.

SECTION 13

Conclusions and Recommendations

The following conclusions can be drawn from the comprehensive investigation that was completed at Swann Park in accordance with the MDE Order:

- Arsenic is the only constituent of concern that is consistently present at the site in excess of the default, non-site specific screening criteria MDE Cleanup Soil Standards for Residential and Non-Residential land use.
- Arsenic is detected in soils across the site, but elevated concentrations are generally limited to the northwest corner of the Site, the surface soils in the central portion of the Site, and in subsurface soils along the northern property boundary.
- Arsenic mineralogy indicates that the arsenic distribution in soil is contained within 90 percent of three relatively insoluble mineral phases and with the exception of the northwest corner of the Site, the soil and groundwater conditions at Swann Park are favorable to retention of arsenic within these mineral phases, now and in the future.
- There were no contaminants of concern requiring further action identified for groundwater.
- Sampling of stormwater and visual inspection of the condition of the storm drain indicates a deteriorated condition that may allow infiltration of groundwater, suggesting that the storm drain should be removed and replaced.
- RGOs for the average concentration of arsenic in soils were calculated for a recreator and construction worker using a conservative Human Heath Risk Evaluation (HHRE) as 212 mg/kg and 454 mg/kg, respectively.

The following conclusions were developed through the Remedial Alternatives Analysis that was completed in accordance with the MDE Order:

- Remediation goals were identified based on development of ARARs that included the RGOs that were calculated as part of the HHRE.
- Although RGOs were identified as average concentrations of arsenic that could remain in the surface soils for protection of the recreator and in subsurface soils to protect the construction worker, for additional protectiveness and conservatism the RGOs were considered as a maximum arsenic concentrations that could remain in soils for development, screening and ranking of remedial alternatives.
- Land Use Controls (LUC), containment by soil and vegetative cover, and selective soil excavation and offsite disposal were retained for development of remedial alternatives after a comprehensive screening of process options and associated technologies was completed. Soil removal to arsenic background levels and default standards was considered but eliminated from further evaluation because it is not necessary for human

health protection at Swann Park, would postpone reopening of the park, and may present unnecessary risks to the community, construction workers and local motorists.

- Five remedial alternatives were developed from the retained process options and associated technologies and screened and ranked against the threshold and balancing criteria specified in the MDE Order that included a "no action" alternative and four alternatives that included elements of land-use controls, select excavation and soil cover.
- In general, alternatives that included select excavation, a soil cover and land-use controls (Alternatives 3 and 4) ranked higher in overall effectiveness than the other alternatives (Alternatives 2 and 5). The no action alternative (Alternative 1) was used for comparative purposes, but ranked as the least favorable alternative.

The conclusions of the Comprehensive Investigation and the Remedial Alternatives Analysis provide sufficient site characterization data and engineering evaluation to select an appropriate remedy for Swann Park. A broad range of technologies were identified, developed, screened and evaluated in the form of remedial alternatives. The alternatives were ranked in each of the evaluation criteria specified in the Order. Although the process and criteria MDE will apply to select the remedy for Swann Park is not identified in the Order, typically the remedy selected must meet the threshold criteria and be cost-effective. In this case the threshold criterion is compliance with ARARs. Alternatives 2 through 5 satisfy the ARARs, leaving cost-effectiveness as the principal means for selection.

Cost-effectiveness is determined by weighing overall effectiveness of a remedy with its cost. Overall effectiveness is a combination of three of the balancing criteria, namely: short-term effectiveness; reduction in toxicity, mobility or volume; and long-term effectiveness and permanence. As presented in Section 12, Alternatives 3 and 4 ranked higher than 2 and 5 in both short-term effectiveness and long-term effectiveness and permanence. Alternatives 2 and 5 ranked higher than 3 and 4 in reduction in toxicity, mobility or volume. However, Alternatives 3 and 4 also include excavation of portions of the Site (northwest corner and other areas) where more elevated concentrations of arsenic have been detected. It is clear that Alternatives 3 and 4 are superior to 2 and 5 because the effectiveness and permanence offered by these alternatives. Alternative 3 would be considered more cost-effective than Alternative 4 because of it offers a similar level of overall effectiveness in meeting all the remedial requirements at a lower cost.

Although Alternative 3 has been identified as the most cost-effective remedy for Swann Park, Honeywell and the City have agreed to recommend Alternative 4, which is equivalent to Alternative 3 in overall effectiveness, but includes a 24-inch soil cover rather than a 12-inch soil cover and will cost approximately $500,000 more than Alternative 3 to construct.

The City's endorsement of Alternative 4 should not be interpreted as an endorsement of the particular exposure levels and durations used in the site-specific risk evaluation for the park. The City believes that Alternative 4, which provides a minimum 2 foot clean soil cover across the entire site, protects the health of park users, regardless of the length of their exposure. The City will always prefer to have contaminated sites cleaned to the highest level of safety, per MDE and EPA standards. In this case the minimum 2 foot clean soil cover negates the need for further discussion or debate about exposure scenarios used in the site-specific risk evaluation.

Upon MDE approval of the recommended remedy, Honeywell and the City will work together to develop and submit design documentation to MDE. The remedial design will include drawings, specifications, a construction health and safety plan, a confirmatory sampling plan for soil excavation in accordance with MDE guidance (MDE, 2001), a land-use controls plan, a monitoring and maintenance plan, a schedule for implementation of the approved remedy, and a cost estimate for long-term maintenance of the remedy.

SECTION 14

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