SECTION 1

Introduction

This *Sediment and Surface Water Study Report* provides the results for the sediment and surface water study conducted in the Patapsco River near Dundalk Marine Terminal (hereafter referred to as DMT or Site) in Baltimore, Maryland. This study was conducted pursuant to the requirements of Section III.B.3 of the April 5, 2006, Consent Decree entered into by and among the Maryland Department of the Environment (MDE), the Maryland Port Administration (MPA), and Honeywell International Inc. (Honeywell). The purpose of the sediment and surface water study is to characterize the nature and extent of chromium in the surface water, pore water, and sediments of the Patapsco River and Colgate Creek within the zone potentially impacted by chromium releases at or from DMT. The investigation was conducted in accordance with the *Final Sediment and Surface Water Study Work Plan, Dundalk Marine Terminal, Baltimore, Maryland* (Work Plan) (CH2M HILL and ENVIRON, 2007a).

The sediment and surface water study included four quarterly sampling events that were conducted in May 2007, August 2007, December 2007, and February 2008. It also included geophysical surveys of the Patapsco River (i.e., bathymetric and acoustic sub-bottom profiling surveys), and two groundwater upwelling surveys. This report presents the results of all of the investigation activities. Technical memoranda summarizing the results of the four quarterly sampling events were prepared and submitted to MDE (CH2M HILL and ENVIRON, 2007b; 2007c; 2008a; 2008b).

The results of the sediment and surface water study will be used in ecological and human health risk assessments for DMT. They will also be integrated with the results of the Chromium Transport Study (CH2M HILL, 2006a) and used to support a Corrective Measures Alternatives Analysis (CMAA) for DMT. The Chromium Transport Study will present the results of groundwater and stormwater investigations being performed at DMT, and evaluate potential chromium transport pathways from DMT to the Patapsco River.

1.1 General Site Description

DMT is located in Baltimore Harbor, on the north side of the Patapsco River, as indicated on Figure 1-1. DMT is on a peninsula that is bounded on the northwest by Colgate Creek, on the west and south by the Patapsco River, and on the northeast by the Broening Highway and Norfolk Southern Railroad. A portion of DMT is located on land that was created by the placement of chromium ore processing residue (COPR) fill material. The fill material includes mixtures of COPR, man-made fill, and locally available fill materials. The extent of COPR fill is shown in Figure 1-1. COPR is composed primarily of calcium, iron, aluminum, magnesium, and chromium, which comprise greater than 90% of its mass (CH2M HILL, 2007). Trace amounts of other metals, including manganese and vanadium, are also present. Chromium occurs in both the trivalent [Cr(III)] and hexavalent [Cr(VI)] forms.

1.2 Objectives

The primary objectives of the sediment and surface water study were as follows:

1. Characterize the nature and extent of chromium in pore water, surface water, and sediments within the zone potentially impacted by chromium releases at or from DMT.
2. Evaluate the fate and transport of chromium in pore water, surface water and sediment.
3. Provide data to support ecological and human health risk assessments.

The distribution and extent of other COPR-related constituents (aluminum, calcium, iron, manganese, and vanadium) in pore water, surface water, and sediment were also assessed.

1.3 Overview of Related Studies

Information from a number of related investigations is considered in this sediment and surface water study. These investigations include historical studies of sediment and surface water near DMT, and recent research related to chromium geochemistry and behavior in Baltimore Harbor. These studies are briefly described below.

1.3.1 Historical Studies

Table 1-1 identifies historical studies that include chromium data for surface water and sediment samples collected in the Patapsco River near DMT. Surface water and sediment samples were collected near DMT in 1987 (EA, 1987), 1997 (MDE, 1997), and 1999 (MPA, 1999). Sample locations near DMT from historical studies are shown in Figure 2 of the Work Plan. Analytical results from these investigations are summarized in Tables 1 and 2 of the Work Plan.

Three rounds of sediment and surface water samples were collected by EA in 1987, several years prior to construction of the groundwater treatment plant and stormwater retention basins at the 14th and 15th Street outfalls. Sediment samples were analyzed for total chromium and Cr(VI), and surface water samples were analyzed for Cr(VI). Maximum total chromium concentrations in sediment ranged from 3.9 to 790 mg/kg, and were highest adjacent to the 14th and 15th Street outfalls. Cr(VI) was detected in sediment samples in one of the three sampling events. As noted in the Work Plan, historical results for Cr(VI) in sediment should be interpreted with caution because the specific analytical method used for Cr(VI) was not reported by EA (1987), the testing method used by EA may not be the currently accepted U.S. Environmental Protection Agency (USEPA) method for measuring Cr(VI), and the measurement of Cr(VI) has a potential for false positive trace concentrations due to method-induced oxidation (USEPA, 2005a). Cr(VI) was detected in some of the surface water samples collected near the 14th, 15th, and 13th Street outfalls.

Concentrations of contaminants in surficial sediments were mapped by MDE in a 1997 study of the Baltimore Harbor/Patapsco River/Back River system (MDE, 1997). Three sample stations from the study were located near DMT. Three composite bulk sediment samples were collected and analyzed in 1999 in conjunction with maintenance dredging in shipping channels along the southeastern portion of DMT. Total chromium concentrations in these sediment samples ranged from 14 to 284 mg/kg.

1.3.2 Recent Chromium-related Research

Much recent work has been conducted in regard to chromium behavior and predictability in order to more clearly understand fate and transport processes as well as potential toxicity associated with chromium in sediments. Some of this work has been performed by Johns Hopkins University (JHU) researchers using Baltimore Harbor sediments (Graham et al., 2009; Graham and Wadhawan, 2007a and b). Section 5.4 of this report summarizes key findings from studies that address chromium in Baltimore Harbor sediments, pore water, and surface water as well as sediments in other estuarine environments. The studies primarily focus on the behavior and stability of chromium in an estuarine environment, fate and rates of reduction of Cr(VI) entering the Harbor, and the likelihood of oxidation of Cr(III) in sediments; as these issues are directly relevant to determinations of the fate and transport of chromium at DMT. The following recent studies are briefly reviewed in Section 5.4:

- *Chromium Occurrence and Speciation in Baltimore Harbor Sediments and Porewater* (Graham et al., 2009)
- *Determination of Conditions Conducive to the Reduction of Cr(VI) to Cr(III) in Aquatic Environments and Sediment* (Graham and Wadhawan, 2007a)
- *Study to Determine the Likelihood that the Reduction of Cr(VI) to Cr(III) will be a Permanent Process – Cr(III) Oxidation* (Graham and Wadhawan, 2007b)
- *Geochemical Stability of Chromium in Sediments from the Lower Hackensack River, New Jersey* (Magar et al., 2008)
- *Chromium Geochemistry and Bioaccumulation in Sediments from the Lower Hackensack River, New Jersey, U.S.A.* (Martello et al., 2007)

JHU researchers also conducted a comprehensive study of potential toxicity associated with exposure to total chromium in sediments. In addition, studies conducted at other estuarine sites provide insight regarding the potential risks associated with elevated total chromium in sediments. These studies, while identified below, are more appropriate and applicable for the assessment of ecological risks associated with DMT. As such, they are only briefly mentioned in Section 5.4.

- *The Sediment Ingestion Pathway as a Source of Toxicity in the Baltimore Harbor* (Watlington et al., 2008)
- *Evaluation of Potential Toxicity and Bioavailability of Chromium in Sediments Associated with Chromite Ore Processing Residue* (Becker et al., 2006)
- *Using a Sediment Quality Triad Approach to Evaluate Benthic Toxicity in the Lower Hackensack River, New Jersey* (Sorensen et al., 2007)

1.4 Organization of Report

This document is organized as follows:

1. **Introduction.** This section provides a general site description, a summary of the objectives of the sediment and surface water study, and an overview of historical studies

conducted near DMT and research related to chromium geochemistry and behavior in Baltimore Harbor.

2. **Preliminary Conceptual Site Model.** This section presents the preliminary conceptual site model (CSM) for the Patapsco River adjacent to DMT, including a description of potential sources of chromium and migration pathways from DMT to the river. Section 2 also discusses chromium geochemistry and the physical fate and transport processes relevant to DMT.
3. **Investigation Scope and Approach.** This section provides an overview of the sediment and surface water study design and data evaluation approach.
4. **Field and Laboratory Methods and Results.** This section describes the field investigation methods and results, laboratory methods and analyses, data management and data validation procedures, and modifications to the approach described in the Work Plan.
5. **Quarterly Sampling Results.** This section presents the results of the four quarterly sampling events, and describes the occurrence and distribution of chromium and key geochemical parameters in pore water, surface water, and sediment at DMT. The distribution and extent of other COPR constituents (aluminum, calcium, iron, manganese, and vanadium) are also discussed. The results of this study are compared with results from historical studies conducted near DMT.
6. **Summary and Conclusions.** This section presents the findings and conclusions regarding the nature and extent, and fate and transport of chromium in the Patapsco River adjacent to DMT. Refinements to the CSM for DMT based on the results of this study are also described.
7. **References.** This section provides the references cited in this report.

The following supporting documentation is provided electronically as appendices to this report:

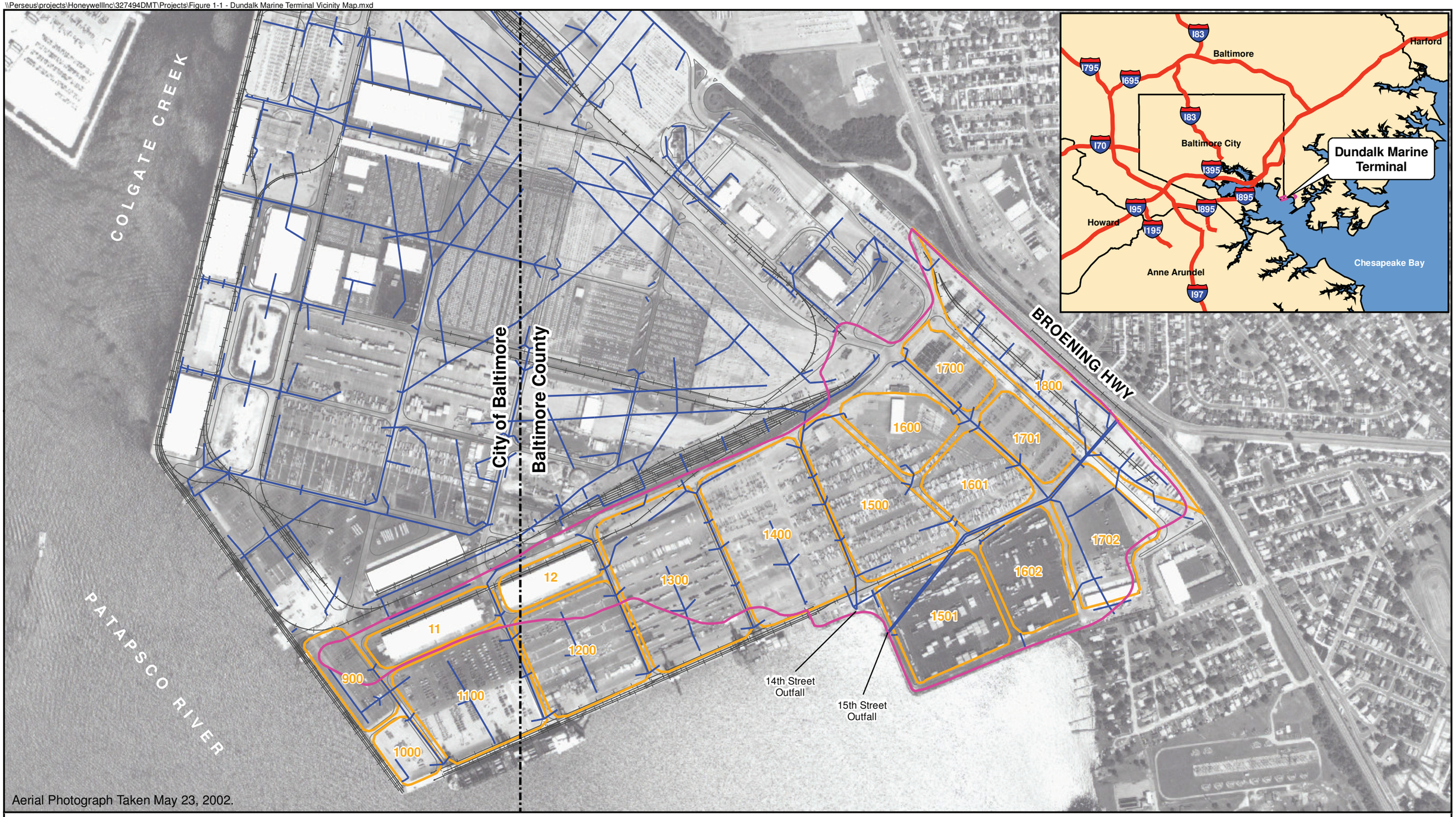
Appendix A: Geophysical Survey Report
Appendix B: Groundwater Upwelling Survey Reports
Appendix C: Field Documentation
Appendix D: Data Validation Summaries
Appendix E: Pore Water, Surface Water, and Sediment Sampling Results

TABLE 1-1
Summary of Historical and Related Studies
Dundalk Marine Terminal, Baltimore, Maryland

Organization	Year	Total Cr in Sediment (mg/kg)	Cr(VI) in Surface Water (mg/L)	Comments
EA Engineering, Science and Technology, Inc. (EA)	1987	3.9–790 [Cr(VI) 8.5–100]	< 0.02–0.28	Sampled prior to construction of wastewater treatment plant and the 14th and 15th Sts. stormwater outfall basins. Majority of surface water results were below the detection limit. Maximum concentration was 100 ft from the 15th St. drain.
Maryland Department of the Environment (MDE)	1997	34.3–283.6	Not sampled	Concentration range from the three sample stations near DMT.
Maryland Port Administration (MPA)	1999	14.4–31.4	Not sampled	Results of three composite bulk sediment samples collected in shipping channels along the SE portion of DMT.

EA Cr(VI) results should be interpreted with caution because the specific analytical method used for Cr(VI) was not reported by EA (1987) and may not be the currently accepted USEPA method for measuring Cr(VI), and the measurement of Cr(VI) has a potential for false positive trace concentrations due to method-induced oxidation (USEPA, 2005).

\\Perseus\projects\HoneywellInc\327494DMT\Projects\Figure 1-1 - Dundalk Marine Terminal Vicinity Map.mxd



Legend

- County/City Boundary
- Storm Sewer Line
- Railroad Centerline
- Curb
- COPR Extent
- Areas

N
W E
S

600 0 600 1,200
Feet

Figure 1-1
DMT Regional Location and Vicinity Map
Dundalk Marine Terminal
Baltimore, Maryland

ENVIRON
CH2MHILL