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October 7, 2009

Mr. Harold Dye, Jr.
Mr. James Carroll

Maryland Department of the Environment
1800 Washington Boulevard, Suite 645
Baltimore, MD 21230-1719

Subject: Chromium Transport Study Report, Dundalk Marine Terminal, Baltimore, Maryland

Dear Messrs. Carroll and Dye:

Honeywell International Inc. (Honeywell) and the Maryland Port Administration (MPA) are submitting the enclosed document titled "Chromium Transport Study Report, Dundalk Marine Terminal, Baltimore, Maryland." This document provides the results of the Chromium Transport Study that was conducted pursuant to the requirements of Section III.B.2 of the Consent Decree entered into by Maryland Department of the Environment (MDE), the MPA and Honeywell.

If you have any questions or comments, please contact me at 973-455-4131.

Very truly yours,

HONEYWELL INTERNATIONAL INC.

Christopher M. French
Project Coordinator

Attachment (4 copies)

cc: Mr. Horacio Tablada/MDE (letter only)
Mr. Matthew Zimmerman/MDE
Mr. Robert Munroe/MPA
Mr. Mark Kreafle/MPA
Mr. Michael Daneker/Arnold & Porter

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Chromium Transport Study Report, Dundalk Marine Terminal, Baltimore, Maryland

Prepared for

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October 2009

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Executive Summary

This Chromium Transport Study (CTS) provides the results of the studies undertaken to investigate chromium transport through groundwater, stormwater, and air at the Dundalk Marine Terminal ("DMT" or the "Site") in Baltimore, Maryland. The investigation was conducted in accordance with the requirements of Section III.B.2 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). Sampling activities were conducted in accordance with a series of work plans identified in Section 3 of this report.

Groundwater. Results of the CTS indicate that direct groundwater transport of chromium does not constitute a major transport pathway to either the river or to deeper groundwater systems (Table ES-1). Reductive mechanisms and physical barriers to groundwater movement limit the offsite transport of chromium through groundwater.

TABLE ES-1
Chromium (VI) Mass Flux in Groundwater (lbs/yr)

Unit	Mass Flux
Shallow Fill	1.60
Upper Sand	0.10*
Patapsco Aquifer	NA

* Chromium (VI) concentrations were not identified in the Upper Sand Unit and Patapsco Aquifer. Mass flux value is based on a concentration equal to one half of the detection limit.

NA, not applicable.

Stormwater. Stormwater discharges from the 12th through 15th Street drain systems currently present a transport pathway to the river. These drains are constructed within COPR, and some infiltration of contaminated groundwater into the drains is possible. However, the discharges appear to have little to no impact on the river. Measured impacts to surface water from storm drain discharges are below EPA Nationally Recommended Water Quality Criteria (CH2M HILL and Environ, 2009) for hexavalent chromium [Cr(VI)], which is very quickly reduced to trivalent chromium, Cr(III), by natural processes when it enters the estuarine environment.

Air and Surface Water. The evaluation of the air transport pathway found no significant difference between upwind and downwind concentrations of hexavalent chromium in air. The findings also indicate that there is no statistical correlation between Cr(VI) concentrations and particulate concentrations. The results support the finding that airborne transport of COPR particulates from DMT is insignificant. This finding is expected given that COPR is contained beneath the surface cover present at DMT. The presence of the surface cover also isolates COPR from contact with overland flow/runoff. The surface cover inspection and maintenance program includes a rigorous inspection and repair program for surface cover which ensures that COPR remains contained, thereby limiting the potential for chromium transport via air and overland flow.

The CTS data are extensive and sufficient to support an assessment of corrective measures and an evaluation of risk to human health and the environment.

Chromium Transport Pathways

The primary objective of the CTS was to quantify the discharge of chromium from DMT to offsite receptors, including the Patapsco River.

A series of investigative studies was performed to determine the fate and transport of chromium in groundwater, stormwater, air, and surface water runoff via overland flow. The studies included the installation of 129 monitoring wells and temporary piezometers, collection and analysis of over 600 soil and groundwater samples, completion of a perimeter air monitoring program, and hydraulic characterization activities, including attempts to quantify mass flux via the stormwater transport pathway.

Fate and Transport of Chromium in Groundwater

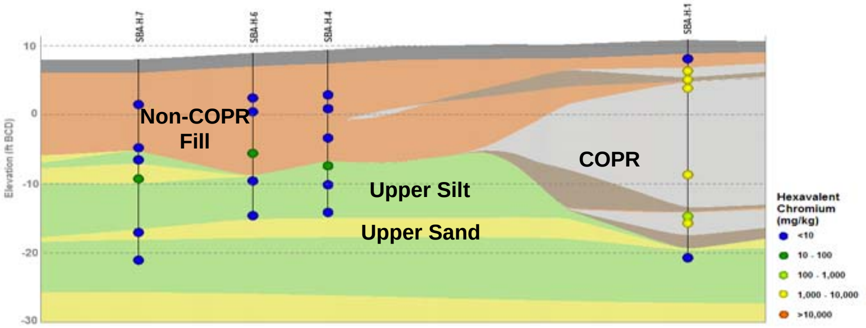
The characteristics of three hydrogeologic units and the extent of chromium impacts to soil and groundwater are defined by investigation results. Chromium impacts were observed primarily within the shallow fill unit, which is partially composed of the 2.5 million cubic yards of COPR that underlie a portion of the DMT. The chromium impacts are spatially related to the COPR limits. Reductive mechanisms and physical barriers to groundwater movement limit the offsite transport of chromium in groundwater. Groundwater is not a major pathway for chromium transport to either the river or deeper groundwater systems.

The investigation results reveal the following:

Extent of Soil Impacts. A substantial decrease in chromium concentrations occurs within a horizontal distance of 25 to 40 feet outside the COPR limits; vertical impacts are limited to within 5 feet of the base of the COPR fill (Figure ES-1).

Extent of Groundwater Impacts. Impacts to groundwater are not observed outside a horizontal distance of approximately 100 to 200 feet from the COPR limits; vertically, chromium impacts are not identified outside of the shallow aquifer (Figure ES-2).

FIGURE ES-1
Cr(VI) Concentrations in Soil



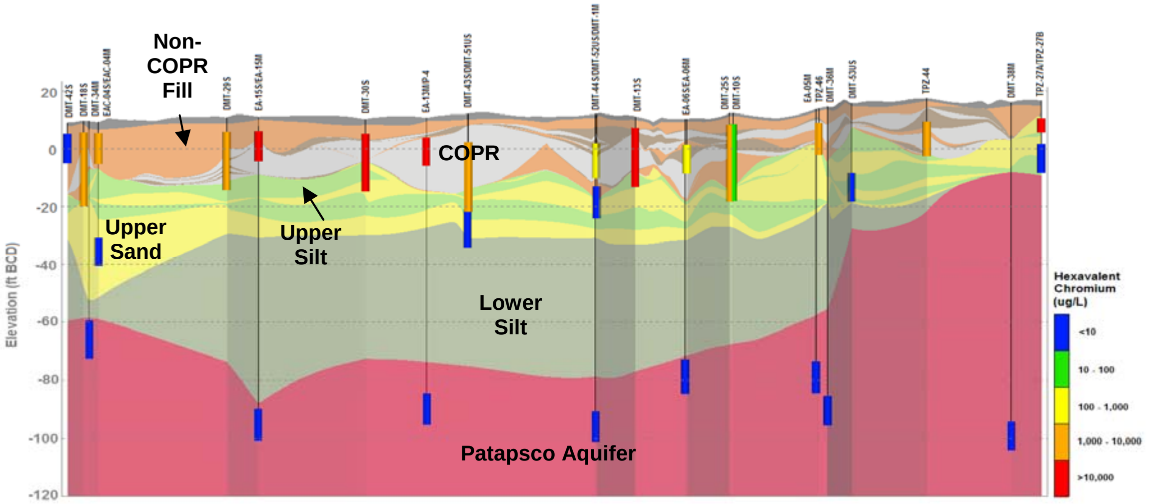
The limited subsurface distribution of chromium impacts is attributed to the following:

1. Geochemical conditions reduce the mobile Cr(VI) species to the relatively immobile Cr(III) species.
2. Low-permeability soil units (Upper and Lower Silt; see Figure ES-2) beneath the shallow aquifer physically impede the vertical migration of impacted groundwater to deeper water-bearing units.

Flux calculations indicate that chromium transport via groundwater transport is negligible. Table ES-1 presents the results of the mass flux analysis.

These estimates are intentionally biased high because the chromium was nondetect in the majority of monitoring wells used in the assessment. For these wells, a concentration of one-half of the method detection limit was utilized to estimate mass flux.

FIGURE ES-2
Cr(VI) Concentrations in Groundwater



EA's 1987 Site Contamination Assessment (SCA) concluded that "the distribution of chromium in the shallow water table (i.e., shallow fill unit) closely replicates the distribution of chromium fill (i.e., COPR) within the study area." Furthermore, the SCA states that chromium impacts related to COPR fill were not observed in the Patapsco Aquifer.

Twenty-two years later, similar conclusions regarding the extent of chromium impacts to groundwater are demonstrated by results of the CTS. The similarity of the results shows that the reductive mechanisms and physical barriers to groundwater migration are very effective at mitigating the extent of chromium impacts over time.

Fate and Transport of Chromium in Stormwater

Portions of the storm drain system, primarily the 12th through 15th Street lines, are a potential pathway for the transport of chromium to the river. Impacts to the river have been characterized. The results from four monitoring events conducted over a one-year period, where the samples were collected directly offshore from the storm drain outfalls, found no Cr(VI) above EPA Nationally Recommended Water Quality Criteria (CH2M HILL and Environ, "Sediment and Surface Water Study Report, Dundalk Marine Terminal, Baltimore, Maryland," 2009).

The potential contribution of chromium to the Patapsco River via the storm drains occurs primarily through the infiltration of impacted groundwater to the storm drains. Six storm drains (12th, 12.5th, 13th, 13.5th, 14th, and 15th Streets) potentially contribute to mass flux and are considered to be priority drains based on the following factors:

- Location within COPR fill
- Submergence below groundwater
- Potential for contaminated dry-weather flow

TABLE ES-2
Estimates of Dry-Weather Flow from Priority Storm Drains (gpm)

Priority Drain	Dry-Weather Flow
12th St.	7
12.5th St.	11
13th St.	5–14
13.5th St.	No flow
14th St.	15–20
15th St.	19

Results for the storm drain monitoring are generally consistent with the previous findings of EA Engineering, Science and Technology ("Dundalk Marine Terminal Site Contamination Assessment," 1987). EA determined that the vast majority of chromium flux originates from storm drains at DMT with less than 1 percent originating from groundwater flow to the Patapsco River. Further, EA concluded that over 97 percent of the chromium flux in stormwater originated from the 13th, 13.5th, 14th, and 15th Street drains. These findings were made prior to the installation of the tidal exclusion devices at 13th, 14th, and 15th Streets and relining of the 13th and 15th Streets drains. Evaluation of nonpriority drains (9th through 11.5th Streets) is also consistent with the prior findings of EA (1987). These drains are insignificant (de minimis) contributors to chromium flux.

FIGURE ES-3
Pilot Study on 13th and 15th Street Storm Drains

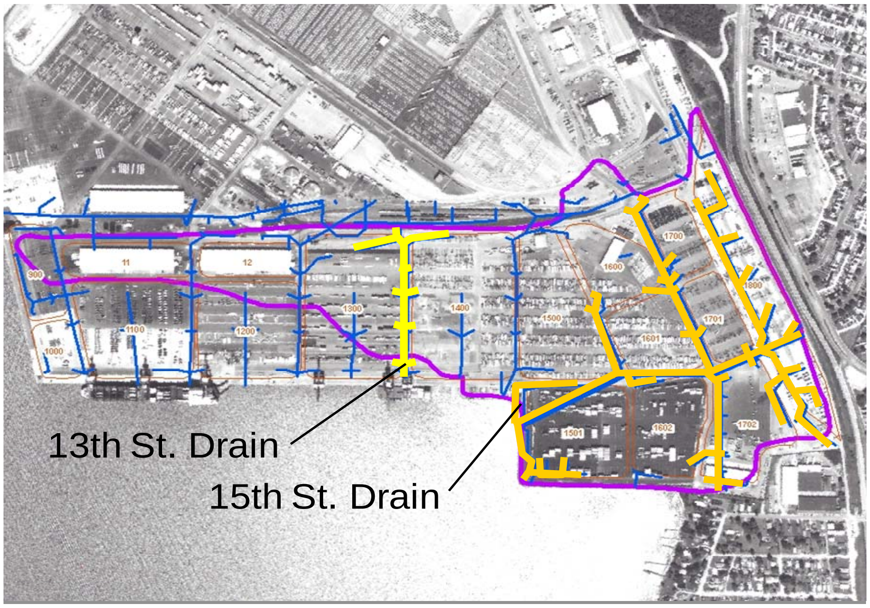


Table ES-2 summarizes the estimates of dry-weather flow from the priority storm drains. Dry weather flow is intercepted where tidal isolation structures have been installed at the 14th and 15th Streets drains. The 14th and 15th Streets drains are maintained in a dewatered condition and dry-weather flow is captured and treated. Honeywell and MPA have proposed and pilot tested the installation of an interceptor vault at the 13th Street storm drain (shown in Figure ES-3) to enable quantification of dry weather flow and relining of the 13th and 15th Street drains as an interim remedial measure to prevent groundwater infiltration. Dry-weather flow has been successfully quantified at 13th Street since installation of the device. Site physical and logistical constraints and health and safety concerns preclude exact quantification of chromium mass flux from the remaining priority storm drains without installation of tidal exclusion devices. The pilot program to install tidal exclusion vaults for the purpose of quantifying mass flux is being expanded to include the remaining priority drains (12th, 12.5th, and 13.5th Streets).

Fate and Transport of Chromium in Air

The air migration pathway was evaluated by a multistation perimeter-monitoring system that measured particulate and Cr(VI) concentrations for a period of over 18 months since September 2007. No significant difference between upwind and downwind total particulate and Cr(VI) concentrations in air samples was observed. The findings also indicate that there is no statistical correlation between Cr(VI) concentrations and particulate concentrations. The results support the finding that airborne transport of COPR particulates from DMT is insignificant. This finding is expected given that COPR is contained beneath the surface cover present at DMT.

Surface Water Runoff/Overland Flow

The surface water runoff/overland flow pathway is not complete under current site use because the site is paved and stormwater is captured by the storm drain system. The integrity of the surface cover is sustained through the surface cover inspection and maintenance program, which includes a rigorous inspection and repair program.

Conclusions

This report documents the findings of the Chromium Transport Study prepared pursuant to the requirements of the April 2006 Consent Decree entered into by and among Honeywell, MPA, and MDE. The report assesses the transport and fate of chromium in groundwater, stormwater, overland flow/runoff and air.

Hexavalent chromium transport via direct groundwater flow (1.60 lbs/year) from the shallow aquifer does not constitute a major transport pathway to the river. Surface water runoff and air are not transport pathways because COPR is contained beneath the surface cover present at DMT. The presence of the surface cover also isolates COPR from contact with overland flow/runoff. The surface cover inspection and maintenance program includes a rigorous inspection and repair program for surface cover which ensures that COPR remains contained, thereby limiting the potential for chromium transport via air and overland flow. The primary pathway of chromium flux from the Dundalk Marine Terminal is storm drain discharge—primarily from the 12th through 15th Streets' drains, the priority drains. This finding is consistent with the SCA. The magnitude of resulting impact to the river is rapidly attenuated due to geochemical processes that act to reduce the hexavalent chromium in the estuarine environment. Sampling results over a one year period found no Cr(VI) detections above EPA Nationally Recommended Water Quality Criteria in surface water transects located at the storm drain outfalls (CH2M and Environ, 2009).

Reliable quantification of stormwater discharge is not possible under current site conditions. MPA and Honeywell have implemented a pilot program at the 15th Street and 13th Street drains to quantify mass flux and isolate and contain groundwater infiltration into these storm drains. The 13th Street vault includes a tidal exclusion device that enables measurement of dry-weather flow and acquisition of water samples. The pilot program demonstrates that chromium flux can be reliably quantified after tidal exclusion and cleanout of the drain. The 13th Street pilot program to quantify flow is being expanded to include the remaining priority drains (12th, 12.5th, and 13.5th Streets) where exact quantification of discharge is not presently possible. The pilot program for relining the 13th and 15th Street storm drains is scheduled to be completed by the end of 2009 and will be followed by a postrelining sampling program. While site conditions prevented exact quantification of chromium mass flux in stormwater, the CTS data are extensive and sufficient to support an assessment of corrective measures and an evaluation of risk to human health and the environment.

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Appendixes

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Abbreviations and Acronyms

ASTM	American Society of Testing and Materials
BCD	Baltimore City Datum
CCTV	closed circuit television
CMAA	Corrective Measures Alternatives Analysis
CMIPP	Corrective Measures Implementation Program Plan
CMO	corrective measures objective
COPR	chromium ore processing residue
CSM	conceptual site model
CTS	Chromium Transport Study
DMT	Dundalk Marine Terminal
EPA	U.S. Environmental Protection Agency's
HIMS	Heave Investigation and Minimization Study
Honeywell	Honeywell International Inc.
IRM	interim remedial measures
MDE	Maryland Department of the Environment
MDL	method detection limit
MES	Maryland Environmental Services
MPA	Maryland Port Administration
NPDES	National Pollutant Discharge Elimination System
NRWQC	Nationally Recommended Water Quality Criteria
PM	particulate matter
PVC	polyvinyl chloride
SAP	sampling and analysis plan
SCM	site conceptual model
SOW	scope of work
SRT	strain relief trench

SECTION 1

Introduction

The Maryland Department of the Environment (MDE), the Maryland Port Administration (MPA), and Honeywell International Inc. (Honeywell), have entered into a Consent Decree dated April 5, 2006 (Consent Decree), which requires MPA and Honeywell to study and develop corrective measure alternatives for areas of the Dundalk Marine Terminal (DMT) that are suspected to contain chromium ore processing residue (COPR). This document, prepared by CH2M HILL on behalf of Honeywell and MPA, presents the results of the Chromium Transport Study (CTS), which is a precursor to the development of corrective measures alternatives.

1.1 Purpose and Scope

Section III.B.2 of the Consent Decree requires that MPA and Honeywell quantify the discharge of chromium to the Patapsco River and Colgate Creek. The CTS was designed to determine the quantities and valence states of chromium potentially being transported via storm drain flow, groundwater, and tidal exchange with groundwater and storm drain flow within the storm drain system. The study also includes a groundwater flow model that, when combined with site characterization data, can estimate the chromium flux via the groundwater and storm drain transport pathways.

1.2 Technical Approach

The approach to quantifying chromium transport includes the four tasks presented below:

- Evaluating discharges from the 9th Street through 13.5th Street stormwater drain outfalls and other outfalls potentially impacted by chromium, including the 14th and 15th Street outfalls. Sampling of the stormwater drains to estimate the flow rate of stormwater that discharges to the Patapsco River and the concentration of chromium it contains during periods of dry weather. Investigation results were also compared to the Site Contaminant Assessment (EA, 1987).

- Conducting an engineering analysis of the hydraulic loading to the stormwater drains to estimate the relative contribution of surface water drainage and tidal infiltration/exfiltration to each storm drain lateral segment.

- Completing a groundwater investigation to determine the configuration of the shallow groundwater table and its interaction with storm drain systems located in COPR fill areas, to assess the impact of COPR on the deeper groundwater systems, and to provide data necessary to support development of the numerical groundwater flow model and refine the conceptual site model (CSM).

- Developing a numerical groundwater flow model to estimate the transport of chromium to the Patapsco River, Colgate Creek, and offsite groundwater systems and to simulate the effects of potential corrective measures on chromium transport.

Although not a specific element of the original CTS work plan, an evaluation of the airborne migration pathway is also presented in this document.

1.3 Report Organization

The rest of this report is organized as follows:

Section 2: Site Setting
Section 3: Investigation Scope and Methods
Section 4: Investigation Results
Section 5: Fate and Transport Mechanisms
Section 6: Calculation of Mass Flux to the Patapsco River
Section 7: Conclusions
Section 8: References and Bibliography

1.4 Interrelated Documents

The Consent Decree requires completion of a multitude of studies summarized in individual documents that, when combined, provide the characterization data necessary to develop remedial alternatives for the site. A complete discussion of the Consent Order requirements is provided in the Corrective Measures Implementation Program Plan (CMIPP) (CH2M HILL, 2007a). This section presents the key documents that either have been completed or are in progress to meet the Consent Decree objectives.

1.4.1 COPR Investigation

The Final COPR Investigation Report (CH2M HILL, 2009a) was prepared pursuant to the requirements of Section III.B.5 of the Consent Decree. The objectives of the COPR investigation were to the following:

- Define the nature and extent of COPR in the fill area
- Define the soil stratigraphy of the native soils underlying the COPR fill
- Define the thickness of cover materials above the COPR fill

The COPR Investigation Report was submitted to MDE on May 20, 2009, and satisfied the objectives of the Consent decree by defining (1) the nature and extent of COPR, (2) the nature of the soil stratigraphy of the native soils underlying the COPR fill, and (3) the thickness of cover materials above the COPR fill; the study resulted in the following conclusions:

- The lateral extent of COPR within the fill area has been defined to include approximately 148 acres of DMT.

- COPR extends to a maximum depth of approximately 38.5 feet and ranges in thickness from 1 foot to 32 feet within the fill area.

- Approximately 2.5 million cubic yards (yd^3) of COPR exists within the fill area.

- COPR is covered by approximately 2 to 22 feet of non-COPR fill and surfacing material within the fill area.

- Two basic types of COPR are present at DMT: gray-black (GB) COPR and hard brown (HB) COPR; their geochemical, physical, and mineralogical properties have been defined to support the evaluations being completed as part of the Heave Investigation and Minimization Study (HIMS) and Corrective Measures Alternatives Analysis (CMAA).
- No additional characterization is required.

The results of the COPR Study were used to support the HIMS, this CTS, and to assist in development and evaluation of potential remedies as part of the forthcoming CMAA.

1.4.2 Heave Investigation and Minimization Study

The HIMS was prepared pursuant to the requirements of Section III.B.6 of the Consent Decree. The objectives of the HIMS were the following:

- Define and validate a conceptual model of the expansion and heave of COPR at DMT by evaluating and investigating the mineralogy, expansion mechanisms, and manifestations of heave
- Establish, by applying and evaluating field investigations, models, engineering studies, and pilot studies, that COPR expansion and heave phenomena can be classified, monitored, modeled physically, and accommodated
- Evaluate, by applying engineering studies, models, and pilot studies, COPR movement and heave mitigation measures that are viable, effective, and constructible and that can be both monitored and maintained

The HIMS Report was submitted to MDE on May 29, 2009. The main findings and conclusions of the HIMS are summarized below.

1. Extent and nature of COPR at DMT are well defined.

The results of field investigations and studies have been used to define the depth and lateral extent of COPR and the relative distribution of GB COPR and HB COPR at the site.

An extensive program of field and laboratory testing was conducted to characterize the chemical, mineralogical, and geomechanical properties of COPR.

2. Transformation and expansion mechanisms are well understood.

The field investigations, monitoring, field and laboratory testing, and pilot programs performed during the HIMS have provided information to develop a thorough understanding of COPR mineralogical transformation and volumetric expansion.

The investigation and study results described in the HIMS Report demonstrate that the transformation and expansion of COPR are primarily a function of the occurrence of wet–dry cycles in the vadose zone, the location of COPR relative to the groundwater table, specific geochemical conditions of the COPR pore water in the vadose zone, differences in geomechanical behavior between nonlithified GB COPR and lithified HB COPR, COPR particle size, and presence/absence of passivation effects.

A validated and unifying conceptual model has been developed for the lithification and expansion of COPR at DMT to demonstrate that the mechanisms causing COPR transformation and expansion are well understood.

3. **COPR movement and heave magnitudes and rates are well understood.**

The results from the displacement monitoring of COPR at the site are used to define the magnitudes and rates of COPR movement (lateral) and heave (vertical) at DMT. This information, together with the understanding of COPR transformation and expansion, demonstrates that COPR movement and heave can be classified, quantified, monitored, and modeled.

4. **COPR movement at DMT is not a significant environmental or public health issue.**

It is demonstrated that heave manifestations do not result in the exposure of COPR at the surface, and appropriate protocols are in place to protect workers and others from exposure during any excavations into COPR.

5. **Effective engineering measures exist to prevent or mitigate impacts associated with COPR movement and heave.**

Special pavements, strain relief trenches (SRTs), and surcharge loads have been effectively used at DMT to prevent or mitigate damage due to excessive COPR movement and heave. These engineering measures can be used individually or in combination to address the COPR heave.

6. **COPR monitoring and maintenance programs have successfully managed heave.**

Monitoring and maintenance programs have been implemented at DMT and have shown that COPR movement and heave occur slowly and can be detected before significant levels of damage occur to pavements or structures. The studies also show that monitoring and maintenance programs conducted at DMT have been effective in preventing heave-related COPR exposure at the ground surface.

1.4.3 Sediment and Surface Water Study

The Sediment and Surface Water Study was prepared pursuant to the requirements of Section III.B.3 of the Consent Decree. The objectives of the study were the following:

- Characterize the nature and extent of chromium in the Patapsco River within the zone potentially impacted by chromium releases at or from DMT
- Characterize the geochemical conditions that influence the fate and transport of chromium in the river

The Sediment and Surface Water Study Report was submitted on May 20, 2009. The key findings of the study are the following:

- Hexavalent chromium, Cr(VI), was not detected in pore water in any of the samples taken from DMT in any of the four quarterly sampling events.
- Cr(VI) was not detected in 97 percent of the surface water samples analyzed; in those limited locations where it was detected, concentrations were well below U.S.

Environmental Protection Agency's (EPA's) Nationally Recommended Water Quality Criteria (NRWQC).

- Measurements of geochemical parameters in pore water, surface water, and sediment demonstrate that conditions are favorable to the presence of chromium as the relatively nontoxic trivalent chromium, Cr(III), species rather than Cr(VI).
- Based on the results of this study and other related studies with respect to chromium geochemistry, total chromium in sediment is unlikely to oxidize to Cr(VI) in the future because the geochemical conditions necessary for this process do not naturally occur in the estuarine environment.
- The data collected as part of this study are extensive and sufficient to support the conclusion that the nature and extent of chromium in the Patapsco River and Colgate Creek have been delineated.

1.4.4 Plan for Quantifying Chromium Transport from Stormwater Outfalls to the Patapsco River

A plan to reliably quantify the discharge of chromium from the 9th through 13.5th Streets' storm drain outfalls was presented (CH2M HILL and MES, 2006) and approved by MDE on February 8, 2007.

The approved work plan included a feasibility study and pilot testing process to develop and field-validate an effective and permanent means to exclude the influence of the tide at affected drains and to facilitate collection of dry-weather storm drain flow. The approved work plan also included modified sampling procedures that were developed to better quantify dry- and wet-weather flow and collect water quality samples until a permanent means of tidal exclusion could be developed, field tested, and constructed at priority drains. Priority drains have been defined as drains that contribute significant mass flux based on the first round of dry-weather flow data that was collected using the modified sampling procedure.

Progress has been significantly hindered because of difficulties in installing the temporary tidal exclusion plugs and plates, health and safety considerations for personnel entering storm drains (confined space entry), weather, tide cycles, sediment and debris accumulation, and port operations. Despite the challenges, the data collected were useful for the following tasks:

- Calibrating the groundwater flow model that will be used to establish transport of chromium from groundwater and predict changes that would occur from candidate corrective measures alternatives
- Determining which drains may be meaningful contributors to overall chromium flux (priority drains) and which drains provide little to no (de minimis) contribution

Although MDE approved the work plan on February 8, 2007, the implementation issues mentioned above led to submittal of an addendum to the work plan, which is discussed below.

1.4.5 Addendum to the Work Plan for Quantifying Chromium Transport from Stormwater Outfalls to the Patapsco River

The effort to collect additional data under the Work Plan for Quantifying Chromium Transport was suspended in late 2007 after one round of data was collected after nearly one year of effort using various methods for blocking the influence of the tide, dewatering, cleaning, and measuring dry-weather flow and quality from each of the storm drains. Sampling was significantly hindered because of difficulties in installing the temporary tidal exclusion plugs and plates, health and safety considerations for personnel entering storm drains, weather, tide cycles, sediment and debris accumulation, and port operations. A storm drain assessment was performed to determine if the available data could be used to identify the path forward at each storm drain.

The results of the storm drain assessment and the proposed path forward for dry- and wet-weather storm drain sampling were presented in the "Addendum to the Work Plan for Quantifying Chromium Transport from Stormwater Outfalls to the Patapsco River, Dundalk Marine Terminal, Baltimore, Maryland" (CH2M HILL and MES, 2008), which was submitted to MDE on July 3, 2008. Responses to MDE comments are being developed for submittal in the third quarter of 2009.

The addendum included a revised sampling and analysis plan (SAP), which presents the revised methods of dry- and wet-weather flow collection. The addendum also included the results of the storm drain assessment, which recommended installation of permanent tidal-exclusion devices in the four priority storm drains (12th Street, 12.5th Street, 13th Street, and 13.5th Street) that appear to contribute to storm drain chromium mass flux to the Patapsco River. The 9th through 11.5th Streets' drains appear to have a de minimis contribution because they present one or more of the following characteristics: no dry-weather flow, very low to nondetectable concentrations of Cr(IV) in dry-weather flow samples that were collected and are not constructed within COPR fill. No further evaluation of these drains is recommended.

1.4.6 Human Health Assessment

The human health risk assessment will be developed in accordance with Section III.B.7 of the Consent Order. The scope and general approach for completing the human health risk assessment will consist of the following:

- Preliminary risk-based screening will be focused on comparing chromium concentrations in the various environmental media to risk-based or other federal or state criteria to determine the need, if any, for further quantitative assessment of risks to human health
- An exposure assessment will be completed to identify potential pathways of exposure; characterize the potentially exposed populations (e.g., workers, residents, and recreational users); and estimate the magnitude, frequency, and duration of exposures
- A toxicity assessment will be completed to identify the types of adverse health effects associated with exposure to chromium along with available toxicity factors to (1) summarize the relationship between magnitude of exposure and occurrence of adverse

health effects and (2) identify related uncertainties (such as the weight of evidence of a particular chemical carcinogenicity in humans) associated with these values

- A risk characterization will be performed to integrate the results of the exposure assessment and toxicity assessment to estimate the potential risks to human health, and pathways that pose an unacceptable risk on the basis of quantitative risk characterization will be identified
- The uncertainties inherent in the assumptions used for each component of the risk assessment (e.g., data evaluation, identification of COPCs, exposure assessment, and toxicity assessment) to estimate these risks will also be addressed since these uncertainties ultimately contribute to uncertainty in risk characterization and may result in the numerical estimates either understating or overstating health risks associated with potential exposures.
- Risk management issues will be considered as part of the human health risk assessment, including sources of uncertainty associated with the data, methodology, the values used in the risk assessment estimation, and other mitigating factors that must be factored into decision-making based on the findings of the human health risk assessment.

The Human Health Risk Assessment Work Plan was submitted to MDE on September 29, 2006 and revised in two subsequent submittals dates August 21, 2008 and July 20, 2009. The Work Plan is currently under review by MDE. The Human Health Risk Assessment report is scheduled for a Q3 2009 submittal to MDE.

1.4.7 Ecological Risk Assessment

The ecological risk assessment was developed in accordance with Section III.B.7 of the Consent Order. The scope of the risk assessment was to evaluate potential risks associated with exposure to chromium and other COPR-related constituents in accordance with the standard EPA guidance for conducting ecological risk assessments.

The basic approach for the ERA is consistent with EPA’s (1997, 2000a) guidance, which is an eight-step process with built-in critical management and decision points to allow stakeholder input on the evaluation of interim findings and refinement of the technical approach.

The Ecological Risk Assessment Work Plan was submitted to MDE on September 29, 2006, and revised on August 21, 2008. The risk assessment report was submitted to MDE on September 14, 2009.

1.4.8 Corrective Measures Alternatives Analysis and Implementation

The purpose of the CMAA is to provide a document that meets the requirements and objectives of Section III.B.8 of the Consent Decree:

- Identify corrective measures objectives (CMOs)
- Identify corrective measures that will meet performance standards stated below, including the removal of all chromium-impacted materials from DMT

- Assess the feasibility of preventing offsite stormwater from entering the fill area by way of the existing stormwater drainage system and assess stormwater diversion in reducing chromium transport at DMT
- Screen all identified corrective measures against the CMOs
- Prepare a detailed cost estimate for each identified corrective measure that has the potential to meet each CMO
- Identify and describe any laboratory, field, or pilot-scale testing that is required to verify the feasibility of implementing any of the identified corrective measures
- Prepare schedules for the design, construction, and implementation of identified corrective measures that are screened out
- Evaluate a corrective measures approach or approaches that have the potential to meet the CMOs, considering at a minimum the following performance standards:
  - Provides overall protectiveness of human health and the environment
  - Complies with applicable and relevant and appropriate requirements under federal and State of Maryland environmental laws and regulations
  - Provides long-term effectiveness and permanence
  - Provides the potential to reduce toxicity, mobility, and volume
  - Provides short-term effectiveness, including minimizing short-term risks and impacts associated with implementation
  - Can be implemented (e.g., relative ease or difficulty in implementing the remedy)
  - Is cost effective
  - Minimizes the degree by which the remedy interferes with the ongoing business operations of MPA, its tenants, clients, and customers

The CMAA is currently under preparation and will be submitted to MDE within the schedule required by the Consent Decree.

SECTION 2

Site Setting and Conceptual Site Model

This section describes the physical setting of DMT and the nature and extent of COPR fill based on the findings presented in the Final COPR Investigation Report (CH2M HILL, 2009a). This section also presents the site conceptual model (SCM) for chromium transport at DMT, which is supported by the investigation results provided in Section 4 and the migration pathways that have been documented at the site.

2.1 Physical Setting

DMT is an active marine shipping terminal located in Baltimore, Maryland, that is owned and operated by MPA (Figure 2-1). The southern portion of the terminal, herein referred to as the "DMT fill area," was constructed on lands reclaimed from prior marshlands and the Patapsco River by placement of COPR and non-COPR fill materials. The southern and western edges of the DMT fill area end at a sheet pile wall with a pile-supported concrete platform, referred to as the "marine platform." To the southeast, the DMT fill area terminates at a riprap embankment, sloping from the terminal area to the Patapsco River. Along the northern extent of the DMT fill area, the East Service Road and a railroad track that roughly parallels the road, separate the original DMT land holdings from the DMT fill area. The eastern limit of the DMT fill area is coincident with the property boundary, which is bounded by the Norfolk Southern Railroad right-of-way. Specific details regarding the placement of fill materials, including COPR, prior to and during construction of the terminal are provided in the COPR Investigation Report (CH2M HILL, 2009a).

2.2 Nature and Extent of COPR Fill

The nature and extent of the COPR at DMT is critical to the CTS because the COPR is the source of the chromium and other COPR-related constituents that have been detected in groundwater and stormwater at the site. Five main elements—calcium, iron, aluminum, magnesium, and chromium—plus the balance of oxygen constitute well over 90 percent of the inorganic mass of COPR. Four of these elements (aluminum, chromium, iron, and magnesium) originate from the raw chromite ore as $(Mg^{2+}, FE^{2+})O\ (Cr^{3+}, Al^{3+}, Fe^{3+})_2O_3)$; the calcium originates from calcined lime that was added during processing and roasting of the ore. At the time of placement at DMT, the COPR likely contained three primary minerals: brownmillerite, periclase, and portlandite (i.e., hydrated lime). Brownmillerite is a mineral that is formed in a high-temperature, oxidizing environment and is thus thermodynamically unstable in low-temperature environments such as the DMT fill area (CH2M HILL, 2009a, b).

After exposure to the environment, the COPR weathers, a process resulting in the two basic types of COPR that have been identified at DMT: GB COPR and HB COPR. GB COPR is generally particulate, grading to a weakly cemented appearance, and typically is very friable (i.e., easily crushed by hand pressure), with a color ranging from black to gray. GB COPR is basically representative of the original condition of the COPR material when it was placed at DMT. In the presence of suitable geochemical conditions and water, GB COPR transforms to HB COPR, which is weakly to strongly indurated, with a color grading to reddish brown and dark brown. The chemical and mineralogical makeup of the two COPR types also differs and a full description of these properties is provided in the Final COPR Investigation Report (CH2M HILL, 2009a). A complete description of the COPR weathering and transformation process is provided in the Heave Investigation and Minimization Study Report (CH2M HILL, 2009b).

The extent of COPR at DMT is defined on the basis of data collected from over 400 investigation locations and a review of historical documents, aerial photography, and drawings detailing the facility's construction (CH2M HILL, 2009a). There are approximately 2.5 million cubic yards of COPR within the approximately 148 acres (Figure 2-2) of fill area. Vertically, COPR extends to a maximum depth of approximately 38.5 feet and ranges in thickness from 1 foot to 32 feet (Figure 2-3). The thickness of the non-COPR fill that overlies the COPR materials ranges typically between 2 and 22 feet.

2.3 Chromium in the Environment

As a free metal ion, chromium is stable in most natural aqueous environments in the 3+ (Cr(III)) and the 6+ (Cr(VI)) oxidation states; however, oxidation states of chromium can range from 2- to 6+ (Fendorf and Zasoski, 1992; Shupack, 1991). The Cr(III) ion is a $Cr(H_2O)_6^{3+}$ complex and has a coordination number of 6, whereas the fully deprotonated Cr(VI) ion (chromate) is a CrO_4^{2-} complex and has a coordination number of 4 (Figure 2-4a). Cr(VI) behaves as a Lewis base, exists in aqueous solution as an anion (e.g., $HCrO_4^{1-}$, CrO_4^{2-}, $Cr_2O_7^{2-}$), and readily complexes with several organic ligands and polymers, such as hydroxyl, sulfate, and ammonium (Weng et al., 1994; Palmer and Wittbrodt, 1991; Richard and Bourg, 1991). In comparison, Cr(III) is a Lewis acid and commonly precipitates as the insoluble $Cr(OH)_3$ form (Weng et al., 1994).

The small size and large charge of Cr(VI) enhance its reactivity, but in solutions that favor its stability, the hydrolyzed forms of Cr(VI) include bichromate or hydrochromate ($CrO_3(OH)^-$ or $HCrO_4^-$), chromate, and dichromate ($Cr_2O_7^{2-}$). The relative proportions of each of these ions in solution are pH dependent. At low concentrations or neutral pH, Cr(VI) exists as $H_2CrO_4^0$, $HCrO_4^-$, and CrO_4^{2-} (Palmer and Wittbrodt, 1991). In basic and neutral conditions and in the absence of reducing agents, the chromate form dominates. At a pH of around 6.0 to 6.2, the hydrochromate concentration increases. At very low pH values, the dichromate species predominate (Palmer and Wittbrodt, 1991; EPA, 1984). Bichromate becomes significant when concentrations of Cr(VI) are greater than 1 mM and may dominate above 30 mM (Palmer and Puls, 1994). For chromium in solution, especially at a Cr(VI) concentration of greater than 1 milligram per liter (mg/L), a yellow tint indicates that chromate ions (e.g., $H_2CrO_4^-$, $HCrO_4^-$, CrO_4^{2-}) are dominant, whereas an orange color is indicative of dichromates (Palmer and Puls, 1994; Palmer and Wittbrodt, 1991).

Latimer diagrams for acid and basic solutions illustrate the thermodynamic stability of reactions involving the chromium species (Figure 2-4b) (Shupack, 1991). In evaluating the Latimer diagrams for the reduction of chromate (CrO_4^{2-}), the negative 0.13 V standard reduction potential for CrO_4^{2-} to $Cr(OH)_3$ (in the lower series of Figure 2-4b) demonstrates that the species to the right ($Cr(OH)_3$) behaves as a reducing agent and reduction is thermodynamically favored. The Latimer diagrams also show that the 3+ oxidation state is most stable, followed by the 2+ state, whereas the 6+ state is unstable in acid solution and goes to 3+. Thus, Cr(III) is a good reducing agent and Cr(VI) is a powerful oxidizing agent (Palmer and Wittbrodt (1991); and Loyaux-Lawniczak et al., 2001) and reacts with organic matter, ferrous iron, sulfides, and other reducing agents to form Cr(III) (Buerge and Hug, 1999; Bartlett and Kimble, 1976; Eary and Rai, 1991; and Weng et al., 1994). Cr(VI) will react spontaneously with ferrous iron but, for organic material, it may require a catalytic mediator, such as bacterial enzymes (Higgins et al., 1998).

Cr(III) is much more insoluble than Cr(VI) and eventually precipitates as $Cr_2O_3 \cdot xH_2O$ (EPA, 1998). In this form, very little chromium is leached from soil because it is present in an insoluble form (Fishbein, 1981). Stability constants for the complexation of chromium are shown in Figure 2-4c (from Palmer and Wittbrodt, 1991). For total chromium concentrations of less than $10^{-6.84}$ M, all chromium will be in the dissolved phase (Richard and Bourg, 1991).

2.4 Mechanisms Affecting Speciation and Complexing of Chromium

The successful study or application of fate and transport phenomena involving chromium requires a basic knowledge of the physiochemical processes that control the migration, transformation, and stability of chromium in the environment. The migration and fate of chromium compounds are determined by competing mechanisms of complexation, dissolution/precipitation, redox processes, and adsorption/desorption (Figure 2-5a). Thus, accurate predictions of the behavior of various trivalent and Cr(VI) species in soil and groundwater require an understanding of these multiple processes and the conditions under which each will occur.

2.4.1 Oxidation Reduction and Chemical Speciation

Under reducing conditions (i.e., neutral to negative Eh for chromium), Cr(VI) readily converts to Cr(III) if appropriate electron donors are present, thus Cr(III) is more thermodynamically stable than Cr(VI) (Figure 2-5b) (Palmer and Wittbrodt, 1991). Any point on the Eh-pH diagram gives the thermodynamically most stable (and theoretically most abundant) form of the element at the given potential Eh and pH condition. At typical Eh and pH conditions in the environment, the reduction of Cr(VI) to the trivalent state, typically $Cr(OH)_3$, is favored. Cr(VI) is a very strong oxidant (because of its position near the top of the Eh-pH diagram) and it is readily and quickly reduced in the presence of electron donors commonly and abundantly present in the environment such as ferrous iron, reduced sulfur, and soil organics. In the presence of these reductive substances, soluble and adsorbed Cr(VI) can be easily reduced to Cr(III) under a variety of conditions (Buerge and Hug, 1999; Weng et al., 1994; Eary and Rai, 1991; Bartlett and Kimble, 1976). Once reduced, Cr(III) complexes with numerous inorganic and organic ligands, which have increased solubility. The oxidation of Cr(III) by oxygen is negligible under atmospheric conditions (James, 1994).

2.4.2 Adsorption and Desorption

Cr(III) is rapidly, strongly, and specifically adsorbed by soil iron, clay minerals, and sand (Richard and Bourg, 1991). Adsorption of Cr(III) exhibits typical cation sorption behavior and increases with increasing pH and organic matter content. In contrast, Cr(III) adsorption will tend to decrease when competing inorganic cations or organic ligands are present.

Although more mobile at neutral to elevated pH, aqueous Cr(VI) in the form of chromate will also adsorb to soil colloids with lower pH, most notably crystalline iron and aluminum oxides and kaolinite (Zachara et al., 1989). Adsorption of Cr(VI) exhibits typical anionic sorption behavior with adsorption decreasing with increasing pH and with competing dissolved anion concentrations (Richard and Bourg, 1991; Zachara et al., 1989). Cr(VI) adsorption is favored on adsorbents that are positively charged at low to neutral pH (i.e., high pH_{ZPC}) (Richard and Bourg, 1991). Thus, Cr(VI) may be adsorbed by manganese, aluminum, and iron oxides; clay minerals; natural soil; and colloids (Figure 2-5c). In addition, similar to Cr(III) forms, CrO_4^{2-} binding is reversible to pH and is depressed in the presence of competing anions, such as SO_4^{2-} and dissolved inorganic carbon (Zachara et al., 1989).

Chromate is readily adsorbed for soil with high oxide content, moderately adsorbed to montmorillonitic soil, and minimally adsorbed to natural layer silicates and amorphous aluminosilicates. Zachara et al. (1989) postulated that the minimal adsorption relationship is due to hydroxylated binding sites being saturated with silica or dissolved inorganic carbon, which in turn prevents CrO_4^{2-} adsorption. Additionally, Anderson and Benjamin (1985) and Zachara et al. (1989) showed that adsorbed or co-reacted silica significantly depresses chromate adsorption on amorphous iron oxide. Zachara et al. (1989) showed that chromate adsorption to soil increased for soil containing higher concentrations of aluminum and iron oxides.

2.5 Subsurface Stratigraphy

The soils that underlie DMT are grouped into four main subsurface units (Table 2-1). The shallow soils include two anthropogenic fill units that comprise non-COPR and COPR fill placed during land reclamation and construction activities (Figures 2-6 through 2-8). The anthropogenic fill units overlie two units of native soil that comprise relatively recent fluvial sediments deposited in the Patapsco River basin and Cretaceous-age sediments of the Potomac Group. The reducing environment in these native sediments, including the organic-rich Upper Silt and the overall Eh/pH relationship in the aquifer system, promotes the reduction of Cr(VI) to Cr(III). These units' physical properties are summarized in Table 2-1 and fully characterized in the Final COPR Investigation Report (CH2M HILL, 2009a). The properties of these units that affect groundwater flow are discussed in Section 2.6.

2.6 Conceptual Site Model

The CSM provides a framework for understanding the distribution and behavior of chromium in the Patapsco River adjacent to DMT based on existing data, and descriptions of relevant chemical and physical fate and transport processes and conditions that influence these processes. According to the USEPA, a CSM typically is a set of hypotheses derived from existing site data and knowledge gained from other sites (USEPA, 2005b). The CSM presented in this section focuses on the chromium sources and migration pathways at DMT, and published information about processes that influence the fate and transport of chromium in an estuarine environment. An illustration of the concepts related to the SCM is provided in Figure 2-9.

The Port of Baltimore is ranked 13th among the most active ports in the United States.[1] It generates more than $1.4 billion in annual revenue and has approximately 126 miles of federal navigational channels. Baltimore Harbor has a long history of industrial use, dating back to the late 1700s, including steel production (Sparrows Point was historically ranked the largest steel mill in the world), ship building, sugar refinement, garment manufacturing, container and shipping industry, and more recently, biotechnology.

DMT is located on land that was in part created by the placement of COPR fill material. A review of aerial photographs and shoreline maps indicates that active filling occurred from before 1940 to the 1970s. The COPR fill area is generally located south of East Service Road; the extent of COPR is shown in Figure 2-2. During land reclamation activities from the late 1960s to the mid-1970s, COPR fill material was stored in the southeast portion of DMT, with uncovered borrow areas and/or stockpiles located in the 1400, 1500, 1600, 1601, and 1702 areas. Surface water runoff from uncovered stockpiles and other filling operations into the Patapsco River reportedly occurred during land reclamation activities.

The locations of storm drains and outfalls at DMT are shown in Figure 2-10. The drains are constructed of reinforced concrete pipe and range in diameter from 12 to 96 inches. At high tide, the Patapsco River waters penetrate the storm drains associated with the whole-numbered streets from 9th to 13th Streets. The drains at the half-numbered streets are approximately 2 feet higher and therefore experience less tidal penetration. Backflow preventers were constructed at the 14th and 15th Streets' outfalls in the 1990s to prevent the intrusion of the Patapsco River waters at high tide. In 2006, a remedial system was installed at the 14th and 15th Streets' outfalls to collect and treat stormwater prior to discharge from a combined outfall managed under a National Pollution Discharge Elimination System (NPDES) permit. An interim remedial measure (IRM) was initiated at the 13th Street storm drain in December 2008.

Groundwater discharge does not appear to be a significant pathway for the transport of chromium from DMT to the Patapsco River. Historical surface water runoff from uncovered COPR fill stockpiles and other filling operations in the southeast part of DMT is likely to have been a former transport pathway to the river. This pathway became inactive when land reclamation activities were completed and the terminal areas were paved. The Surface Cover Maintenance Plan which includes a routine inspection and repair program has been implemented and greatly reduces the potential for the presence of COPR at the ground surface. An Excavation Standard Operating Procedure (SOP) is also in place that presents detailed procedures for penetrating the surface cover in COPR and non-COPR areas and managing COPR and chromium impacted soil.

Potential migration pathways for the transport of chromium from DMT are conceptualized as (1) direct discharge of groundwater to the river, (2) groundwater seepage into storm drains that discharge directly to the river via outfalls and tidal inundation of storm drains, (3) overland runoff, and (4) air. These potential pathways are shown in Figure 2-9 and are discussed in more detail below.

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[1] Source: 2006, Intermodal Association of North America; Journal of Commerce PIERS—Port Import/Export Reporting Service.

2.6.1 Groundwater

The SCM for chromium transport in groundwater is discussed below and references the four hydrogeologic units that have been defined beneath the site. A detailed characterization of the soils that comprise these hydrogeologic units is provided in the Final COPR Investigation Report (CH2M HILL, 2009a).

Shallow Fill Unit

The shallow fill unit is the uppermost hydrogeologic unit beneath the site, which is partly comprised of the approximately 2.5 million cubic yards of COPR that underlie DMT. The remaining volume of the shallow fill unit is comprised almost entirely of non-COPR fill. Groundwater flow in the unit is generally to the southwest, but local variations are observed where flow is affected by the heterogeneity of the fill material or by subsurface features, including storm drains, buried historic bulkhead features, and the sheet pile bulkhead that bounds the terminal to the south and west. Excluding Areas 1501 and 1602 (discussed below), the DMT fill area is bounded by vertical sheet pile bulkheads that impede the discharge of shallow groundwater to the Patapsco River. Evidence for the impeded discharge is based on groundwater levels along the immediate inboard face of the bulkheads that are approximately 2 feet above the river level and on the lack of tidal influence observed in shallow wells close to the bulkheads. The bulkhead terminates at 13.5 Street. While no bulkhead exists between 13.5th and the 15th Streets' outfalls, computer modeling indicates the presence of a low-permeability zone along the shoreline in this area.

Reductive processes appear to be reducing Cr(VI) to Cr(III) within the shallow fill unit. Horizontal migration of Cr(VI) is typically limited to within 100 to 200 feet of the COPR fill. There are also physical and chemical barriers to the vertical migration of shallow groundwater and associated COPR-related chemical constituents to deeper hydrogeologic units that underlie the shallow fill unit. The vertical migration of shallow groundwater is also physically impeded by the presence of the upper silt unit, which acts as a semiconfining layer beneath the shallow fill unit.

Areas 1501 and 1602

The characteristics of the shallow fill unit in the vicinity of Areas 1501 and 1602 are discussed separately because they differ slightly from the rest of the shallow fill unit owing to the way this area was constructed. The land that underlies Areas 1501 and 1602 was reclaimed by construction of an engineered containment cell where the COPR is encapsulated within a low permeability liner and cover (CH2M HILL, 2009a). The COPR cell was constructed above the water table and the cell is hydraulically separated from the shallow fill unit based on the substantial difference between water levels measured inside the cell and water levels measured outside (below) the cell in the shallow fill unit. Minor Cr(VI) impacts have been observed in wells along the south shoreline of Areas 1501 and 1602 (e.g., DMT-63S, DMT-45S, and DMT-58S).

Cr(VI) concentrations detected in these wells do not exceed the EPA NRWQC, typically do not exceed MDE Cleanup Standard for Cr(VI) in groundwater, and do not appear to impact the river based on the absence of Cr(VI) in pore water that was collected on four occasions as part of the Sediment and Surface Water Study (CH2M HILL and Environ, 2009).

Alluvial Sand Unit

The alluvial sand unit is defined as the first unit of sand that is encountered beneath the upper silt confining layer, which underlies the shallow fill unit. The characteristics of the alluvial sand unit are defined by testing and sampling at the upper sand wells. Most of the of the upper sand wells are located to the west of 14th Street and are screened within thin and discontinuous lenses of fine sand that are interlayered within the upper silt. The upper sand wells east of 14th Street are mostly screened within the upper portion of the Potomac Group sediments. The investigation has focused on evaluating the characteristics of the alluvial sand unit to establish whether the unit has been impacted, and further how the unit promotes the horizontal and vertical movement of groundwater beneath the site.

Patapsco Aquifer

Regional geologic data suggests that the upper portions of the Potomac Group sediments beneath DMT are classified as the Patapsco Formation. Therefore, the medium depth aquifer beneath the site is referred to herein as the Patapsco Aquifer and its characteristics are defined by testing and sampling at the medium depth (M-series) well locations. The M-series wells are screened in a portion of the Potomac Group sediments that is comprised mainly of sand.

Soil and groundwater sample results collected from the M-series wells and transmitted to MDE in two technical memoranda (CH2M HILL, 2008a, b) suggests that the Patapsco Aquifer is not impacted by chromium constituents. The absence of chromium-related impacts in the aquifer is explained by the presence of the upper and lower silt layers, which lie between the shallow fill units and the Patapsco Aquifer. Both silt units have low permeability, which allows them to function as confining units, and the presence of organic material facilitates the reduction of Cr(VI) to the relatively immobile Cr(III) species, which prevents the chromium constituents from reaching the deeper hydrogeologic units.

D-Series Wells (Patuxent Formation)

Three deep (D-series) wells are screened in what regional geologic data suggest is the Patuxent Aquifer (CH2M HILL, 2009c). Several thick sequences of clay strata exist between the M-series and D-series wells. The clay strata are characteristically similar to the Arundel Formation, which is a regional aquitard that separates the Patapsco and Patuxent Aquifers. The function of the clay strata as an aquitard beneath the DMT is supported by the low average permeability (9.20×10^{-8} cm/sec) of the clay strata and by a substantial difference in water elevations measured in colocated D- and M-series well pairs. Because prior sampling of M-series wells indicates that overlying units have not been impacted, and given that the Patuxent is separated from the Patapsco by the Arundel Aquitard, it may be safely hypothesized for purposes of the CSM that the Patuxent Aquifer is unaffected by conditions at the site.

2.6.2 Stormwater

The SCM for chromium transport in stormwater is based on port construction drawings, historic reports, and the current and historic stormwater-sampling results. This section discusses the overall storm drain system, dry- and wet-weather flow components, storm drain inundation/exchange, and potential migration along the storm drain backfill material.

DMT is underlain by stormwater conveyance infrastructure that includes a series of large (36- to 96-inch-diameter) trunk lines and smaller laterals that are identified by the street number that they parallel (Figure 2-10). The pipes, which include the main trunk lines and a series of progressively smaller-diameter laterals, serve to convey stormwater from the port to the Patapsco River. The 15th Street storm drain system also conveys stormwater from the upgradient community of Dundalk. A portion of the 14th Street system parallels a former bulkhead that remains buried beneath the site.

The Site Contamination Assessment (EA, 1987) concluded that the most significant mass flux occurred from what was referred to as "tidal exchange" (chromium-impacted groundwater discharging into the storm drain system, mixing with the tide, and then discharging from the outfall). Tidal exchange was estimated to result in approximately 3.65 lbs/day of chromium. Approximately 97 percent of the storm drain chromium mass flux was discharged from the 13th through 15th Streets' storm drains. The remaining drains (9th to 12.5th Streets) typically exhibited less than 0.5 mg/L of chromium and composed less than 3 percent of the storm drain mass flux and thus were not given additional consideration.

Dry-Weather Flow

Chromium-impacted groundwater enters the storm drain system mainly through cracks and at the joints between pipe connections. The chromium-impacted seepage (now considered stormwater) referred to as dry-weather flow, is characteristically high in pH and chromium but constitutes relatively little flow. The dry-weather flow either discharges directly to the river via storm drain outfalls or is captured where tidal isolation and flow collection structures have been installed (14th and 15th Streets) and conveyed to the onsite treatment plant.

The dry-weather inflow rate is influenced by the water level in the surrounding shallow aquifer and typically decreases when the shallow aquifer is low (drought) and increases when the water level in the aquifer is higher (spring or other wet seasons). The groundwater inflow is also restricted if high tide inundates the storm drain to a height that is equal to the surrounding water table, resulting essentially in no net flux. On very infrequent cases such as extreme lunar events, hurricanes, etc., the tidal level can rise to the point where the tidal exchange is capable of overcoming the potentiometric head in the shallow aquifer, resulting in exchange with the shallow aquifer.

Wet-Weather Flow

During a storm event, rainfall becomes runoff, which is managed by the DMT storm drain system. The runoff, accumulated dry-weather flow, and suspended sediment, now referred to as wet-weather flow, is flushed from the storm drain system by the surge of "first flush" stormwater. The degree of suspended sediment is a function of the velocity of the first flush and may vary significantly. This first flush is either (1) captured for onsite treatment at storm drains equipped with tidal isolation devices or (2) discharged to the Patapsco River from the drains that are not equipped with isolation structures. The treated flow from the treatment plant and untreated discharges are monitored under an existing NPDES permit. During larger storm events, the tidal isolation devices may be overtopped or pumped in accordance with the Interim Operations Plan (CH2M HILL and MES, 2007) until flow returns to dry-weather conditions. After the storm passes, dry-weather conditions ensue, and this resumed dry-weather flow is also managed according to the Interim Operations Plan.

Storm Drain Bedding Material

EA (1987) postulated that permeable backfill along the 14th Street drain might be a potential conduit for chromium transport to the river. Significant modifications to the shoreline have been made between 14th and 15th Streets since the EA report was published, including construction of tide interceptor vaults at 14th and 15th Streets. Per the request of MDE, storm drain bedding material has been assessed to determine its potential to act as a preferential groundwater flow pathway. The assessment included application of the computer model for groundwater flow, evaluation of groundwater potentiometric data, evaluation of aquifer geochemistry, contaminant transport, and review of MPA design drawings. The assessment presents multiple lines of evidence indicating that the bedding material does not present a pathway for the discharge of chromium to the river. The assessment findings are presented in detail in Section 4.2.3 of this report.

2.6.3 Fate and Transport for Surface Water, Sediment, and Pore Water

Fate and transport processes in surface water, sediment and sediment pore water are described in detail in CH2M HILL and Environ (2009). Measurements of geochemical parameters in pore water, surface water, and sediment (e.g. acid volatile sulfides (AVS) and divalent iron) demonstrate that conditions are favorable to the presence of chromium as Cr(III) rather than Cr(VI). Sediments at DMT consistently contained measurable concentrations of these geochemical constituents despite fluctuations that naturally occur with the change of season. A statistically significant relationship was observed between dissolved total chromium and Cr(VI) concentrations in surface water samples where Cr(VI) was detected. This relationship demonstrates that Cr(VI) is rapidly reduced to Cr(III) in the water column, where it most likely precipitates to the sediment. Based on the results of this study and other related studies with respect to chromium geochemistry, total chromium in sediment is unlikely to oxidize to Cr(VI) in the future because the geochemical conditions necessary for this process do not naturally occur in the estuarine environment.

2.6.4 Air

The airborne pathway has the potential to transport COPR or chromium-impacted materials to adjacent communities or the Patapsco River via wind. This potential pathway was assessed by installing a multistation air-monitoring system along the perimeter of DMT and monitoring total particulate and Cr(VI) concentrations for over 18-months. Conceptually, air is not a viable transport pathway because the site is covered and the Surface Cover Maintenance Plan includes routine inspection and repair of the surface cover that has been effective at controlling this potential pathway.

SECTION 3

Investigation Scope and Methods

This section provides an overview of the CTS investigation by summarizing the scope of the groundwater, stormwater, and air investigation components of the CTS and discussing any changes required during implementation of the investigation.

3.1 Groundwater Investigation Overview

The groundwater investigation sampling and analysis tasks were performed during five investigation events, which are summarized below. Many of the groundwater investigation tasks were executed in conjunction with the COPR investigation, which was also being performed as part of the Consent Decree. Thus, the tasks described in the investigation work plans were designed to provide data for both the COPR and the groundwater investigations. Details of the COPR investigation are provided in the Final COPR Investigation Report (CH2M HILL, 2009a). A complete description of methodology for each groundwater investigation task is provided in Appendix A.

3.1.1 Voluntary Investigation Work[2]

The Groundwater Investigation Work Plan (CH2M HILL, 2005) describes the proposed investigation work that was proactively initiated by MPA and Honeywell in 2005. This work plan was transmitted to MDE in October 2005. The voluntary investigation began in November 2005 and was completed in June 2006.

The proposed scope of the voluntary investigation included the following elements:

- Installing 25 shallow monitoring wells (DMT-01S through -25S)
- Installing two Patapsco (M-Series) wells (DMT-01M and -02M)
- Installing three temporary piezometers (TPZ-01, -02, and -03)
- Redeveloping or repairing 14 existing monitoring wells
- Conducting 10 slug tests at DMT-01S through -10S
- Conducting four constant-rate aquifer tests in the shallow aquifer
- Conducting one aquifer test in the Patapsco Aquifer using the Neuman-Witherspoon method at the well cluster near DMT-01M
- Conducting separate tidal studies for the shallow and Patapsco Aquifers
- Collecting two rounds of synoptic water levels

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[2] The CTS Work Plan describes the voluntary investigation work as the “Phase I Groundwater Investigation” and describes the Phase 1 Groundwater Investigation (Section 4.1.2) as the “Phase II” investigation. Following submittal of the Work Plan, the Phase 2 and 3 groundwater investigations were implemented, and a report of the Phase 3 investigation findings was submitted to MDE. Thus, the investigation event nomenclature has been amended as described herein.

- Collecting groundwater samples from all newly installed monitoring wells
- Collecting a minimum of two grab soil samples from each soil boring location

3.1.2 Phase 1 Groundwater Investigation

Tasks associated with the Phase 1 groundwater investigation (described in an internal addendum to the groundwater investigation) were carried out pursuant to the CTS Work Plan (CH2M HILL, 2006a), which was submitted to MDE on June 29, 2006. The work plan used data from the voluntary investigation to identify data gaps which needed to be addressed to achieve the CTS objectives. The Phase 1 work began in fall 2006 and was completed in spring 2007.

The proposed scope of the Phase 1 investigation included the following elements:

- Installing eight shallow monitoring wells (DMT-26S through -33S)
- Installing five Patapsco (M-Series wells) (DMT-34M through -38M)
- Installing 20 temporary piezometers (TPZ-4 through -23)
- Collecting geochemical samples from four shallow monitoring wells (DMT-21S, -23S, -24S, and -25S)
- Conducting four constant rate aquifer tests in the shallow aquifer to complete the testing proposed in the Voluntary Investigation Work Plan
- Conducting a second Patapsco Aquifer test using the Neuman-Witherspoon method at the well cluster near DMT-01M to complete the testing proposed in the Voluntary Investigation Work Plan
- Conducting a tidal study in the five new Patapsco (M-Series) wells
- Collecting one round of synoptic water level measurements
- Collecting groundwater samples from each newly installed monitoring well
- Conducting a water quality and geochemical assessment at select shallow and Patapsco (M-Series) well pairs

3.1.3 Phase 2 Groundwater Investigation

The “Phase 2 COPR and Groundwater Investigation Work Plan, Dundalk Marine Terminal, Baltimore, Maryland” (CH2M HILL, 2007b), which described the tasks associated with the Phase 2 groundwater investigation pursuant to the CTS work plan (CH2M HILL, 2006a), was submitted to MDE on June 8, 2007. The work plan used data from the Phase 1 investigation to identify data gaps necessary for achieving the stated objectives of the CTS. The Phase 2 work began in June 2007 and was completed in February 2008.

The proposed scope of the Phase 2 investigation included the following elements:

- Installing 10 CPT borings (CPT-400 through -409)

- Installing 14 temporary piezometers[3] along the northern COPR boundary in Areas 1200, 1300 and 1400 and in Area 1501 adjacent to the 15th Street storm drain (TPZ-33 through -46)
- Installing sixteen shallow monitoring wells (five of which are background wells) (DMT-40S through -48S, -55S through -59S, -61S, and -62S)
- Installing six monitoring wells screened in the alluvial deposits and referred to as upper sand or US-series wells (DMT-49US through -54US)
- Installing one background Patapsco (M-Series) monitoring well (DMT-60M)
- Collecting groundwater samples from the newly installed monitoring wells and resampling a select set of existing wells
- Additional scope items that were discussed in the work plan, including test trenches, soil boring arrays, multipurpose borings, and inclinometer installation, were performed as part of the COPR Investigation, which is discussed in the Final COPR Report (CH2M HILL, 2009a).

3.1.4 Phase 3 Groundwater Investigation

The "Phase 3 Groundwater Investigation Work Plan, Dundalk Marine Terminal, Baltimore, Maryland" (CH2M HILL, 2008) was submitted to MDE on July 8, 2008. A subsequent modification to the Phase 3 Work Plan was described in the "Phase 3 Groundwater Investigation: Areas 1501/1602 Revised Scope of Work, Dundalk Marine Terminal, Baltimore, Maryland," which was submitted to MDE on February 9, 2009. The purpose of Phase 3 investigation was to address MDE's May 9, 2008, Proposed Resolution to the March 17, 2008, Notice of Dispute regarding groundwater issues at DMT. The Phase 3 work began in September 2008 and was completed in March 2009. A report of the Phase 3 investigation findings was submitted to MDE on May 28, 2009 (CH2M HILL, 2009c).

The proposed scope of the Phase 3 investigation included the following elements:

- Abandoning two monitoring wells (DMT-46S and EAC-01M)
- Installing one shallow monitoring well (DMT-63S)
- Installing 13 upper sand (US-Series)monitoring wells (DMT-64US through -76US)
- Installing four Patapsco (M-Series) monitoring wells (DMT-77M through -80M)
- Installing three Patuxent (D-Series) monitoring wells (DMT-81D through -83D)
- Collecting soil samples for analysis of COPR constituents at the Phase 3 shallow and Upper Sand well locations
- Collecting soil samples for geotechnical analysis at the Phase 3 M- and D-series well locations

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[3] The Phase 2 work plan stated that 15 temporary piezometers s would be installed during the investigation, however; only 14 (TPZ-33 through TPZ-46) were identified in the text and site map. The addition of TPZ-47, which was not proposed in the work plan, brings to 15 the total number installed during the Phase 2 investigation.

- Collecting pore water samples from water-bearing intervals encountered at each D-series well location
- Collecting groundwater samples from all Phase 3 monitoring wells
- Collecting one round of synoptic water level measurements
- Conducting a tidal study at Phase 3 monitoring wells

3.1.5 Interim Groundwater-Sampling Program

An interim groundwater-sampling program was implemented in the second quarter of 2009. Details of the interim program are provided in the "Interim Groundwater Sampling Plan, Dundalk Marine Terminal, Baltimore, Maryland," which was submitted to MDE on April 20, 2009. This program temporarily replaces the previously discontinued semiannual monitoring program using a select set of mostly new wells, which were installed during the groundwater investigation. The first interim groundwater-sampling event occurred in June 2009, and the data from that event are discussed herein. The interim sampling program is planned to continue semiannually until a new sentinel monitoring program is approved by MDE.

The proposed scope of work for the interim sampling program included the following elements:

- Collecting synoptic water levels from 118 monitoring wells
- Collecting and analyzing groundwater samples from 35 monitoring wells

3.2 Changes to the Groundwater Investigation Work Plans

This section compares the proposed and actual investigation activities for each of the groundwater investigation events summarized in Section 3.1. The text below discusses any changes from each event's work plan and lists any voluntary activities that were implemented to further the understanding of site conditions. A map of the investigation sampling locations is provided in Figure 2-4 and a summary table of well construction details is provided in Table 3-1.

3.2.1 Modifications to the Voluntary Investigation Scope of Work

Except as noted below, the proposed investigation tasks outlined in Section 3.1.1 were completed in accordance with the groundwater investigation work plan. The following items represent changes from the work plan or voluntary modifications to the scope of work (SOW):

- An aquifer test was successfully completed at the DMT-01M test cluster, but the test could not be analyzed by the Neumann-Witherspoon methods due to the methodology of data collection. The methodology was subsequently adjusted, and a second test, which allowed this assessment to be completed, was performed during the Phase 1 groundwater investigation. Further explanation is provided in Appendix A.
- EA-09M was the only existing monitoring well to be replaced during the voluntary investigation.

- Four shallow aquifer tests were attempted at DMT-24S, but the tests could not be run to completion due to fouling caused by elevated levels of dissolved calcium in the well. Consequently, further testing at DMT-24S and the remaining shallow test locations were postponed until the aquifer geochemistry could be characterized. All of the shallow aquifer tests were subsequently completed in November 2006 and January 2007 during the Phase 1 groundwater investigation.
- Groundwater samples were collected from DMT-24S and DMT-01M for the purpose of characterizing the geochemistry of the aquifer. These data confirmed that geochemical conditions were optimal for precipitation of calcium carbonate.
- Soil samples were not collected from DMT-02S, -04S, -11S, -13S, -15S, -16S, -17S, and -23S. Soil samples were also not collected from DMT-21S, -24S, and 25S, but these are aquifer test locations that are paired with another well where soil samples were collected.
- Only one grab soil sample was analyzed from each of the following locations: DMT-01S, -05S, -14S, -18S, and -19S.

3.2.2 Modifications to the Phase 1 Groundwater Investigation Scope of Work

Except as noted below, the proposed investigation tasks outlined in Section 3.1.2 were completed in accordance with the groundwater investigation work plan addendum. The following items represent changes in the work plan implementation or voluntary modifications to the SOW:

- Soil samples were voluntarily collected and analyzed from the following Phase 1 well locations: DMT-29S through -33S, DMT-34M through -38M, DMT-39S, and TPZ-25 through -32. It was not proposed in the groundwater investigation work plan addendum that soil samples would be collected; rather, these samples were collected for use in the concurrent Phase 1 COPR investigation.
- DMT-39S was voluntarily installed during the Phase 1 investigation to provide additional groundwater characterization data from the southeastern site boundary.
- Three additional TPZs—TPZ-24, -A, and -B—were voluntarily installed to provide additional observation points for shallow aquifer tests. The locations of these piezometers were chosen because of their proximity to the test well location (e.g., TPZ-24) or because of their position with respect to historic bulkhead features (e.g., TPZ-A and -B).
- TPZ-27A/B, -28, -29, and -30A/B were voluntarily installed along the eastern site boundary to monitor groundwater elevations and chemical concentrations. TPZ-27A/B and -30A/B are nested piezometer pairs installed to measure groundwater elevations and chemical concentrations above and below a shallow silt layer.
- The Phase 1 synoptic water level measurements were collected on January 18, 2007, prior to installation of the eastern site boundary TPZs. One additional round of synoptic water level measurements was voluntarily collected on April 23, 2007, and this round included measurements from the eastern site boundary TPZs.

- Additional TPZs were planned along the eastern site boundary at locations TPZ-25, -26, -31, and -32. TPZs were not installed at these locations due to the presence of COPR.
- The following set of existing monitoring wells were voluntarily resampled during the Phase 2 investigation: DMT-12S, -14S through -20S, -01M, and -02M; EA-08S and -10S; and EAC-02S, -03S, -2M, and -3M. Additional sampling was conducted at the DMT wells to rectify results from an earlier sampling round, which were rejected or qualified during data validation.

3.2.3 Modifications to the Phase 2 Groundwater Investigation Scope of Work

Except as noted below, the proposed investigation elements outlined in Section 3.1.3 were completed in accordance with the Phase 2 groundwater investigation work plan. The following items represent changes from the work plan or voluntary modifications to the SOW:

- One additional piezometer was voluntarily installed at location TPZ-47 to provide additional control on groundwater levels in the vicinity of the consolidation sheds.
- Delineation borings B-130 and -131 were not completed as monitoring wells due to the presence of COPR at these locations.
- Tidal studies were voluntarily performed for the following wells that were installed during the Phase 2 investigation: DMT-45S, -46S, -56S, -57S, -58S, -60M, -49US, -50US, -51US, -52US, and -54US. A second tidal study was also voluntarily performed in existing well EA-11S.
- Two rounds of synoptic water level measurements were voluntarily collected during the Phase 2 investigation on September 24, 2007, and November 19, 2007. These rounds were collected to provide additional data for the groundwater model.
- Groundwater samples were collected from the following existing wells during Phase 2: DMT-30S, -35M, and -38M; EA-08S and -8M; and EAC-04M.
- Groundwater samples were collected at the following piezometer locations to provide additional groundwater characterization data in key areas of the site: TPZ-33, -36, -38, -44, -45, and -46.

3.2.4 Modifications to the Phase 3 Groundwater Investigation Scope of Work

Except as noted below, the proposed investigation elements outlined in Section 3.1.4 were completed in accordance with the Phase 3 work plan. The following items represent changes from the work plan or voluntary modifications to the SOW:

- DMT-66US was not completed as a well because the upper silt was not present in this location; however, adjacent monitoring well DMT-31S is partially screened within the alluvial sands that directly underlie the fill in this area.
- DMT-68US and -69US were not completed as wells because the upper sand unit was not encountered at these locations.
- DMT-76US was not installed because a suitable drilling location was not identified by MDE in Areas 1501 and 1602 during the investigation kick-off meeting. Per MDE

request, TPZ-48 and -49 were subsequently installed near the proposed location of DMT-76US. TPZ-48 and -49 were installed per the methods outlined in the "Phase 3 Groundwater Investigation: Areas 1501/1602 Revised Scope of Work, Dundalk Marine Terminal, Baltimore, Maryland."

- Per agreement with MDE, pore water samples were not collected from the water-bearing interval where the D-series well screens were set since this interval is represented by the groundwater sample collected after the well was installed.

3.2.5 Modifications to the Interim Groundwater-Sampling Program Scope of Work

Groundwater samples were collected from all 35 monitoring wells during the June 2009 interim sampling event. Changes from the sampling plan are noted below along with additional tasks that were completed during the June 2009 event:

- The sampling plan states that the wells would be sampled using low-flow sampling procedures consistent with the Phase 3 work plan. These procedures call for the use of a submersible sampling pump. DMT-45S and -58S could not be sampled with a submersible pump due to bent well casings that prevented installation of the pump into the well. Consequently, these wells were sampled with a peristaltic pump.
- At the request of MDE, the three D-series wells—DMT-81D, -82D, and -83D—were sampled during the June 2009 interim event.

3.3 Stormwater Investigation Overview

The purpose of the stormwater-sampling program was to quantify the amount of chromium potentially discharged to the Patapsco River via the 9th through 13.5th, 14th, and 15th Streets' stormwater drains. Although not a part of the CTS, additional NPDES monitoring is performed at the DMT by MES and reported to MDE on a quarterly basis.

The conceptual plan to quantify the chromium inputs from dry-weather flow (largely seepage from the surficial aquifer through cracks into the storm drains) and wet-weather flow (runoff from storm events) was to collect flow and chromium concentration data for a series of dry- and wet-weather flow events that would allow estimation of annual mass loading.

From observations, it was inferred that some of the storm drains could yield dry-weather flow and chromium concentrations sufficiently large to represent a quantifiable load to the river. Regarding wet–weather flow, it was surmised that runoff from precipitation would be devoid of chromium and would only dilute the exfiltrating groundwater that enters the storm drain from the surrounding COPR fill. Therefore, the premise was that wet-weather flows would not be a significant source of chromium, and a wet-weather monitoring program was devised to verify this hypothesis.

The sampling plan was designed to verify this conceptualization of the site response. However, as explained below, the ability to collect reliable stormwater samples and flow data was hampered by site conditions, engineering, operational and safety factors such as tidal submergence, the condition of the stormwater drain system, MPA operations and logistics, and confined-space entry requirements.

The following subsections summarize the evolution of the sampling plan and the changes in the investigative approach in response to the challenges presented above.

3.3.1 Evolution of the Sampling Plan and its Implementation

As part of the renewal process for the NPDES permit in 2005, MDE requested that MPA prepare a plan to reliably quantify the discharge of chromium from the 9th through 13.5th Streets' storm drain outfalls. A plan was presented in the "Plan for Quantifying Chromium Transport from Stormwater Outfalls to the Patapsco River, Dundalk Marine Terminal, Baltimore, Maryland" (CH2M HILL and MES, 2006), which was approved by MDE on February 8, 2007. The approved work plan included a feasibility study and pilot testing process to develop and field-validate a method to eliminate the influence of the tide at affected drains and facilitate collection of dry-weather flow. The approved work plan also included modified sampling procedures developed to better quantify flow and collect water quality samples until a permanent means of tidal exclusion could be developed, field tested, and constructed at drains that contribute significant chromium mass flux. Procedures were also specified for wet-weather flow measurements and water quality sampling.

Dry-Weather Flow

The objective of the modified sampling procedures was to collect water quality data and flow data that are more representative of site conditions than the procedures used to meet the NPDES permit requirements. The goal was to temporarily exclude the influence of the tide during dry-weather flow sampling events by temporarily installing tidal exclusion plugs and plates. In addition, the data would be used to identify and prioritize drains for installation of permanent tidal-exclusion infrastructure after such infrastructure was field-proven on a pilot scale.

In March 2007, MPA's contractor, Maryland Environmental Services (MES), began applying the modified sampling procedure. The effort involved various methods for blocking the influence of the tide, dewatering, cleaning, and measuring dry-weather flow and water quality from each of the storm drains. There were numerous difficulties caused by the tidal exclusion plugs and plates, confined-space entry, weather, tide cycles, sediment and debris accumulation, and port operations.

It should be emphasized that the data collected using the modified sampling procedures represent flow that could occur were the tide not present. Therefore, these tidally excluded data cannot be used directly to quantify the flux of chromium from the storm drains in their current configuration since the dilution and backflow effects of the tide were temporarily eliminated during sampling. Nevertheless, the data collected under the modified sampling procedures are useful for the following purposes:

- Calibrating the groundwater flow model that will be used to establish transport of chromium from groundwater to the Patapsco River and predict changes that would occur from candidate corrective measures alternatives
- Determining which drains may be meaningful contributors to overall chromium flux (priority drains) and which drains' contribution is insignificant

Significant time and resources were devoted to obtaining a single complete round of dry-weather flow data from the 9th through 13.5th Streets' storm drains with the goal of collecting water quality that was free of tidal influence. One year and over 10,000 worker-hours were required to accomplish the one round of sampling. Numerous methods were deployed in an attempt to isolate the tide, including combinations of cleaning, expandable plugs, and metal plates. In view of the myriad difficulties and the need to keep the project on schedule, the sampling effort under this methodology ceased in late 2007 after collection of this single round of data.

The data analysis and the proposed path forward for dry- and wet-weather storm drain sampling were presented in the "Addendum to the Work Plan for Quantifying Chromium Transport from Stormwater Outfalls to the Patapsco River, Dundalk Marine Terminal, Baltimore, Maryland" (CH2M HILL and MES, 2008), which was submitted to MDE on July 3, 2008. The addendum included a modified sampling and analysis plan for dry-weather sampling in an attempt to adapt to the challenging conditions. In addition, the results were used to rank the storm drains as priority (requiring action) or nonpriority (de minimis mass flux—no action required) depending on their potential to discharge chromium. Through the assessment and on the basis of qualitative evaluations of potential mass flux, the 9th through 11.5th Streets' storm drains were identified as nonpriority drains, and the 12th through 15th Streets' storm drains were identified as priority drains. The storm drain prioritization is more completely summarized in Section 4.

Tidal inundation measurements were recorded during several years of NPDES sampling and during the storm drain sampling performed for the CTS. The degree of tidal inundation was plotted on cross sections to estimate the extent to which tidal inundation could impact sampling efforts. This information was used to develop the dry-weather modified sampling plan presented in the addendum (CH2M HILL and MES, 2008).

Although the goal of obtaining multiple rounds of dry-weather data was not achieved, the available data were sufficient for determining the priority storm drains that required additional action. Furthermore, the data were sufficient to advance the Human Health and Ecological Risk Assessments and the CMAA.

Wet-Weather Flow

The "Plan for Quantifying Chromium Transport from Stormwater Outfalls to the Patapsco River, Dundalk Marine Terminal, Baltimore, Maryland" (CH2M HILL and MES, 2006) presented an approach to collecting wet-weather samples, but the experience during the attempts at dry-weather sampling indicated that the same challenges would be encountered during sampling of wet-weather flow.

The addendum (CH2M HILL and MES, 2008) included a revised sampling and analysis plan for wet-weather flow sampling, but its implementation presented equally challenging difficulties. Again the tidal inundation and the condition of the pipes did not allow use of suitable control sections that could be instrumented for monitoring flow. No wet-weather flow measurements or water quality sampling events were completed.

3.3.2 Changes to Investigative Scope

Having determined that tidal exclusion is a necessary prerequisite for quantification of stormwater mass flux, the stormwater assessment approach shifted toward deployment of structures that, in addition to facilitating reliable quantification would enable performance of a conditions assessment and rehabilitation of the storm drains, as needed. With the added capabilities of this approach, the estimation of chromium inputs to the river became less important because the storm drain conditions assessment would allow determination of rehabilitation methods designed to eliminate dry-weather flow and its associated mass flux contributions. Dry-weather flow would be significantly reduced or eliminated following storm drain rehabilitation, and the presence of the tidal exclusion chambers will provide a point for future quantification of mass flux and compliance monitoring.

To test the IRM concept, a pilot study for the 13th Street storm drain was designed. The "Work Plan for Pilot Study of Stormwater Interim Remedial Measures" (CH2M HILL, 2007c) was submitted to MDE on June 9, 2008. The two objectives of this plan were (1) to develop and test methods to collect data that can be used to quantify pollutant loads and (2) to evaluate the feasibility of collecting the dry-weather flow from the 13th Street storm drain as a proactive remedial measure. Results are presented in Section 4.2.

3.4 Perimeter Air-Monitoring Program

A perimeter air-monitoring program was conducted at DMT for Cr(VI) and total particulate matter at nine sampling sites (Figure 3-1). Meteorological data were collected at a single sampling site. The air-monitoring plan was approved by the MDE in August 2007; sampling began in September 2007. The objectives of the plan were the following:

- Evaluate the efficacy of the surface cover and maintenance systems in COPR fill area
- Supplement real-time personnel and work area exclusion-zone air monitoring

The field-sampling equipment consisted of the following:

- Cr(VI) was collected using a 37-mm-diameter polyvinyl chloride (PVC) filter with a polystyrene cassette connected to a GAST Model 1532 pump, in accordance with OSHA ID 215 methodology.
- Particulate matter was collected using a sample cassette and filter in accordance with NIOSH 0500 methodology.
- Meteorological data consisted of ambient temperature, wind speed, wind direction, barometric pressure, dew point, and relative humidity, which were downloaded as 1-hour averages for each 24-hour sampling period.
- EA Engineering, Science and Technology provided the field-sampling services. Laboratory services were provided by St. Paul Travelers Laboratory of Windsor, Connecticut. Twenty-four-hour sampling data were collected once per week from September 2007 to August 2008. Sampling was briefly discontinued from September through December 2008 when the original scope of work had been completed.

3.4.1 Modifications to the Perimeter Air-Sampling Program Scope of Work

In January 2009, sampling voluntarily resumed, with a single round of 24-hour sampling data collected each month. The data for each month were summarized in a series of reports that included the results of the monitoring program and all related quality control documentation.

3.5 Groundwater Model

As proposed in the CTS work plan, a numerical groundwater flow model has been developed using results from all phases of investigation at DMT. The groundwater model was created to:

- Provide a computational framework that combines the diverse forms of hydrogeologic information collected at DMT into a predictive tool governed by the equations of groundwater flow
- Estimate, under current site conditions, the potential for offsite migration of chromium via groundwater discharge to the storm drains or through direct interactions between the hydrogeologic units and the Patapsco River
- Provide a quantitative mechanism for future predictive simulations of potential actions that could be taken to mitigate dissolved chromium migration, including storm drain repair

The stated objectives were achieved by developing a groundwater flow model that is based on the site conceptual models for groundwater and storm water flow and transport as discussed in Section 2.6. The model was created using the modular, three-dimensional, finite-difference flow model code MODFLOW-2000. MODFLOW-2000 is an updated version of the original MODFLOW code that was developed by the U.S. Geological Survey in 1984. The MODFLOW codes are widely used and are capable of simulating steady-state or transient flow in combinations of confined, unconfined, and semi-confined aquifers with a variety of boundary conditions and hydrologic stresses. The codes have been thoroughly peer-reviewed and are considered highly reliable for solving the equations of flow in saturated porous media. The development and calibration of the site-specific numerical groundwater flow model is described in Appendix B and the modeling results are discussed in Sections 4 and 6.

SECTION 4

Investigation Results

The CTS investigation was composed of a multitude of investigation tasks that were completed during the groundwater investigation: installing over 120 monitoring wells and piezometers, collecting and analyzing over 400 soil samples and over 200 groundwater samples, conducting tidal studies in 75 wells, collecting nine rounds of synoptic water elevation measurements, performing multiple aquifer tests. During the course of the CTS, stormwater was monitored as part of the NPDES compliance process and one round of tidally isolated samples were collected, and perimeter air monitoring was conducted for approximately 18 months to assess the air migration pathway. The results for the groundwater, stormwater, and air investigation components of the CTS are provided in Sections 4.1 through 4.3, respectively.

4.1 Groundwater Investigation Results

Data obtained during the groundwater investigation were used to define the characteristics of groundwater flow beneath the site and to delineate the extent of COPR-related impacts to soil and groundwater. For consistency with the objectives of the CTS, defined pursuant to Section III.B.2.a of the Consent Decree, the discussion regarding the extent of COPR-related impacts focuses on the concentrations and extent of chromium, including Cr(VI). The analytical results for other COPR-related constituents are provided in the data tables that are referenced in this section. The data presented below form the basis for the groundwater flow model that was used to quantify the mass flux of chromium to the Patapsco River.

4.1.1 Soil Analytical Results

A total of 404 soil samples were collected and analyzed for chromium and COPR-related constituents during the groundwater investigation (Table 4-1). The CTS soil analytical data are provided in Appendix C. Total chromium concentrations in soil ranged from 1.14 J mg/kg to 41,100 mg/kg, and Cr(VI) concentrations ranged from 0.22 U mg/kg to 19,500 mg/kg. The concentration range observed is large because 123 of the soil samples are COPR material, which typically contains elevated metals concentrations. For comparison purposes, the soil data set was split into COPR and non-COPR populations, which revealed the following:

- The average concentrations of Cr and Cr(VI) in the non-COPR samples were substantially lower than those of Cr and Cr(VI) in the COPR samples (Table 4-2).
- Cr and Cr(VI) concentrations in non-COPR samples typically were highest when the samples were collected within approximately 3 feet of COPR fill or from a soil horizon that was potentially exposed to COPR during the time of COPR fill placement. These conditions are represented by 20 soil samples, and when these samples are excluded from the data set as outliers, the average total Cr and Cr(VI) concentrations in the non-COPR data set decrease further, to 90 mg/kg and 2 mg/kg, respectively(Table 4-2).

- In approximately 32 percent of the non-COPR samples, Cr(VI) was below the laboratory method detection limit (MDL); in 82 percent of the non-COPR samples, the detected value of Cr(VI) was less than 5 mg/kg.
- The maximum detected value of Cr(VI) in the non-COPR samples (outliers removed) was 84 mg/kg.

MDE regulates chromium in soil as total Chromium unless Cr(III) and Cr(VI) speciation is performed as was done at DMT. The Cr (III) and Cr(VI) nonresidential cleanup standards for the chromium species are 150,000 mg/kg and 310 mg/kg, respectively.

Analytical data from DMT shows that the concentration of Cr(III) in soil is very closely approximated by subtracting the concentration of Cr(VI) from the concentration of total Cr, which is consistent with the fact that Cr(III) and Cr(VI) are the most common valence states found in most natural environments. The following observations can be made with respect to the MDE criteria:

- Average concentrations of total Cr and Cr(VI) in the non-COPR soil data set (including the outliers) did not exceed the MDE non-residential criteria.
- Total Cr and Cr(III) concentrations in the non-COPR soil samples also did not exceed the MDE non-residential criteria.
    - Only five out of a total of 281 samples collected in non-COPR soils exceeded the MDE non-residential criteria for Cr(VI). These locations represent a very small subset of the total investigation and are not significant enough to change the overall soil impact findings.

Low-level concentrations of Cr(VI) were detected in some deep soil samples that were collected at DMT-34M, -35M, -36M, -37M, and -38M (Table 4-1). These monitoring wells were installed by mud-rotary drilling techniques using a recirculating, high-pH, bentonite drilling mud, and the soil samples were collected through the drilling fluid. The elevated pH and occasional low levels of Cr(VI) in the deep soil samples are most likely derived from residual drilling mud that was captured within the sampler and became incorporated into the soil sample. It is believed that shallow fill materials impacted by Cr(VI) became entrained with the drilling fluid through incomplete decontamination of drilling and sampling equipment. The multiple lines of evidence that support this conclusion were presented in a technical memorandum submitted to MDE on April 2, 2008, entitled "Groundwater Issues: Follow-up to March 21, 2008, Meeting, Dundalk Marine Terminal, Baltimore, Maryland."

Horizontal Extent of Soil Impact

A comparative analysis of the analyte concentrations in COPR and non-COPR fill materials suggests that elevated Cr and Cr(VI) concentrations are limited mainly to within the COPR fill boundary. The DMT fill area was constructed entirely of either COPR or non-COPR imported fill, so the horizontal impacts of Cr and Cr(VI) may be approximated by examining the concentration of these constituents in samples of non-COPR fill. Within the non-COPR soil sample data set discussed above, there are 72 non-COPR fill samples that were collected from borings south (Areas 900, 1100, and 1200, and the south part of Area 1300) and generally east (TPZ-28 and DMT-39S) of the COPR boundary. The average concentrations of Cr and Cr(VI) in the non-COPR fill samples are substantially lower than those in the COPR fill samples (Table 4-2), suggesting that Cr and Cr(VI) impact does not extend very far beyond the COPR boundary.

Analytical data from three boring arrays completed during the Phase 2 investigation shows a substantial decrease in Cr and Cr(VI) concentrations within horizontal distances of 25 to 40 feet from the COPR boundary (Figures 4-1 and 4-2). Therefore, the COPR fill limits defined during the COPR investigation (Figure 2-2) also very closely approximate the horizontal limit of Cr and Cr(VI) impact to soils beneath DMT and the extent of chromium impact is limited to within approximately 40 feet of the COPR body.

Vertical Extent of Soil Impact

The vertical extent of Cr and Cr(VI) impact to non-COPR soils appears to be limited to within 5 feet of the base of the COPR fill. Data trends from several individual boring locations (e.g., B-127 and -128; CSG-2; DMT-08S, -10S, -29S, -30S, and DMT-34M through -37M; INC-9, -12, and -14; SBA-D-1, -F-1, and -H-1; and TPZs 25, 26, 31, and 32) support this interpretation (Table 4-1). For example, data from location B-127 show that within a vertical distance of less than 4 feet below the COPR body, the concentrations of Cr and Cr(VI) decrease by several orders of magnitude; a similar trend is observed in the remaining borings.

An expansive data set of DPC field readings also provides evidence for a limited vertical extent of Cr(VI) impact to non-COPR soils. DPC readings recorded on boring logs from the investigation indicate that Cr(VI) is present through intervals of COPR, as indicated by a "++" or "+" reading on the log. Immediately below COPR, DPC readings are typically "–," which indicates that Cr(VI) is no longer present. Exceptions to this trend may include areas where COPR is underlain by alluvial sand or coarse fill. In these cases, the DPC reading has typically been recorded as "+" but generally reduces to "–" within a vertical span of 2 to 4 feet. Boring logs are included in an appendix to the Final COPR Investigation Report (CH2M HILL, 2009a).

Vertical profiles of soil concentrations reveal that a substantial decrease in Cr and Cr(VI) concentrations occurs in the upper alluvial silt, which directly underlies COPR across much of the site (Figures 4-1 through 4-4). Elevated Cr concentrations have been detected in the alluvial silt at relatively shallow depths in borings such as SBA-H-4, but given the fill history of the site, it is likely that some COPR may have been mixed into the soft alluvial silt during placement. Despite the slightly elevated Cr concentrations in the shallow portions of the silt, the analytical data still suggest that the concentrations of Cr(VI) are very low relative to concentrations observed in COPR (Figure 4-2). Accordingly, the vertical extent of chromium impact is limited to within approximately 4 to 5 feet of the COPR body.

4.1.2 Groundwater Geochemical and pH Assessment Results

Geochemical conditions in the shallow fill unit and Patapsco Aquifer were evaluated during a pH assessment and an aquifer characterization sampling event that was completed during the groundwater investigation. The primary purpose of the pH assessment was to compare and contrast the geochemistry of groundwater samples obtained from the shallow and Patapsco wells in an effort to determine whether leakage from the shallow fill unit to the Patapsco Aquifer was occurring. A complete description of the pH assessment has been presented to MDE, and the results are included in Appendix D (CH2M HILL, 2007d). The pH assessment data have been further supplemented with geochemical characterization data (Table 4-3) to draw the following general conclusions:

- Historically elevated pH values observed in Patapsco (M-series) wells do not appear to be a characteristic of the Patapsco Aquifer; elevated pH observed in the M-series wells was a short-lived phenomenon that was greatly reduced after the wells were pumped for a sustained period (e.g., use of conventional purge and sample techniques).
- Elevated pH measurements are typically associated with shallow wells within the COPR boundary. Water quality measurements collected from the US-, M-, and D-series wells indicates that pH-neutral to slightly acidic conditions are encountered in the upper sand unit, the Patapsco Aquifer, and the Patuxent Aquifer, respectively.
- Groundwater samples collected from the shallow wells contained different percentages of major ions than groundwater samples collected from the M-series wells (Table 4-3 and Figure 4-5). Two shallow wells (EAC-1S and EA-11S) did show some geochemical similarity to the Patapsco Aquifer wells; however, both of these shallow wells are outside the COPR boundary and are less likely to exhibit geochemical characteristics similar to COPR.
- Across the site, the carbon dioxide concentrations detected in samples collected from the M-series wells was generally one to two orders of magnitude greater than in samples collected from the shallow monitoring wells suggesting different water geochemistry and thus different source provenance.
- Analytical results from DMT-24S showed that elevated concentrations of calcium are present in shallow groundwater, and X-ray diffraction results showed that a precipitant scale observed during aquifer testing was composed primarily of calcite ($CaCO_3$). In samples collected from the M-series wells, concentrations of TDS, TSS, and calcium were comparatively low and the precipitant scale was not present again suggesting these are different water types.

On the basis of the above findings, it appears that the geochemistry of the groundwater in the shallow fill unit is different than the geochemistry of the groundwater in the Patapsco Aquifer. This serves as further evidence that the alluvial silt units provide an effective physical or geochemical barrier between the shallow fill unit and Patapsco Aquifer.

4.1.3 Synoptic Water Level Monitoring Results

Over the course of the phased groundwater investigation, nine rounds of synoptic water level measurements were conducted: on April 28, 2006; May 15, 2006; January 18, 2007; April 23, 2007; September 24, 2007; November 19, 2007; March 14, 2008; November 24, 2008; and June 2, 2009. The November 24, 2008, and June 9, 2009, rounds are the most comprehensive data sets because these measurements were collected after the DMT monitoring well network was established.[4] The results from these two rounds are representative of site conditions and are discussed in detail below. A description of the field

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[4] Monitoring wells TPZ-48 and TPZ-49 were not installed until March 2009, so water measurements from these wells were not measured in November 2008.

methodology for synoptic water level monitoring as well as potentiometric surface maps for the other seven synoptic events are provided in Appendix A.

The groundwater elevations used to map potentiometric surfaces for each hydrogeologic unit were tidally corrected according to the procedure outlined in Appendix A. As discussed in Section 4.2, water levels at DMT also appear to respond to barometric pressure changes; however, no correction for barometric change is applied to the groundwater elevations. Barometric correction is not required because the synoptic measurements are collected over a short time period, typically 4 to 7 hours, and the pressure changes that occurred during each monitoring round were on the order of 0.1 foot of water or less.

Shallow Fill Unit

Two classes of shallow wells are shown on the potentiometric surface maps that display contoured groundwater data for the shallow fill unit (Figures 4-6 and 4-7). One class comprises the shallow wells that are screened in the continuous, laterally extensive, and transmissive sediments that form the shallow unit. Data from these wells are used to generate the contours (Figure 4-8). The second class is composed of nonaquifer wells that are screened in localized sand lenses or in materials of low permeability. Data from the nonaquifer wells are posted on the maps, but the posted values are not included in the contoured data set. Also, the shallow groundwater elevations were contoured separately in the areas north and south of the railroad tracks along the East Service Road that marks the northern extent of the DMT COPR fill area. The area north of the railroad tracks was constructed in the late 1920s and early 1930s by placing fill on the Patapsco River bed inside a peripheral dike and steel-clad wooden bulkhead. The discrepancy in water levels measured to the north and south of the location of the bulkhead structure appear to indicate that the bulkhead inhibits hydraulic communication between the DMT COPR fill area and the area to the north of the railroad tracks.

Shallow groundwater beneath the east portion of DMT flows generally southwestward toward the location of the historical shoreline and bulkhead, which is roughly coincident with the current location of 14th Street drain (Figures 4-6 and 4-7). Hydraulic gradients from the northeast corner of the site, at well EA-03S, toward 14th Street are up to 0.006 ft/ft. This area of higher horizontal gradient diminishes to the south and west of the location of the early shoreline and bulkhead. Factors which contribute to the reduction in gradient include (1) thickening sequences of COPR and more permeable fill deposits west of the bulkhead, (2) thinning of the semiconfining unit which separates the shallow fill from the underlying alluvial deposits, and (3) the physical presence of the old bulkhead, which likely impedes lateral groundwater flow upgradient from and across the historical bulkhead. Leakage into the 14th Street drain exerts a localized influence on piezometric levels, but the effect is more likely due to point sources of infiltration (cracks, pipe separations) rather than the effect of permeable backfill around the drain. As discussed in Section B.5.6 of Appendix B, calibration adjustment of the drain coefficients was done by drain segment, and in some locations on a cell-by-cell basis to simultaneously match simulated aquifer levels and drain leakage rates to the calibration targets. Dry-weather flow rates in the 14th Street storm drain are estimated to range from 15 to 20 gpm.

A convergence of shallow groundwater flow toward the 15th Street storm drain is observed in the upper reaches of the 15th Street drain in the vicinity of TPZ- 44 on both potentiometric surface maps (Figures 4-6 and 4-7). Effluent from the 15th Street drain is captured and pumped to the groundwater treatment plant at rates that fluctuate significantly but generally average between 20 and 100 gpm. A portion of the captured groundwater emanates from areas offsite to the east, where the drain serves the community of Dundalk. The onsite component of groundwater infiltration into the storm drain has been estimated at 19 gpm. The downgradient portion of the 15th Street drain does not appear to exert any noticeable influence on potentiometric contours even though, downgradient of G Street, the 15th Street storm drain was constructed in a trench backfilled with non-COPR-containing permeable material. The MPA design drawings indicate that the slopes of the trench were constructed with an "impervious borrow" which may isolate the lower portion of the 15th Street storm drain from hydraulic communication with shallow fill.

As discussed in Section B3.6.1 of Appendix B, a zone of relatively low hydraulic conductivity (0.1 ft/day) is assigned along the bank of the Patapsco River between 13.5th Street and the outfall of the 15th Street drain. Groundwater levels in close proximity to the shoreline in this area are approximately 2 feet higher than the mean river level, as has consistently been observed in groundwater monitoring. Groundwater levels would be in equilibrium with the river level in the presence of hydraulic communication, as is observed to the east beneath the engineered cell of Area 1501/1602. Consequently, even if the 15th Street storm drain south of G Street is constructed in permeable backfill, it does not appear to assert any influence on groundwater levels, nor does the backfill appear to demonstrate any hydraulic communication with the river. Groundwater elevations measured in wells within Areas 1501 and 1602 suggest that the COPR cell that underlies this area provides hydraulic containment for water that collects inside the cell. Groundwater elevations in the wells that are screened within the cell (TPZ-39, -40, -41, and -43) typically range from approximately 5 to 9 feet BCD while groundwater elevations in wells screened in the shallow fill unit below the COPR cell (DMT-11S, -45S, -57S, and -58S) are typically less than approximately 2.5 feet BCD. Water levels in the shallow fill unit beneath the cell are generally very similar to the water level in the river. Potentiometric levels within the 1501/1602 cell are much higher than the level in the underlying formation, and the gradient beneath the cell is very flat, suggesting that there is essentially very limited recharge to the shallow permeable unit in this area.

Relative to the east portion of the site, the shallow potentiometric surface is relatively flat beneath areas of DMT that are west of the 14th Street drain (Figures 4-6 and 4-7). In this area of the site, the shallow fill unit is comprised of coarser deposits and is physically separated from the Patapsco River by the continuous steel sheet-pile bulkhead that was driven into the subsurface during construction of the ship berths. Groundwater levels adjacent to the bulkhead are generally 1.5 to 2.5 feet higher than the river, which indicates that the bulkhead serves as a hydraulic barrier.

The potentiometric surface in the areas west of 12th Street is dominated by a groundwater mound under consolidation sheds 11 and 12, which is apparent on the November 24, 2008, and June 2, 2009, potentiometric surface maps (Figures 4-6 and 4-7). Gradients from the mounded area toward the river are on the order of 0.0015 ft/ft toward the western bulkhead and 0.002 ft/ft toward the southern bulkhead. The mound is thought to be caused by a combination of roof drainage from the sheds, which is routed into subsurface drain lines, and leaking utility lines. Between the September and November 2007 monitoring rounds, a water line leak estimated at approximately 50 gpm was repaired, and some decrease in mounding was observed in the November synoptic round. The groundwater mound is truncated on its northern side by the bulkhead between the DMT fill area and the area north of the railroad tracks.

Field measurements of dry-weather flow are provided in Table 4-4 and suggest that shallow groundwater also discharges to the 11th and 13th Streets' storm drains, but under normal conditions the discharge to the drains is not apparent on potentiometric surface maps. The lack of an apparent gradient toward the drains is due in part to the low magnitude of dry-weather flow that has been observed in these drains. Approximately 5 gpm of dry-weather flow was observed in the 11th Street drain and 5 to 14 gpm of dry-weather flow has been observed in the 13th Street drain. Dry-weather flow has not been observed in the 10th Street drain.

One exception to the drain effects on the potentiometric surface is the groundwater depression that is apparent on the November 24, 2008, and June 2, 2009, potentiometric surface maps near the southern end of the 13th Street drain (Figures 4-6 and 4-7). According to a visual survey of the drain pipe, the location of the depression coincides with an area of the pipe that is damaged. The damaged area is just upstream of the 13th Street drain stormwater collection vault, and activities associated with vault construction and cleaning likely increased the magnitude of the depression during the monitoring events. The 13th Street collection vault was constructed in the fall of 2008, and the drain and surrounding vicinity were being dewatered by pumping when the water level measurements were collected on November 24, 2008, and on June 2, 2009. The presence of a defined cone of depression confirms that point discharge rather than seepage along backfill material is the cause of this water level deflection. A focused groundwater depression was not observed at this locality during previous monitoring events.

Alluvial Sand Unit

Groundwater elevations measured at the upper sand well locations are posted on the shallow potentiometric surface maps developed for November 24, 2008, and June 9, 2009, (Figures 4-6 and 4-7). The sands screened by the upper sand monitoring wells are not laterally extensive or continuous; therefore, the groundwater elevations measured in the upper sand wells are not contoured. In general, the groundwater elevations measured in the upper sand wells mostly west of 14th Street are comparable to groundwater elevations measured in nearby shallow monitoring wells, and the vertical gradient between the shallow and upper sand well pairs is not spatially consistent; nor is it always consistent from one monitoring round to the next. The magnitude and consistency of the vertical gradient increases for the upper sand wells near the eastern margin of the site, likely because these wells are screened within the upper portion of the Potomac Group sediments.

In addition to the analytical results for groundwater, the potentiometric data also indicate that the characteristics of the alluvial sand unit do not promote the horizontal and vertical movement of groundwater beneath the site. The alluvial sand unit is very thin and discontinuous beneath most of the site, and yield tests indicate that the individual sand units do not produce substantial amounts of water. In addition, groundwater elevations and tidal study results indicate that the alluvial sand unit is hydraulically separated from the Patapsco River by the sheet pile bulkheads that are driven into the underlying lower silt.

Patapsco Aquifer

Groundwater flow in the Patapsco Aquifer beneath DMT, as represented by the November 24, 2008, and June 9, 2009, potentiometric surface maps, is directed toward the south-southwest at gradients ranging from approximately 0.0008 ft/ft to 0.0026 ft/ft (Figures 4-9 and 4-10). The flow direction and gradient determined for these two events is very consistent with results from previous synoptic events. Groundwater levels in the M-series wells are consistently lower than water elevations in the shallow fill and alluvial sand units, and the magnitude of the difference in vertical head increases toward the eastern portion of the site. The difference in water elevation suggests that the confining units serve as effective barriers to hydraulic communication between the shallow fill unit, upper sand unit, and Patapsco Aquifer.

Groundwater levels in wells EA-11M, -14M, and -15M were frequently lower than the mean tide level in the Patapsco River, which is 1.67 feet BCD. Because the Patapsco groundwater elevations were tidally adjusted to be representative of mean tide conditions, these low water levels could only be the result of offsite groundwater withdrawals. The nature and locations of these groundwater withdrawals are unknown.

D-Series Wells (Patuxent Aquifer)

Groundwater elevations were measured in the D-series wells on November 24, 2008, and June 9, 2009, but are not contoured due to the limited density of the well network. These monitoring wells are screened at approximately similar elevations, but there were variations in the borehole stratigraphy, and it is possible that the screen intervals may be separated by low-permeability clay strata encountered within the Potomac Group Sediments and may not be in hydraulically communication. On November 24, 2008, groundwater elevations in these wells ranged from -1.51 to -4.36 feet BCD, and a similar elevation range was observed on June 9, 2009 (Figure 4-11). Water levels in the D-series wells are greater than 3 feet lower than groundwater elevations in the Patapsco Aquifer, upper sand unit, and shallow fill unit. The magnitude of the potentiometric difference indicates there is hydraulic separation between these units.

4.1.4 Groundwater Analytical Results

The detected concentrations of dissolved Cr and Cr(VI) in groundwater are discussed in the following subsections. The validated analytical results for samples collected from the shallow wells, upper sand wells, M-series wells, and D-series wells are presented in Tables 4-5 through 4-8. Concentrations of total Cr, representative of unfiltered samples, are also included in Tables 4-5 through 4-8; however, dissolved Cr is considered to be the more mobile component, and the results for this constituent, including Cr(VI), are the focus of the discussion below. Dissolved Cr concentrations include all valence states of Cr that are present in a filtered groundwater sample where all solids greater than 0.45 µm in diameter have presumably been removed through filtration.

Shallow Wells

Investigation results suggest that the horizontal migration of chromium beneath the site is limited to a narrow zone within the shallow monitoring well network that immediately surrounds the COPR fill boundary. This finding is supported by soil analytical results from 95 sample locations and by groundwater analytical data from 121 groundwater-monitoring wells including a series of detailed horizontal and vertical transects across the COPR boundary. The groundwater results show that samples collected from the wells that are screened in non-COPR fill typically contain low to non-detectable levels of Cr(VI). Since there is a buffer of non-COPR fill between the COPR fill area and the shoreline of the entire terminal, this finding suggests that the migration of Cr(VI) to the river is impeded both physically by the sheet pile bulkheads (except in Areas 1501 and 1602) and chemically by the instability of Cr(VI) in the geochemical environment. Shallow well data indicates that reductive processes rapidly reduce Cr(VI) to Cr(III) within 100 to 200 feet of the COPR fill. These results are more fully discussed below.

Dissolved Total Cr detections in shallow groundwater range from 1.7 J micrograms per liter (µg/L) to 70,400 µg/L (Table 4-5a). The large concentration range is apparent because 26 of the shallow wells are screened across COPR whereas the remaining 47 wells are positioned outside the COPR boundary. The following observations regarding dissolved Cr were noted:

- Samples collected from wells screened across COPR contained much greater concentrations of dissolved Cr than samples collected from wells not screened across COPR.
- Approximately 70 percent of the sample results collected from non-COPR wells is "U" flagged, indicating that dissolved Cr was not detected above the MDL, which was typically 2.3 µg/L.
- The wells with the highest dissolved Cr concentrations tended to be immediately adjacent to the COPR boundary (e.g., DMT-39S, -45S, -47S, -48S, and -63S and TPZ-27B and -30B) which is within the range of colloidally transported Cr(III).
- If the dissolved Cr concentrations in the wells proximal to the COPR limits are excluded, the detected concentrations of dissolved Cr in wells outside the COPR boundary ranged from 1.7 J µg/L to 60.6 µg/L and did not exceed the MDE criterion for chromium (100 µg/L) in groundwater.

Cr(VI) concentrations in shallow groundwater ranged from 5 U µg/L to 70,000 µg/L (Table 4-5a). Again, the large range is due to some samples being collected from wells screened across COPR, and these samples constitute the upper range of the Cr(VI) concentrations. The following observations regarding Cr(VI) were noted:

- If the seven wells immediately adjacent to the COPR boundary, given as examples above, are excluded as outliers because of their proximity to the boundary, Cr(VI) was not detected above the MDL (typically 5 µg/L) in 97 percent of the samples that were collected from wells located outside the COPR boundary.
- The samples from outside the COPR limits where Cr(VI) was detected were collected from DMT-03S (20 J µg/L) and DMT-40S (5.2 J µg/L). Cr(VI) concentrations in these wells did not exceed the MDE criterion for chromium (100 µg/L) in groundwater.

The shallow aquifer analytical data indicate that the horizontal extent of chromium impact is limited to within approximately 200 feet of the COPR boundary. Concentrations of chromium downgradient of the COPR body are typically well below MDE groundwater standards for Cr and Cr(VI). Furthermore, Cr and Cr(VI) are typically not detected near the areas of active groundwater discharge.

Shallow Wells: Areas 1501 and 1602

As discussed in Section 4.1.3, groundwater elevations measured in wells within Areas 1501 and 1602 suggest that the COPR cell that underlies this area provides hydraulic containment for water that collects inside the cell. For example, water levels within the cell in Area 1501 range from between approximately 6.5 to 8 feet BCD (piezometers TPZ-41 and TPZ-43), whereas wells completed in the formation located beneath the cell range from approximately 1 to 2 feet BCD (Wells DMT-58S, -57S and -45S). This constitutes a substantial degree of difference in potentiometric head which would not be sustained if the cell were not hydraulically contained. Water levels in the shallow fill unit beneath the cell are generally very similar to the water level in the river and the gradient beneath the cell is very flat, suggesting that there is essentially very limited recharge to the shallow permeable unit in this area from within the cell.

Dissolved Cr and Cr(VI) were detected in samples collected from DMT-45S, -46S, -63S, and -58S (Table 4-5a). Results for DMT-45S, -46S, and -58S are questionable because the wells have been determined to be of faulty construction or the well casings have been observed to be compromised. DMT-46S was replaced with DMT-63S, which was screened below the COPR cell. Follow-on sampling events revealed low-level detections of dissolved Cr and Cr(VI) in DMT-63S. DMT 63S is located in close proximity to upgradient terminus of the engineered cell. Evaluation of groundwater piezometric levels in the shallow fill (Figures 4-6 and 4-7) indicate the well lies within the flow path of groundwater emanating from the main body of COPR present upgradient of the cell in the eastern portion of Area 1602 and Area 1702. A comparison of dissolved total chromium and hexavalent chromium concentrations in this well suggests that it is located in a zone of active reduction.

Analytical results from DMT-11S, -57S, -58S, and -59S did not detect Cr(VI) which suggests impacts to the shallow fill unit beneath Areas 1501 and 1602, if any, are localized and of very limited in extent. Concentrations of dissolved Cr detected in these wells did not exceed the MDE groundwater criterion and ranged from 2.3 U µg/L to 16.9 µg/L; Cr(VI) was not detected above the typical MDL (5 µg/L). The Sediment and Surface Water Study (CH2M HILL and Environ, 2009) concluded that Cr(VI) was not detected in discharging groundwater (measured as pore water) suggesting that reductive processes are effectively reducing Cr(VI) to Cr(III) over short distances.

Minor Cr(VI) impacts have been observed in wells located along the south shoreline of Areas 1501 and 1602 (e.g. DMT-63S, DMT-45S, and DMT-58S).

Cr(VI) concentrations detected in these wells do not exceed the EPA NRWQC, typically do not exceed MDE Cleanup Standard for Cr(VI) in groundwater, and do not appear to impact the river based on the absence of Cr(VI) in pore water that was collected on four occasions as part of the Sediment and Surface Water Study (CH2M HILL and Environ, 2009).

Upper Sand Wells

Analytical results from the upper sand wells provide evidence that the chromium has not migrated from the shallow fill unit to the alluvial sand unit. As with the soil analytical results, which showed reduction of Cr(VI) within 5 feet of the base of the COPR body, this provides additional evidence that the reductive processes in the formation and low permeability of the upper silt restrict chromium transport in groundwater. A number of upper sand wells are screened immediately below the COPR fill area, and Cr(VI) has not been detected in groundwater samples collected from these wells. Additionally, per MDE request, an extensive network of the upper sand wells was established immediately inboard of the bulkhead during the Phase 3 groundwater investigation. As with the other upper sand wells, Cr(VI) was not detected in samples collected from these Phase 3 upper sand wells.

Dissolved Total Cr was detected at five upper sand well locations: DMT-50US, -52US, -67US, and -70US, and TPZ-49 (Table 4-5a). The maximum concentration of dissolved Cr (21.6 µg/L) was detected at DMT-50US, and concentrations in the remaining four samples ranged from 3.4 µg/L to 5.1 µg/L and only slightly exceeded the MDL, which is typically 2.3 µg/L to 3.4 µg/L. None of the concentrations of dissolved Cr exceeded the MDE groundwater criterion. The sample from DMT-53US is "B" flagged, meaning that the concentration is associated with contamination in a blank sample, but this concentration is within the typical MDL range. The other "B"-flagged sample, collected from DMT-54US on October 1, 2007, was resolved during a later sampling round, and the concentration was 3.4 U µg/L (nondetect).

Cr(VI) was not detected in any of the 31 groundwater samples that were collected from 17 upper sand well locations (Table 4-5a). All of the concentrations are "U" or "UJ" flagged indicating that Cr(VI) was not detected above the MDL of 5 µg/L. These results represent a significant finding since two of the upper sand wells are screened beneath a 15- to 20-foot thickness of COPR, seven of the upper sand wells are adjacent to the sheet-pile bulkhead, and TPZ-48 and -49 are in the Area 1501–Area 1602 shoreline area.

The upper sand unit analytical data indicated that the alluvial sand is not impacted by Cr(VI) regardless of the well's position relative to COPR and confirmed that downward migration from the shallow aquifer is not occurring.

M-Series Wells

Representative soil and groundwater samples collected from the M-series wells suggest that the Patapsco Aquifer is not materially impacted by chromium constituents. Existing data indicate that the confining beds present between the shallow unit and deeper groundwater units have effectively limited chromium transport such that only the shallow fill aquifer has been impacted.

Concentrations of dissolved Total Cr in the M-series wells ranged from 0.89 B to 71.7 µg/L (Table 4-7a). Only four of the concentration values exceeded 10 µg/L, and these were associated with initial samples that were collected from DMT-02M and DMT-35M. These four detections are attributed to incomplete well development and potential cross-contamination due to the well installation methodology (mud-rotary techniques), as discussed in Section 4.1.1. The most recent round of data from DMT-02M and -35M, collected after redevelopment, indicates that dissolved Cr concentrations were below the MDL at each of the wells that were resampled. When these suspect detections are removed from the data set, the dissolved Cr concentrations in the Patapsco Aquifer range from 0.89 B to 10 U µg/L which is essentially nondetect.

The representative groundwater analytical results indicate that Cr(VI) is not present in the Patapsco Aquifer. Cr(VI) was detected at well locations DMT-02M, -35M, and -38M; EA-13M; and EAC-04M; however, these detections are not believed to be representative because the concentrations detected at DMT-02M, -35M, and -38M were present during initial sampling rounds and are attributed to incomplete well development and potential cross-contamination due to the well installation methodology (mud-rotary techniques) as discussed in Section 4.1.1.

The most recent round of data from these wells, collected after redevelopment, indicates that Cr(VI) concentrations were below the MDL (5–10 μg/L) (Table 4-7a). Likewise, the Cr(VI) concentrations detected at EAC-04M during the pH assessment appear to have been associated with fines accumulated in the borehole annulus because Cr(VI) was not detected after redevelopment. The low level of Cr(VI) detected at EA-13M during the pH assessment (6 B μg/L) is "B" flagged, which indicates that the concentration is associated with contamination in a corresponding blank sample and this result is within the typical MDL range.

The analytical data collected from the M-series wells indicates that Cr and Cr(VI) are generally not detected in this interval and that Cr and Cr(VI) impact is limited to the shallow aquifer.

D-Series Wells

Dissolved Cr and Cr(VI) was not detected in groundwater samples collected from the D-series wells (Table 4-8), confirming that the shallow chromium impact has not migrated beyond the shallow aquifer. Existing data indicate that the confining beds present between the shallow fill unit and deeper groundwater units are effectively limiting chromium transport; no impact to the D-series wells was observed.

Extent of Impact to Groundwater

The analytical results presented above indicate that the impact to groundwater beneath DMT is spatially associated with the approximate limits of COPR fill material and that there are minimal impacts to groundwater outside the COPR limits. The horizontal and vertical extents of dissolved Cr and Cr(VI) in groundwater are discussed below and the discussion is supplemented through the use of concentration maps and cross-sections that illustrate conditions beneath the site (Figures 4-12 through 4-15). The concentrations depicted on these drawings were selected from the most recent sampling event unless the recent data was flagged during validation in which case a result from an earlier sampling event was selected.

Analytical results for sediment and pore water samples have been plotted on the concentration maps so the issue of groundwater–surface water interaction can be addressed (Figures 4-12 and 4-13). The pore water sampling was conducted in support of the Sediment and Surface Water Study (CH2M HILL and Environ, 2009).

Horizontal Extent of Impact to Groundwater

Detections of dissolved Cr and Cr(VI) in groundwater have a direct spatial relationship with the COPR boundary (Figures 4-12 and 4-13). Without exception, the maximum concentrations of these constituents were detected in shallow wells within the COPR boundary (i.e., screened across COPR). In the non-COPR wells (i.e., those not screened in COPR), there appears to be a general relationship between the dissolved Cr and Cr(VI) concentration and the proximity of the well to the COPR boundary (Figures 4-12 and 4-13). Concentrations of these constituents were detected in seven shallow wells—DMT-39S, -45S, -47S, -48S, and -63S and TPZ-27B and -30B—which are very close to the COPR boundary. A depiction of subsurface conditions across the southern portion of Areas 1200 and 1300 reveals that the concentrations of dissolved Cr and Cr(VI) decrease (typically to nondetect) within short distances outside the COPR limits (Figure 4-14). The absence of Cr and Cr(VI) in shallow wells completed near the bulkhead indicates that reductive processes are effectively converting Cr(VI) to Cr (III) in this unit. Furthermore, the bulkhead limits the volume of groundwater discharging from the western portion of the site. Available shallow groundwater data indicates that shallow and upper sand wells are not impacted at the point of discharge to the river.

As a further illustration, Figure 4-16 shows path lines of particles that simulated groundwater flow in the shallow aquifer in the western part of the site. This location was chosen because the flow paths are relatively straight and the water bearing formation is composed of coarser materials. These path lines were traced using the calibrated groundwater flow model representing the hydrologic conditions of June 2009 (see Appendix B). Simulated particles were started at several monitoring wells where groundwater sampling has shown Cr(VI) is not present above the limit of quantitation. These particles were tracked upgradient toward the recharge areas where the groundwater entered the flow system from the COPR boundary. Travel times from the edge of the COPR fill to the downgradient monitoring wells vary from less than 5 years to approximately 20 years. Even though the COPR has been present for more than 30 years, Cr(VI) has not been transported to these monitoring wells. This illustrates the rapid decline in concentration that occurs in the non-COPR fill materials due to the prevailing geochemical reductive processes. If reduction were not occurring, Cr(VI) would have migrated as much as 1,800 feet from the COPR source; rather, Cr(VI) detections are typically limited to within 200 feet of the COPR fill area.

In Areas 1501 and 1602, dissolved Cr in groundwater does not exceed MDE comparison criteria and Cr(VI) is nondetect except for Wells DMT-45S and -63S which present concentrations of dissolved Cr (404 µg/L to 1190 µg/L) and Cr(VI) (21.9 J µg/L to 124 J µg/L), respectively These wells are screened in the shallow fill unit just below the COPR cell. Well 45S was determined to be damaged and results are of questionable value. Well 63S is located in close proximity to the upgradient boundary of the engineered cell with unlined COPR fill. The results from these wells, while interpreted to represent localized impacts, have been included for purposes of evaluating chromium flux. With respect to chromium transport and fate, the Sediment and Surface Water Study (CH2M HILL and Environ, 2009) concluded that Cr (VI) was not detected in discharging groundwater (measured as pore water). This supports the investigation finding that reductive processes are rapidly converting the unstable Cr(VI) to its more stable Cr(III) form.

Vertical Extent of Impact to Groundwater

Analytical results from the upper sand, M-series, and D-series wells indicate that the upper sand unit, the Patapsco Aquifer, and the Patuxent Aquifer are not impacted by vertical contaminant migration emanating from the COPR fill (Figures 4-14 through 4-15). Dissolved

Cr concentrations in the upper sand, M-series, and D-series wells are substantially lower than concentrations detected in the shallow wells that are screened across COPR, and Cr(VI) has not been detected in representative samples collected from the deep hydrogeologic units. The low levels of dissolved Cr and absence of Cr(VI) in the upper sand wells is significant because it suggests that the processes that restrict movement of these constituents (i.e., Cr(VI) reduction to Cr(III) and confining properties of the upper silt) operate very closely to the COPR limits.

4.1.5 Tidal Study Results

Tidal studies were completed in 78 monitoring wells at various times during the groundwater investigation. The primary function of these studies was to quantify tidal response so that groundwater gradients and flow directions could be accurately assessed. Additionally, the tidal studies provide information regarding the connectivity of each hydrogeologic unit with the Patapsco River. Many of the wells included in the tidal studies respond to barometric or tidal effects, and each component was quantified when present. The barometric response has no effect on groundwater flow beneath the site, but it was necessary to remove these effects from the data records to quantify the tidal response. The results of the tidal studies are summarized below. A description of the tidal study methodology and an explanation of how the tidal and barometric response parameters were derived are provided in Appendix A. A complete set of the tidal study hydrographs is provided in Appendix D.

Tidal Response in the Shallow Fill Unit

Tidal response in the shallow fill unit is negligible except along the margins of Areas 1501 and 1602 (Figure 4-17). The lack of observed response in many of the shallow wells is because the shallow fill unit is hydraulically separated from the Patapsco River by a sheet-pile bulkhead in areas west of 14th Street. The tidal response of the shallow wells in this area was generally negligible except in two wells, DMT-14S and EA-10S, which had relatively low tidal efficiencies of 4 percent and 6.3 percent, respectively (Table 4-9). Well DMT-56S, located contiguous to the northeast side of the 15th Street drain, presented a low but measurable tidal efficiency of 15.8 percent. Southeast of the 15th Street interceptor vault, along the shoreline in Areas 1501 and 1602, wells DMT-45S, -46S, -57S, -58S, and -63S showed tidal responses with efficiencies ranging from 18.1 to 69.6 percent. The tidal response in this locality suggests that there is some degree of hydraulic communication between the shallow fill unit and the Patapsco River in this area. The negligible tidal response observed in well EA-7S, which is in the corner of Area 1501, is explained the fact that this well is completed within the Area 1501 and Area 1602 COPR cell.

Tidal Response in the Alluvial Sand Unit

Tidal response parameters determined for the upper sand well locations indicate that the greatest response is observed in the upper sand wells that are immediately inboard of the sheet-pile bulkhead. The tidal efficiency in the wells along the bulkhead varies from 6 percent to 45.2 percent (DMT-50US, -64US, -65US, -67US, -70US, -71US, and -72US) (Table 4-9). DMT-50US has the unexpected behavior of showing a negative tide lag of 1.5 to 2 hours. Because of this counterintuitive response, the tidal study for DMT-50US was performed twice, with both studies yielding similar results. The tidal efficiency values were relatively low; 10.6 percent for the November 2007 study and 9.2 percent for the December

2007 study. The lack of quantifiable response in wells farther inland (DMT-49US, -51US, -52US, and -54US) indicates that the tidal effects dissipate rapidly in the unit.

The results from TPZ-48 and -49 are included with the upper sand wells because these piezometers are screened in the upper sand unit in a manner similar to the upper sand wells in the western portion of the terminal. TPZ-48 and -49 are approximately 500 feet apart along the shoreline of Areas 1501 and 1602, where there is no sheet-pile bulkhead. The piezometers are screened at approximately the same elevation but have distinctly different tidal efficiencies (Table 4-9). The results from TPZ-48 and -49 are suggestive of the variability and discontinuity within the upper sand unit.

A tidal response was quantified for DMT-73US, -74US and -75US even though these wells are farther inland, in the eastern portion of the terminal. This finding is consistent with the interpretation that these wells are screened in the upper portion of the Patapsco Aquifer. As discussed below, the tidal response propagates farther inland in the Patapsco Aquifer.

Tidal Response in the Patapsco Aquifer

Tidal efficiencies for the M-series wells range from zero for wells DMT-35M, -38M, and -60M to approximately 68 percent for EA-11M (Table 4-9). The spatial distribution of the tidal efficiency and lag time for these wells show that the M-series wells in the eastern portion of the site generally have a lower tidal efficiency and longer lag time than the M-series wells closer to the Patapsco River. The highest tidal efficiency was quantified in monitoring well EA-11M, which is in the southwestern corner of DMT. These findings are consistent with the general nature of tidal propagation in aquifers and illustrate the need to tidally correct water level measurements from the M-series wells before interpreting the groundwater flow regime in the Patapsco Aquifer.

Tidal Response in the D-Series Wells (Patuxent Aquifer)

A quantifiable tidal response was present in each of the D-series wells, and the calculated tidal efficiencies ranged from 4.8 to 52.4 percent (Table 4-9). The highest tidal efficiency was determined in DMT-83D, which is in the southwest corner of the facility, and the lowest tidal efficiency was determined for DMT-82D, which is farther inland just outside the northeast corner of Area 1800. These findings are consistent with the general nature of tidal propagation in aquifers and illustrate the need to tidally correct the water level measurements from the D-series wells.

4.1.6 Aquifer Test Results

Pumping tests were completed during the groundwater investigation to quantify the transmissivity and storativity of the shallow fill unit and Patapsco Aquifer for groundwater modeling purposes. Field conditions encountered during testing caused a number of the tests to be repeated or analyzed by various methods in the shallow fill unit, and two attempts were made to complete the proposed Neuman-Witherspoon test in the Patapsco Aquifer. A detailed description of the field methodology and test analysis methods is provided in Appendix A and a description of how these hydraulic parameters are used in the groundwater model is provided in Section 3. A complete set of aquifer test hydrographs and analyses sheets, including results from slug testing at the site, are provided in Appendix E.

Shallow Fill Unit Results

Pumping tests were competed at four shallow well locations to assess the spatial variability of the hydraulic parameters in the shallow fill unit (Table 4-10). The location of the tests provides estimates of the hydraulic parameters for the various fill materials that underlie the site. Transmissivity estimates for the COPR fill material range from 296 to 546.6 ft^2/day at location DMT-24S and 4.8 ft^2/day at location DMT-25S and storativity values in COPR range from 4.5×10^{-4} to 8.5×10^{-3}. The likely source of variability of these estimates is the well screen for DMT-24S, which penetrates into sandy material that underlies the COPR in the vicinity of the test location. The transmissivity of the non-COPR fill materials in the southwest portion of the DMT fill area was determined to be 1052.5 ft^2/day (DMT-23S) and the transmissivity of the non-COPR fill materials in the area of DMT to the north of the fill area was determined to be 64.7 ft^2/day (DMT-21S). Storativity values in the northern non-COPR fill area range from 8.57×10^{-3} to 2.4×10^{-2} and the storativity of the non-COPR fill within the DMT fill area was determined to be 2.7×10^{-2}. The transmissivity estimates obtained from the non-COPR fill areas are consistent with the soil types that are typically encountered in these areas.

Patapsco Aquifer Results

The hydraulic properties of the Patapsco Aquifer were assessed at test well location DMT-01M, which is in the central portion of the DMT fill area. The results from each observation well location are fairly consistent, and estimates of transmissivity in the aquifer range from 1540.8 to 3788.2 ft^2/day and estimates of storativity range from 4.97×10^{-5} to 1.23×10^{-3} (Table 4-10).

4.1.7 Hydraulic Properties of the Confining Units

The confining properties of the fine-grained units that are encountered beneath DMT were verified through laboratory permeability and hydraulic testing. Laboratory tests have been performed on samples collected from the upper silt, lower silt, and clay strata within the Potomac Group sediments. Hydraulic tests were only performed in piezometers that are screened in the lower silt. Results from each unit are described below.

Upper Silt

The upper silt underlies the shallow fill unit across much of the site and from east to west the unit grades from a gray to brown soft to stiff silt and clay to a dark green to black organic silt and/or clay beneath much of the DMT COPR fill area (CH2M HILL, 2009a). The permeability of the unit was determined at five locations in a transect that generally bisects the site from southwest to northeast. The permeability of these samples ranges from 3.69×10^{-5} to 1.9×10^{-3} ft/day (1.3×10^{-8} to 6.7×10^{-7} cm/s) and the average permeability is 4.6×10^{-4} ft/day (1.6×10^{-7} cm/s) (Table 4-11). The low permeability is consistent with the fine-grained nature of the unit. This characteristic provides an explanation for the apparent difference in water levels observed in well pairs that contain one shallow well (screened above the upper silt) and one upper sand well (screened below the upper silt). The low permeability of the upper silt provides a physical barrier to the vertical migration of shallow groundwater to deeper hydrogeologic units.

Lower Silt

The lower silt is described as a relatively homogeneous unit of olive-green to dark-gray silt (ML) or clay (CL) with trace amounts of micaceous fine sand, shell fragments, and organic material. The unit is thickest (40 to 50 feet) beneath the western and central third of DMT, and it thins near the eastern boundary of the site. Seventeen samples were analyzed from eight locations, which are distributed such that they provide a good spatial representation of conditions within the unit. The laboratory determined permeability in the lower silt ranges from 8.65×10^{-6} ft/day to 6.24×10^{-4} ft/day (3.05×10^{-9} to 2.2×10^{-7} cm/s) and the average permeability is 2.77×10^{-4} ft/day (9.77×10^{-8} cm/s) (Table 4-11). Again, the low permeability characteristic of the unit appears to provide an explanation for the apparent difference in water levels observed in well pairs that contain one shallow well or one upper sand well (screened above the lower silt) and one M-series well (screened below the lower silt). The low permeability of the lower silt provides a physical barrier to the vertical migration of shallow groundwater to deeper hydrogeologic units.

Temporary piezometers TPZ-1, -2, and -3 are screened within the lower silt and these piezometers were monitored during the aquifer tests that were performed to quantify the hydraulic properties of the Patapsco Aquifer. The intent was to use the time-drawdown records from the piezometers to analyze the vertical flow properties in the lower silt by the Neuman-Witherspoon ratio method. As explained in Appendix A, the Neuman-Witherspoon method was not applied because the piezometers did not respond to pumping in the test well, but the test data did yield some valuable information regarding the hydraulic properties of the lower silt. For the first aquifer test, application of the Bouwer and Rice (1976) slug test analysis method for TPZ-2 and -3 produced hydraulic conductivity estimates of 7.22×10^{-4} ft/day (2.5×10^{-7} cm/s) and 2.25×10^{-3} ft/day (7.94×10^{-7} cm/s), respectively. For the second aquifer test an alternative analysis method performed on data from TPZ-3 estimated an upper bound of 6×10^{-4} ft/day (2.1×10^{-7} cm/s) for hydraulic conductivity in the lower silt. The estimates from the first aquifer test apply to the horizontal component of flow while the estimate from the second aquifer test applies to the vertical component of groundwater flow.

Potomac Group Clay

Three deep (D-series) well borings were drilled to depths of up to 267 feet below grade within the Potomac Group sediments, and the wells were screened in what regional geologic data suggests is the Patuxent Aquifer (CH2M HILL, 2009c). During the well installation, several thick sequences of clay strata were encountered within the depth interval that now separates the M-series and D-series well screens. The Potomac Group sediments beneath the DMT contain layers of mottled white, red, gray, and reddish brown lean clay (CL) that are stratified throughout the unit and these clay units are characteristically similar to the Arundel Formation as described in the vicinity of Baltimore, Maryland. During the Phase 3 investigation, ten samples of the unit were collected from seven boring locations. Five of the boring locations are in the eastern portion of the site, where subsurface conditions are dominated by the Potomac Group, and two locations (DMT-78M and -83D) are in the western portion of the site. The permeability results for the clay strata range from 3.49×10^{-5} ft/day to 1.03×10^{-3} ft/day (1.23×10^{-8} to 3.63×10^{-7} cm/s) (Table 4-11). Again, the low permeability characteristic of the unit provides an explanation for the apparent difference in water levels observed in well pairs that contain one M-series well (screened above the clay strata) and one D-series well (screened below the clay strata). The low permeability of the Potomac Group clay strata provides a physical barrier to the vertical migration of groundwater to the deeper Patuxent Aquifer. The function of the clay strata as an aquitard beneath the DMT is supported by the low average permeability (9.20 × 10^{-8} cm/sec) of the clay strata and by a substantial difference in water elevations measured in colocated D- and M-series well pairs.

4.1.8 Groundwater Upwelling Surveys

Groundwater upwelling surveys were performed in the Patapsco River adjacent to DMT in December 2006 and October and November 2007. The surveys collected in situ measurements of temperature and conductivity in subsurface sediment and in overlying surface water using a Trident probe equipped with direct push temperature and conductivity sensors. Spatial patterns of surface and subsurface temperature and conductivity are used to identify areas where groundwater may be discharging to a surface water body (Chadwick et al., 2003). A detailed survey methodology and results are presented in the "Sediment and Surface Water Study Report, Dundalk Marine Terminal, Baltimore, Maryland (CH2M HILL and Environ, 2009).

The results of both upwelling surveys indicated that the strongest evidence of groundwater discharge was in the southeastern part of the study area near Areas 1501 and 1602 (Figure 4-18). This area of upwelling was identified primarily on the basis of lower subsurface specific conductivity conditions (averaging 5.15 to 6.77 mS/cm) relative to the overlying surface water (averaging 15.6 to 23.32 mS/cm). By contrast, SC measurements within COPR fill average 15 mS/cm. Subsurface conductivity measurements were similar in both surveys, whereas subsurface temperatures were 4°–5°C warmer and less variable in November 2007 compared to December 2006. The results of the upwelling study provide further evidence that Areas 1501 and 1602 are the primary discharge points for shallow groundwater to the Patapsco River, and the discharging water does not exhibit characteristics of COPR leachate as determined from comparison of specific conductance values.

4.1.9 Modeling Results

As discussed in Section 3.4, the groundwater model was developed and calibrated to simulate groundwater flow in the shallow fill, the alluvial sands, the Patapsco Aquifer, and the upper and lower semiconfining units that separate these flow zones. It also simulates flow between these aquifers and the following hydrologic boundaries:

- Groundwater discharge to the submerged portions of the storm drains
- Groundwater flow to the Patapsco River through the bulkheads
- Groundwater flow to the Patapsco River through the riverbank east of 14th Street

Model Reliability

Calibration of the model has been evaluated by comparing the simulated groundwater levels at monitoring wells to the levels measured on June 2, 2009, which is the date of the most comprehensive piezometric monitoring event that has been performed at DMT. Statistical evaluation of the calibration residuals (differences between simulated and measured heads) indicates that the model was generally accurate to within approximately 0.2 foot in the shallow fill aquifer, 0.3 foot in the alluvial sands, and 0.2 foot in the Patapsco

Aquifer. In each aquifer the residuals were essentially unbiased. That is, model deviations from the measured values were approximately centered on the measured levels and were no more likely to be positive than negative. In general, the magnitudes of the residuals were comparable to the probable measurement error of piezometric monitoring.

The model’s reliability was further verified by its accuracy in simulating the drawdown produced at observation well DMT-02S during the aquifer test that was performed at well DMT-23S in November 2006. The maximum difference between simulated and measured drawdown values over the 53 hours of pumping was approximately 8 percent of the actual drawdown. This is comparable to the measurement accuracy of the field data.

Sensitivity analysis was performed for the purpose of studying the potential effects of input uncertainty on the conclusions to be drawn from the modeling results. Even though a substantial amount of hydrogeologic investigation and testing has been completed, there are still remaining levels of uncertainty about exact parameter values and their spatial distributions.

The sensitivity analysis showed generally that changes to specific input values produced changes in the model residuals, such that deviation from the calibration inputs degraded the quality of model calibration. This is a favorable condition, because it indicates that significant errors in assignment of any specific input value would be detected through increased model residuals and would not unknowingly carried through to the modeling results.

For a more detailed examination of the model calibration and sensitivity analysis, see Appendix B.

Simulated Water Balance

A primary objective of model development was to synthesize the site hydrogeologic information into a numerical framework that can be used to quantify the rates of groundwater flow within and between the aquifers and between the aquifers and such external hydrologic features as the storm drains and the Patapsco River. These flow rates, or fluxes, express the volume of water that passes through a specific cross section of the subsurface per unit time. Cross sections of specific interest in the CTS are the segments of the river bank through which groundwater can discharge to the river.

One of the outputs produced by the model is the simulated volumetric flux between each pair of adjacent model cells and the flux to and from each boundary condition. By using appropriate postprocessing software, this information can be examined to quantify the simulated flux through any desired cross section of the model domain. The postprocessing program ZONEBUDGET (Harbaugh, 1990) was used for this purpose. In Section 6, cross sections between the monitoring wells along the bank of the river are examined to produce estimates of chromium mass transport. Here, the procedure is used on a layer-by-layer basis to examine the components of the site hydrologic budget.

Simulated Groundwater Fluxes to and from Model Layer 1. The water-balance components of the calibrated model for layer 1 were as follows:

Layer 1 Inflows (gpm):

Direct recharge	102.48
Upward flow from layer 2	14.80
Net inflow from constant head boundaries	31.25
Total inflows	148.53

Layer 1 Outflows (gpm):

Seepage to drains	58.61
Flow through bulkheads	10.95
Flow to river east of the bulkheads	10.86
Downward flow to layer 2	68.11
Total outflows	148.53

The value listed above for total outflow through the river bank east of the bulkheads (10.86 gpm) in layer 1 includes a segment of the Patapsco River bank that is south of the DMT. The portion of flow to the river that occurs on the DMT, but east of the bulkheads in layer 1 is 7.63 gpm.

Simulated Flow to and from Model Layer 2. The water-balance components of the calibrated model for layer 2 were as follows:

Layer 2 Inflows (gpm):

Downward flow from layer 1	68.11
Flow from upgradient constant head boundaries	3.39
Total inflows	71.50

Layer 2 Outflows (gpm):

Flow through bulkheads	10.78
Flow to river east of bulkheads	3.28
Upward flow to layer 1	14.80
Downward to layer 3	0.63
Outflow to constant-head boundaries	42.01
Total outflows	71.50

The value listed above for total outflow through the river bank (3.28 gpm) in layer 2 also includes a segment that is south of the DMT. The portion of flow to the river that occurs on DMT but east of the bulkheads in layer 2 is 2.82 gpm.

Simulated Flow to and from Model Layer 3. The water-balance components of the calibrated model for layer 3 were as follows:

Layer 3 Inflows (gpm):

Downward flow from layer 2	0.63
Inflow from upgradient boundaries	154.35
Total inflow	154.98

Layer 3 Outflows (gpm):

Outflow to downgradient boundaries 154.98

The model-derived flow results presented herein will be combined with the concentration data presented earlier in this section to calculate the mass flux in Section 6 of this report.

4.2 Stormwater Characterization Results

The site contamination assessment (SCA) (EA, 1987) concluded that the most significant mass flux occurred from what was referred to as "tidal exchange" (chromium-impacted groundwater discharging into the storm drain system, mixing with the tide, and then discharging through the outfall). Tidal exchange was estimated to result in approximately 3.65 lbs/day of chromium. The SCA estimated that approximately 97 percent of the storm drain chromium mass flux was discharged from the 13th through 15th Streets' storm drains. The remaining drains (9th to 12.5th Streets) typically exhibited less than 0.5 mg/L of total chromium and composed less than 3 percent of the storm drain mass flux, and thus were not given additional consideration during the SCA. The 14th and 15th Streets' storm drains were equipped with tidal isolation structures in the 1990s that divert the collected dry-weather flow to an onsite groundwater treatment plant so the majority of the mass flux to the river has been eliminated under dry-weather conditions.

Physical conditions at the site preclude quantification of flow from drains without tidal exclusion devices. However, the stormwater assessment performed for the CTS has determined that the 12th through 13.5th Streets' drains have the potential to contribute mass flux to the river, whereas the remaining nonpriority drains do not (Table 4-4). The findings of the CTS are very similar to those presented in the SCA; the CTS identified six storm drains (12th, 12.5th, 13th, 13.5th, 14th, and 15th) as priority drains whereas the SCA considered four storm drains (13th, 13.5th, 14th, and 15th) to be a priority. The 9th to 11.5th Streets' drains were not considered in the SCA, and similarly are considered nonpriority drains in the CTS.

Semiquantitative observations suggest that the 13th Street drain presents the greatest potential for discharge of the remaining priority drains not fitted with tidal exclusion vaults. Accordingly, Honeywell and MPA selected the 13th Street storm drain to pilot a collection box IRM. The pilot IRM allowed the tide to be isolated and provided for a point of controlled, confined space entry so that flow conditions could be reliably and safely quantified. The pilot testing has progressed and the following steps have been achieved since installation of the tidal exclusion device:

- A precleaning sample collected from the 13th Street storm drain in April 2009 yielded a Cr(VI) concentration of 15 mg/L at a flow of 14 gpm.
- A postcleaning sample was collected in June 2009, and the dry-weather Cr(VI) concentration was 27 mg/L at a flow of 5 gpm.
- Storm drain cleaning and a closed circuit television (CCTV) assessment were conducted in the 13th Street storm drain in April through May 2009 to determine potential rehabilitation options.

These measurements confirm that stormwater discharges can be reliably quantified and that installation of the tidal exclusion device provides the added benefit of enabling a conditions assessment and evaluation of rehabilitation options. The 13th Street storm drain is scheduled for relining in the fourth quarter of 2009, which will eliminate groundwater infiltration into the storm drain.

Relining of the 15th Street storm drain is under way and will further reduce or eliminate residual mass flux to the river. An assessment of any further flux contribution from the 15th Street drain will be made following completion of the IRM.

Honeywell and MPA anticipate deployment of similar IRMs at the remaining priority storm drains to provide for reliable quantification of storm drain discharge.

4.2.1 Dry-Weather Stormwater Drain Sampling Results

As mentioned in Section 3.2, a revised SAP was proposed in the "Addendum to the Work Plan for Quantifying Chromium Transport from Stormwater Outfalls to the Patapsco River, Dundalk Marine Terminal, Baltimore, Maryland" (CH2M HILL and MES, 2008). The results of the dry-weather assessment are summarized in Figures 4-19a and 4-19b. The dry-weather analytical results used to generate the figures are provided in Table 4-4. The table includes notes on whether the sampling was likely impacted by sediment (drains not cleaned prior to sampling) or tidal influence (plugs or plates were not fully sealed).Measurements collected by MES and presented on Table 4-4 suggested the following which were incorporated into the groundwater model:

- **9th Street drain.** Measurements were made on December 21, 2007, and flows ranged from no flow to 100 gpm, suggesting tidal isolation was not effective. Concentrations of chromium and Cr(VI) were typically less than 1 mg/L, so the drain is considered to be a de minimis contributor. This drain is not constructed within COPR.
- **9.5th Street drain.** Entry was attempted on April 30, 2007, but entry could not be made through the small infrastructure, so no data are available. This drain is of limited extent and is not constructed within COPR.
- **10th Street drain.** Measurements made on November 30, 2007, along this drain, after exclusion of tidal influences, indicated a flow of 7 gpm at an upstream manhole (M-2) and no flow at downstream manholes (M-1 and S-1). Because the storm drain inverts upgradient of manhole M-2 are at or above the groundwater table, the indication of 7 gpm in the drain line was not attributed to groundwater inflows. Chromium and Cr(VI) concentration data were consistently less than 1 mg/L, so the drain is considered to be a de minimis contributor. This drain is not constructed within COPR.
- **10.5th Street drain.** Measurements were made on May 12, 2007; however, no flow was detected. Sampling of the ponded water yielded very low chromium, and Cr(VI) was not detected, so the drain is considered to be a de minimis contributor. This drain is not constructed within COPR.
- **11th Street drain.** The first entry into this drain was performed on April 30, 2007, and no flow was detected. Sampling of the ponded water yielded chromium and Cr(VI) concentrations less than 1 mg/L. During the second entry, dry-weather flows of 5 gpm were measured at manholes M-115 and M-116 on October 12, 2007. These measurements

are accepted as plausible estimates. Chromium and Cr(VI) concentration data were consistently less than 1 mg/L, so the drain is considered to be a de minimis contributor. This drain is not constructed within COPR.

- **11.5th Street drain.** Entry was made on May 9, 2007, and no flow was detected. The ponded water was sampled; chromium concentrations were very low, and Cr(VI) was not detected, so the drain is considered to be a de minimis contributor. This drain is not constructed within COPR.
- **12th Street drain.** Three entries into this drain were performed. The first, on April 26, 2007, encountered no flow, so the ponded water was sampled. Concentrations of 7.66 to 11.1 mg/L of chromium and 7.4 to 10 mg/L of Cr(VI) were found, suggesting this is a priority drain. The second entry occurred on October 4, 2007; a flow of 6.7 gpm was recorded with a chromium concentration of 10.5 mg/L and a Cr(VI) concentration of 9.2 mg/L. Tidal exclusion was implemented for this drain on October 8, 2007, but no flows were recorded; however, the ponded water was sampled and chromium concentrations ranged from 3.82 to 37.1 mg/L and Cr(VI) ranged from 3.0 to 44 mg/L, again confirming this is a priority drain. This suggests minor groundwater leakage into this storm drain and this drain is partially constructed within COPR.
- **12.5th Street drain.** The first entry into the drain was performed on March 28, 2007, and a flow of 11.3 gpm was observed with chromium concentrations ranging from 7.66 to 12.8 mg/L and Cr(VI) concentrations ranging from 4.8 to 8.7 mg/L, suggesting this is a priority drain. The second entry occurred on April 30, 2007; however, no flow was observed. The ponded water was sampled and chromium was present at 45.5 mg/L, and Cr(VI) was present at 45 mg/L, confirming this as a priority drain. This drain is partially constructed within COPR.
- **13th Street drain.** Measurements made on six occasions ranged from 0 to 3.2 gpm with chromium concentrations ranging from 5.32 to 36.6 mg/L and Cr(VI) concentrations ranging from 5.4 to 32 mg/L, confirming this is a priority drain. In addition to the MES measurements, observations made during and after installation of an interim remedial measure near the downgradient end of the 13th Street Drain provided a more reliable estimate of 5.1 gpm. This drain is constructed within COPR.
- **13.5th Street drain.** Measurements were made on two occasions, the first on April 11, 2007, and the second on May 16, 2007; both yielded no flow and concentrations less than 1 gpm. This drain is considered a priority drain due to its completion largely within the COPR body.

Groundwater inflow estimates for the 14th Street storm drain have been made using the pumping records from the groundwater treatment plant. Dry-weather flow in the 14th Street storm drain is captured in a sump at the drain outlet structure and is pumped to the treatment plant on an almost daily basis. Recorded inflows measured between February 1, 2007, and March 31, 2009, were examined with the objective of estimating the average groundwater inflow rate to the drain. The average total daily flow pumped from the 14th Street Drain over this period was 28.27 gpm. However, adjusting for wet-weather events, an estimate of approximately 21 gpm for the dry-weather inflows was obtained. Because this estimate is an average of the total flow with identifiable storm events excluded, it is likely that the groundwater inflow component is less than 21 gpm. Therefore, the target flow for model calibration is estimated to be from 15 to 20 gpm.

Similar analysis of treatment plant inflow records suggested a dry-weather flow rate of 37 gpm for the 15th Street storm drain. However, this drain extends off-site into the community of Dundalk and not all of its dry-weather flow can be attributed to groundwater inflow from the DMT. It has been estimated that DMT groundwater leakage accounts for approximately half of the 15th Street drain dry-weather flow. A weir has been installed near the site boundary to measure these off-site inflows; an estimate of 19 gpm was used as the groundwater model calibration target for the 15th Street drain.

Figures 4-19a and 4-19b indicate that for the sampling events conducted in 2007, only the 12th, 12.5th, and 13th Streets' storm drains present a measurable flow that carries a moderate concentration of Cr(VI). In all other drains, either the flow was negligible or the concentration of Cr(VI) was at or near the method detection limit. Stormwater analytical data are provided in Appendix F.

Tidal inundation was also assessed during the storm drain assessment effort. It was determined that the whole-numbered streets were heavily influenced by the tide and the half-numbered streets were impacted but to a lesser degree. In both cases, tidal influence typically extended for several hundred feet into the storm drain. Figures 4-20 through 4-22 present the degree of inundation in a cross-sectional view. Table 4-12 presents the tidal inundation that was observed during NPDES sampling performed by MES. As indicated on the above figures, tidal inundation greatly impacts the storm drain system making collection of representative samples nearly impossible without infrastructure improvements such as those installed at 13th Street and proposed at the remaining priority drains. It should be noted that tidal exchange (tidal flow into the shallow aquifer) is very infrequent, occurring only under certain lunar conditions or extreme weather. Accordingly, tidal exchange appears to be an insignificant mass flux from the storm drain system.

4.2.2 Wet-Weather Stormwater Drain Sampling Results

The addendum (CH2M HILL and MES, 2008) included a revised SAP for wet-weather flow sampling, but as stated above, its implementation presented equally challenging difficulties, and no wet-weather flow measurements or water quality sampling were completed.

Nonetheless, given that runoff entering the pipes during a storm event can be assumed to be low or free of chromium, the lack of storm flow data does not have a significant impact on the load estimation. This assertion is supported by the Sediment and Surface Water Study (CH2M HILL and Environ, 2009), which included transects that originated at the storm drain outfalls. The four quarters of surface water sampling resulted in no detections of Cr(VI) above the NRWQC. Furthermore, Cr(VI) was only detected above the MDL in a total of 9 of the 320 surface water samples; a portion of the two events were performed during wet-weather events and NRWQCs were not exceeded indicating that the storm drain mass flux to the river is not causing a material impact to the river.

The deployment of the tidal intercept vaults will allow for improved ability to collect wet-weather samples.

4.2.3 Evaluation of Storm Drain Backfill

Granular backfill is typically placed for structural purposes to support the weight of a pipe and to ensure for construction of a uniform grade. EA (1987) postulated that permeable backfill along the 14th Street drain might be a potential conduit for chromium transport to the river. MDE (letter correspondence, 2009) has requested that the potential for chromium transport laterally along the granular backfill be evaluated and that the potential for vertical transport through the backfill into underlying permeable deposits also be assessed. The latter request is based upon review of a boring log collected during the design of the final extension of the 15th Street lateral.

The storm drain system can be divided into two categories: those storm drains that terminate at the bulkhead (9th through 13.5th Streets) and those that terminate at a tidal isolation and stormwater collection chamber (14th and 15th Streets). Numerous lines of evidence support the conclusion that in neither circumstance does the permeable backfill contribute chromium transport to the river or to underlying aquifer systems.

Two hydraulic parameters that govern groundwater flow in an aquifer are transmissivity and storativity. Transmissivity is a measure of how much water can be transmitted horizontally within an aquifer and is directly proportional to the hydraulic conductivity and thickness of the aquifer. Storativity is the volume of water released from storage per unit decline in hydraulic head per unit area of the aquifer. Because the bedding material (which is up to 34 inches thick, according to construction drawings, and 2 to 12 inches thick as observed beneath the 13th and 14th Streets' drains) is thinner than the shallow aquifer (typically 30 to 40 feet thick), the transmissivity of the bedding material is less than that of the shallow aquifer. Similarly, since the area of the bedding material is much smaller than the total area of the shallow aquifer, the storativity of the bedding material is also much smaller than that of the aquifer. Finally, it is noted that calibration of the groundwater model did not require the assignment of distinct hydraulic properties around the storm drains to account for flow along the bedding material. These observations suggest that groundwater flow within the bedding material is insignificant relative to the shallow aquifer as a whole and that the bedding material does not provide a preferential pathway for groundwater flow to the river.

Storm Drain Terminations at Bulkhead (9th through 13.5th Streets' Drains)

Review of the as-built drawing for the 13th Street storm drain indicates that pipe bedding was terminated against the storm drain on a 15-foot-long concrete receiving slab. The bulkhead penetrations have been equipped with neoprene seals to eliminate seepage at the storm drain penetrations. The bulkhead surrounding most of the terminal is in turn typically seated in low-permeability silt and lean clay and greatly reduces groundwater discharge to the Patapsco River. The calibrated groundwater model has estimated total groundwater seepage from the shallow and upper sand units at approximately 11 gpm each for the entire 4,300-foot-long bulkhead. The groundwater potentiometric head behind the bulkhead is typically 2 feet higher than the level of the river, indicating that the bulkhead serves to impede groundwater flow to the river. If the permeable backfill were to act as a zone of groundwater transmission, hydraulic head potentials between the bulkhead and the river would equilibrate.

Storm Drain Terminations at Tidal Interception Vaults (14th and 15th Streets' Drains)

Since the EA (1987) report was published, significant modifications to the shoreline have been made between 14th Street and 15th Street, including construction of tide interceptor vaults at both. Assuming that EA's original conclusions were correct, it is apparent that these conditions have been altered by subsequent construction based on the configuration of the shallow potentiometric surface. The tide interceptor vaults are also significantly larger than the backfill and serve to intercept potential flow along that backfill. As discussed in Section 4.1.3 and in Section B3.5 of Appendix B, a zone of relatively low hydraulic conductivity (0.1 ft/day) must be assigned along the bank of the Patapsco River between 13.5th Street and the outfall of the 15th Street drain. Groundwater levels in close proximity to the shoreline in this area are approximately 2 feet higher than the mean river level, as has consistently been observed in groundwater monitoring wells EA-17S and DMT-12S. Groundwater levels would be in equilibrium with the river level in the presence of hydraulic communication, as is observed to the east beneath the engineered cell of Areas 1501 and 1602. Monitoring wells DMT-12S and EA-17S exhibit no tidal influence, suggesting that there is no open "communication" with the river along this segment of the shoreline, nor any associated with the backfill along the 14th Street drain. If gravel bedding along the drain was a significant zone of groundwater transmissivity and in open communication with the river, it would be anticipated that (1) groundwater levels and river levels would be at an equivalent level and (2) shallow wells adjacent to the river would exhibit tidal communication. Consequently, even if the lower reaches of the 14th Street storm drain south of G Street were constructed in permeable backfill, it does not appear to assert measurable influence on groundwater levels; nor does the backfill appear to demonstrate hydraulic communication with the river. DMT-56S, which is screened in permeable backfill associated with the 15th Street drain does exhibit a limited degree of tidal influence, and monitoring results from this well indicate that the backfill is not impacted by COPR-related constituents.

Groundwater–Storm Drain Potentiometric Data

The potential influence of permeable backfill has been evaluated through examination of potentiometric data and computer modeling. Leakage into the 13th, 14th, and 15th Streets' storm drains has been documented in the range of 5 to 20 gpm. This leakage causes deflections and gradient changes around the drains. The scale of the deflection observed in the shallow aquifer potentiometric surface is consistent with significant point inflow to the storm drains, not seepage along the storm drain bedding material.

Detailed computer calibration was required to model potentiometric heads around the drains. Leakage into the 14th Street drain exerts a localized influence on piezometric levels, but the effect is more likely due to point sources of infiltration rather than the effect of permeable backfill around the drain. Calibration adjustment of the drain coefficients was done by drain segment, and in some locations on a cell-by-cell basis to simultaneously match simulated aquifer levels and drain leakage rates to the calibration targets. Variations between the physical characteristics of the bedding materials and the surrounding soils do not warrant the use of a different hydraulic conductivity for the bedding material in the model.

As second line of evidence is presented with respect to the behavior of the potentiometric surface in the vicinity of 13th Street during a period of active storm drain repair. (See section

4.1.5.) Potentiometric response is quite evident during both monitoring events, but the cone of depression has not been elongated along the storm drain, as would be expected if backfill were exerting a hydraulic effect.

14th Street Extraction System and Geochemistry

An attempt to capture groundwater along the alignment of the 14th Street drain was undertaken in 1993. A visual site inspection (VSI), which included an evaluation of the extraction system, was performed by CH2M HILL (2007e). A series of extraction wells, EW-1 through EW-6, were drilled within the backfill of the drain in 1993. Intermittent intervals of gravel backfill were encountered; however, the hydraulic performance of the system was not consistent with the design performance criteria. It appears that the gravel bedding was either not as continuous or as permeable as anticipated, or calcification was reducing the transmissivity of the material. The VSI evaluation suggests that the wells and pumping system are subject to calcification. General aquifer testing and operation of the 14th Street extraction system both encountered calcification of pumps and valves providing additional evidence of calcium carbonate presence.

Calcification has been widely observed at the site within the storm drain system, gravel backfill material, and shallow aquifer system. Flow through the storm drain gravel bedding material is likely reduced due to the high alkalinity of groundwater. Geochemical modeling suggests that this groundwater contains about 5,000 mg/L carbonate and 125 mg/L hydroxide ions. Trilinear plots suggest that geochemical conditions are conducive to cementation within the storm drain–bedding material, thus reducing porosity and the potential for conveyance to the river.

4.3 Perimeter Air Characterization Results

The Cr(VI) concentrations measured as part of the perimeter air-monitoring program from September 2007 through August 2008 were compared to the orientation of the prevailing wind to determine whether there was an association between Cr(VI) concentrations observed upwind of the site that may be attributed to local background levels. An evaluation was also made between the observed Cr(VI) concentrations and particulate matter (PM) concentrations to determine whether the observed Cr(VI) concentrations were associated with potential fugitive dust from either site or offsite sources.

4.3.1 Particulate Concentrations at Perimeter Monitoring Locations

The total particulate concentrations are presented in Table 4-13. These values are not directly comparable to the National Ambient Air Quality Standard for 24-hour PM_{10} concentration of 0.15 mg/m^3 in that the monitored values include size fractions greater than 10 µm and NIOSH rather than EPA sampling methodologies were followed. However, the highest measured 24-hour concentration, of 0.09 mg/m^3, was less than the ambient standard.

The difference in concentrations among stations is less than the standard deviation, suggesting that there is no statistically significant variation in the monitored particulate concentrations based on station location.

4.3.2 Cr(VI) Concentrations at Perimeter Monitoring Locations

The Cr(VI) concentrations are presented in Table 4-14. There is no National Ambient Air Quality Standard established for Cr(VI). As with the particulate data, the differences among the average values for each monitoring location is less than the standard deviation, suggesting there is no statistically significant variation in the monitored concentrations based on station location.

4.4 Statistical Evaluation of Upwind, Downwind and Crosswind Data

Prevailing wind direction for each sample location was classified as upwind, downwind, or crosswind for each data collection event depending on the orientation of the sampler to the site boundary and center of DMT. Figure 4-23 provides a specific classification of upwind, downwind, or crosswind based on the direction of prevailing wind, measured in degrees clockwise from the north. For example, if the prevailing wind direction for sampler 3 were measured as 90° (a wind blowing from east to west), then the collected sample would be classified as upwind (column 1 for sampler 3). For a given prevailing wind direction, an upwind sampler would be minimally influenced by potential onsite sources of Cr(VI). A downwind sampler would be strongly influenced by potential onsite sources. A crosswind sampler could have been partially influenced by potential onsite sources, depending on the extent of fluctuations in the wind directions.

The Cr(VI) and PM concentrations at crosswind samplers were not included in the analysis because of the uncertainty about whether the observed concentrations were associated with potential onsite activities. The total number of upwind and downwind air-sampling events based on all the available observations was 35 (hereafter referred to as "all data").

Determining a prevailing wind direction over a 24-hour period in which sampling occurred involved some subjective interpretation of the meteorological data. For some periods, the wind direction fluctuations remained within a 90° sector, making the selection of a prevailing wind direction fairly straightforward. For other observations, the wind direction varied across several compass sectors. To minimize the subjective nature of wind direction interpretation, specific days for which clear upwind and downwind determinations could be made were selected. There were 18 such events (hereafter referred to as "selected data").

4.4.1 Upwind Versus Downwind Cr(VI) Concentrations

An upwind value presented the concentration of the incoming air entering the site. Therefore, an upwind value represented the local background (fence line) concentration. A downwind value presented the concentration of the onsite air.

The mean and median Cr(VI) concentrations in onsite air are slightly higher than those for the background concentrations. The difference in mean values is 0.1 ng/m^3, which is less than one-sixth of the standard deviation. The difference in median values is 0.17, which is less than one-third of the standard deviation, as shown in Table 4-15.

Using the nonparametric Gehan's test (a modified version of the Wilcoxon Rank Sum test used when nondetects are plentiful) with a significance level of 0.05, the calculated probability for a one-tailed statistical test considering whether the downwind and upwind populations are the same is 0.076. Since this probability is above the significance level, the conclusion is that there is not an overall shift of the downwind concentrations higher than the upwind concentrations.

4.4.2 Downwind Concentrations of Cr(VI) as a Function of PM Concentrations

For COPR particulate matter in fugitive dust from the site to be the primary source of Cr(VI) emissions, a strong correlation should exist between the observed Cr(VI) concentrations and PM concentrations in the downwind samples. The scatter plot (Figure 4-24) of Cr(VI) and PM concentrations shows that no correlation exists between them, as evident by the R^2 (R = the correlation coefficient) value of 0.0094. When observed Cr(VI) concentrations were compared to wind speed; the correlation coefficients were also weak. Therefore, the slight difference found in Cr(VI) concentrations between offsite and onsite air cannot be attributed to fugitive dust.

SECTION 5

Fate and Transport Mechanisms

A generalized discussion of the environmental fate and transport of chromium is provided in Section 2.1.3 and the following subsections address the site-specific conditions that influence the fate and transport of chromium at DMT. These findings are based on geochemical evidence collected during the groundwater, COPR, and surface water and sediment investigations. The findings of each investigation component suggest that geochemical conditions at DMT are favorable to reduction of Cr(VI) to Cr(III), which significantly reduces the mobility and toxicity of chromium in the environment and thereby reduces the quantity of chromium that can be transported to the Patapsco River via the groundwater, storm water, and airborne migration pathways.

5.1 Fate and Transport of Chromium in Soil and Groundwater at DMT

The analytical results presented in Section 4 illustrate that although the COPR fill contains appreciable amounts of Cr and Cr(VI), these constituents are only detected in soil and groundwater within a very limited horizontal and vertical distance from the COPR fill limits. The distribution of the chromium constituents is explained by the presence of physical barriers to migration (e.g. confining units and historic and sheet pile bulkheads), but more importantly due to the instability of Cr(VI) in the environment and the immobility of Cr(III). In addition to the physical factors limiting transport, the fate and transport of the chromium species at DMT can be summarized in three basic statements:

1. COPR exhibits a high partition coefficient and it is very difficult to leach significant amounts of Cr(III) and Cr(VI) out of the COPR fill area.

2. Cr(VI) is only stable over a narrow range of environmental conditions that are not present at DMT outside the COPR fill boundary.

3. Environmental conditions at DMT favor the reduction of Cr(VI) to Cr(III), typically insoluble $Cr(OH)_3$, and the subsequent precipitation of Cr(III) as an amorphous hydroxide. Thus, the Cr(III) becomes strongly and specifically adsorbed in the subsurface with little potential for reoxidation to Cr(VI). Additionally, it has been documented that conversion of Cr(III) to Cr(VI) under the geochemical conditions present at DMT and the adjacent estuarine environment is very unlikely (Graham and Wadhawan, 2007a, b).

The above statements are expounded upon in the text below and are supported by site-specific data and empirical evidence from numerous studies that have been conducted to determine the environmental fate and transport of chromium species.

5.1.1 Fate and Transport of Chromium from COPR

The occurrence, reduction, and immobilization of Cr(VI) in groundwater are affected by the ability of Cr(VI) to leach from COPR. Commonly, this is expressed as an estimate of the partitioning coefficient, K_d. Although Cr(VI), principally present as a chromate anion, is typically a soluble and mobile anion, its presence in COPR is the result of roasting of chromite ore with soda ash and calcined lime followed by an aggressive repetitive extraction with hot water for product recovery. COPR, while still containing appreciable amounts of Cr(III) and Cr(VI), exhibits very high partition coefficients (i.e., it is difficult to leach out significant amounts of either total Cr or Cr(VI) from COPR) because most of the soluble fraction has already been removed (Tinjum et al., 2008).

There is a very narrow band of pH (7.6–8.1) in which aqueous Cr(VI) concentrations are maximized (0.04 mol/kg) in COPR (Tinjum et al., 2008) and the partitioning is substantially lower at the highly alkaline environment of the COPR body (about 0.005 mol/kg). The maximum equilibrium concentration of Cr(VI) from COPR aggressively treated with HNO_3 (pH $\approx$ 8) represents only $\approx$ 33 percent of the available Cr(VI) in the solid phase, suggesting that it is very difficult to remove significant quantities of Cr(VI) from the solid phase of COPR. Residual Cr(VI) likely remains in undissolved Cr(VI)-bearing minerals because of relatively slow dissolution kinetics (Geelhoed et al., 2002) and because the residual Cr(VI) is bound within stable mineral lattices (Chrysochoou et al., 2009). Residual Cr(VI) may also reside on poorly ordered or amorphous precipitates (Tinjum et al., 2008). pH-dependent Cr(VI) adsorption/desorption tendencies in COPR limits the amount of Cr(VI) leached from COPR and extends the time of Cr(VI) leaching.

5.1.2 Fate and Transport of Chromium Outside COPR

The suitability and efficiency of natural processes such as advection and dispersion and in situ reduction or precipitation to attenuate and retard chromium migration requires an examination of the environmental conditions necessary for the desired mechanisms to act. Adsorption retards only the rate of advection of Cr(VI) but allows time for reduction processes to occur. If ferrous iron, soil organic carbon, or other natural mineral reductants (e.g., hematite, biotite) are present in the subsurface, then Cr(VI) is likely to be reduced to Cr(III) with the proper environmental (e.g., Eh–pH) conditions. Figure 5-1 shows that the soil units and, more importantly, the groundwater at DMT offer a reductive environment for the reduction of Cr(VI) to Cr(III), typically $Cr(OH)_3$, which is insoluble. Upon reduction, precipitation of Cr(III) as a fairly insoluble hydroxide is possible, thus having the chromium “immobilized” in the subsurface under alkaline to slightly acidic conditions. Ferrous iron–bearing minerals in geologic formations include silicates (e.g., olivine), pryroxenes (e.g., augite, dedenbergite), amphiboles (e.g., hornblende, cummingtonite, grunerite), and micas (e.g., biotite, phlogopite, glauconite) (Palmer and Puls, 1994). The geochemical conditions within the estuarine environment of the Patapsco River are such that continued reduction of Cr(VI) to Cr(III) will continue (Graham and Wadhawan, 2007a, b).

In a pH environment between 6 and 12, Cr(III) readily precipitates as an amorphous hydroxide when Cr(III) concentrations are less than 10^{-6} M (Palmer and Wittbrodt, 1991). In addition, for COPR fill sites that have existing layers of organic-rich soil layers overlying or underlying the COPR layer (e.g., the upper silts at DMT), the organics may act as a natural barrier to the migration of Cr(VI) due to the reducing environments promoted by bacterial activity (Higgins et al., 1998). Biological reduction of Cr(VI) to Cr(III) has been demonstrated in the laboratory and in the field (Higgins et al., 1998). This reduction may be direct (the bacteria use the Cr(VI) as an electron acceptor) or indirect (the bacteria produce an environmental suitable for Cr(VI) reduction).

There is no evidence that Cr(III) would reoxidize to Cr(VI) because of the lack of oxidizing conditions at DMT and the absence of strong oxidizers such as manganese oxide (James and Bartlett, 1983; Fendorf and Zasoski, 1992; Fendorf, 1995; Martello et al., 2007). Furthermore, in the near-neutral to slightly basic environment under much of the underlying sediments at DMT, the oxidation of aqueous Cr(III) would be very slow if it occurred at all and limited by the very low solubility of $Cr(OH)_3$ (Eary and Rai, 1987).

5.2 Fate and Transport of Chromium in Stormwater and Resultant Impact to Surface Water and Sediments

Transport in storm water is one mechanism by which chromium may discharge from DMT to the Patapsco River. The transport and interaction of the chromium with actual storm water flow is a relatively short lived phenomenon since the site borders the Patapsco River and the storm water would rapidly mix with surface water in the river. Once released into the aquatic environment, chromium can be transported in dissolved phase in the water column, or can be adsorbed to sediment particles and transported in the solid phase. The Sediment and Surface Water Study included transects that originated at the storm drain outfalls. The four quarters of surface water sampling resulted in no detections of Cr(VI) above the NRWQC. Furthermore, Cr(VI) was detected above the MDL in only nine of the 320 surface water samples; two events were performed during wet-weather events, and NRWQCs were not exceeded, indicating that the storm drain mass flux to the river is not causing a material impact to the river.

It should be noted that based on the sediment results, which show a nearshore accumulation of chromium in bottom sediments, precipitation of chromium has occurred historically. It is believed that a combination of surface runoff and storm drain discharges have contributed to the nearshore chromium detections. Mass flux estimates and groundwater modeling indicates that groundwater mass flux is not sufficient to achieve the nearshore detections.

A simple scoping calculation was performed to estimate what portion of the measured concentrations of chromium in sediments in the vicinity of Areas 1501 and 1602 could be attributable to groundwater discharge during the 30 years since Areas 1501 and 1602 have existed. If groundwater were the only source of chromium in the sediments located 250 feet from shore and to a depth of 3 feet, and no attenuation were to occur in observed groundwater concentrations, the average concentration of chromium in those sediments would be approximately 2 ppm. The average concentration of chromium in the sediments that was measured in this area was nearly 1,000 ppm, clearly indicating that the vast majority of sediment impact is historic in nature and that groundwater contribution is insignificant.

The surface runoff pathway has been eliminated since completion of the storm drain system at DMT, and the 14th and 15th Streets’ storm drains have been outfitted with tidal exclusion devices, which have greatly reduced the mass flux to the river. As noted elsewhere in this document, Cr(VI) has been documented to rapidly convert to Cr(III) in the estuarine environment. As presented in detail below, once the Cr(VI) is reduced to CR(III), conversion back to Cr(VI) is very unlikely in the estuarine environment of the Patapsco River.

The presence of Cr(III) is generally favored in natural waters because the concentrations of constituents known to reduce Cr(VI) to Cr(III) generally far outweigh the concentrations of the few constituents known to oxidize Cr(III) to Cr(VI). Measurements of geochemical parameters in pore water, surface water, and sediment (e.g. Fe(II)) in the nearshore area of DMT) demonstrate conditions favorable to the presence of chromium as Cr(III) rather than Cr(VI). Sediments at DMT contained consistent measurable concentrations of these geochemical constituents despite fluctuations that naturally occur with the change of season (CH2M HILL and Environ, 2009). Furthermore, a statistically significant relationship was observed between total dissolved chromium and Cr(VI) concentrations in surface water samples where Cr(VI) was detected. These results demonstrate that Cr(VI) is rapidly reduced to Cr(III) in the water column, where it most likely precipitates to the sediment (CH2M HILL and Environ, 2009) after some period of suspension in the water column. Thus, due to the affinity of Cr(III) with solid particles, the fate of the chromium is toward sediments where it is more likely to exist as Cr(III) rather than Cr(VI) (James and Bartlett, 1983; Fendorf and Zasoski, 1992; Milacic and Stupar, 1995; Weaver and Hochella, 2003).

Based on the results of the sediment and surface water study at DMT and other related studies with respect to chromium geochemistry, total chromium in sediment is unlikely to oxidize to Cr(VI) in the future because the geochemical conditions necessary for oxidation do not naturally occur in the estuarine environment. Cr(III) oxidation is not likely to occur in the environment because aged waste materials containing Cr(III) are typically less soluble and more inert to oxidation, especially because $Cr(OH)_3$ precipitates may form on manganese (hydr)oxide surfaces (James and Bartlett, 1983; Fendorf and Zasoski, 1992; Fendorf, 1995; Martello et al., 2007). This finding was confirmed in research conducted in 2007 by Johns Hopkins University Center for Contaminant Transport, Fate, and Remediation. During the study, sediments from the Baltimore Harbor were oxidized for 10 days, and Cr(VI) was not detected in any of the daily time series measurements that were taken from the water in the sediment that was being aerated (Graham and Wadhawan 2007a, b). This research suggests that Cr(III) is highly stable in Baltimore Harbor sediments.

5.3 Fate and Transport of Chromium in Runoff and Resultant Impact to Surface Water and Sediments

The fate of chromium associated with runoff at DMT is controlled by the surface cover material. The surface cover consists of bituminous and concrete paving that are regularly inspected and repaired in accordance with the procedures presented in the "Surface Cover and 14th and 15th Streets' Storm Drain Inspection and Maintenance Plan" (CH2M HILL, 2007f). This inspection and maintenance plan allows this pathway to be considered incomplete with respect to current operations.

5.4 Fate and Transport of Chromium in Air

The fate of chromium associated with the airborne pathway at DMT is also controlled by the "Surface Cover and 14th and 15th Streets Storm Drain Inspection and Maintenance Plan" (CH2M HILL, 2007f). A perimeter air monitoring program has been in place at the DMT for over 18 months and the absence of a statistically significant particulate and Cr(VI) contribution from the DMT has confirmed that the surface cover is effectively controlling this potential pathway.

SECTION 6

Calculation of Mass Flux to Patapsco River

The concentration and flow data collected during the groundwater investigation was used to develop an SCM and calibrated groundwater model. The mass flux was calculated by using the model-derived flow from a given portion of the model and concentration data from wells sampled during the Interim Groundwater Sampling Event to calculate mass flux out of each zone within the model. The flow and concentration data collected during the stormwater investigation were not considered robust enough to accurately calculate a mass flux; however, the hydraulic loading has been completed, so flux calculation can be made once additional concentration data become available.

6.1 Storm Drain Mass Flux

As explained above, the original intent of the sampling plan was to quantify the annual mass of chromium arriving to the Patapsco River via the storm drains. This computation requires the following elements:

1. Average dry-weather Cr(VI) concentrations, C_D
2. Average annual dry-weather volume, V_D
3. Average wet-weather Cr(VI) concentrations, C_W
4. Average annual wet-weather flow volume, V_W

The total annual Cr(VI) load L_{Cr} to the river is estimated as

$$L_{Cr} = \sum V_D C_D + V_W C_W$$

where the summation takes place over all of the storm drains.

As explained above, the original sampling plan produced only one round of concentration data for dry-weather flows, which is insufficient to estimate V_D or C_D reliably. Nevertheless, the dry-weather load to the river will be eliminated once all of the priority storm drains have been repaired and relined. If post-relining flow still exists, further dry- and wet-weather sampling will be performed to confirm that the concentrations are de minimis. Although no wet-weather data were collected, the annual volume of runoff generated by the site can be estimated using the following equation:

$$V_W = 0.9 P\, R_v$$

Where V_D is the annual runoff volume (inches), P the annual rainfall (about 44 inches for Baltimore), and R_v is a runoff coefficient estimated as

$$R_v = 0.05 + 0.9 I_a$$

where I_a is the site's impervious fraction, which for sites similar to DMT is assumed to be 98 percent.

The hydraulic loading analysis indicates, the resulting annual runoff volume is about 37 inches, which multiplied times the 92 acres drained by the 9th through the 13.5th Streets' storm drains, results in 284 acre-feet of runoff discharged to the Patapsco River on an annual basis.

In summary, the evolution of the data collection efforts led to an approach to quantification of the chromium load that is different from that envisioned in the initial work plans. Storm events introduce a dilution effect; therefore, wet-weather is not expected to cause an additional load to the river. The Sediment and Surface Water Study (CH2M HILL and Environ, 2009) included transects that originated at the storm drain outfalls. The four quarters of surface water sampling resulted in no detections of Cr(VI) above the NRWQC. Furthermore, Cr(VI) was detected above the MDL only in nine of the 320 surface water samples; two events were performed during wet-weather events, and NRWQCs were not exceeded indicating that the storm drain mass flux to the river is not causing a material impact to the river..

Dry weather constitutes the majority of the load entering the river from the storm drains. Remedial methods to address dry weather flow will be evaluated in the Corrective Measures Alternatives Analysis.

6.2 Shallow Groundwater Flux

The rate of chromium transport to the river via groundwater discharge from the shallow fill unit was calculated using groundwater flow rates simulated by the calibrated groundwater model for model layer 1 and concentrations of dissolved Cr(VI) and Cr(III) collected from shallow monitoring wells.

Volumetric flux of groundwater from the shallow fill unit to the river was determined using the ZONEBUDGET software package (Harbaugh, 1990) to process the cell-to-cell flux data provided as output by the model. Fifteen flow budgeting zones were delineated along the bank of the river from the western corner of the COPR fill area to the southeastern corner, as shown in Figure 6-1. The boundaries of the zones correspond to the locations of monitoring wells where dissolved Cr(VI) and Cr(III) concentrations near the river bank have been obtained by sampling.

In general, the most recent available sampling results were used for each well. For nine of the 15 river bank wells, data from the Interim Groundwater Sampling Event conducted in June 2009 were used. Well DMT-58S was damaged prior to the June 2009 sampling round, so analytical results from September 2007 were used. Also, the June 2009 analysis for Cr(VI) at well DMT-63S was qualified with a "J" indicating an estimated concentration which may be imprecise, so the result from the November 2008 sample was used.

Concentrations of Cr(III) were calculated for this analysis by subtracting the analytical results for total dissolved chromium and dissolved Cr(VI). Total dissolved chromium is assumed to be the sum of dissolved Cr(III) and Cr(VI).

Calculation of mass flux was performed for each flow zone by multiplying the volumetric flux of groundwater by the average concentrations of the two wells at either end of the zone. This is equivalent to applying the trapezoidal rule of numerical integration. The calculation for flow zone 1 was an exception to this procedure, because only one monitoring well adjacent to the river was available in that zone.

Table 6-1 lists the groundwater fluxes, and Cr(VI) concentrations used in the calculations for each zone. Volumetric flux for each zone is reported by the groundwater model in cubic feet per day. That flow rate is also reported in gpm in the table. Dissolved Cr(VI) was not reported above the detection limit for the majority of monitoring wells adjacent to the river. For these wells, the concentrations used in the mass flux estimates were one half the detection limit, or 2.5 µg/L.

As shown in Table 6-1, the total estimated rate of Cr(VI) discharge to the river from the shallow fill unit is approximately 1.60 pounds per year. Of this total mass flux, approximately 0.12 pounds per year passes through the bulkhead and 1.48 pounds per year discharge from the nonbulkheaded portion of the shallow aquifer. The majority of this mass flux occurs along the boundary of Areas 1501 and 1602 (flow zones 13 through 15). It should be noted that a large percentage of the shallow monitoring wells did not detect chromium; in those cases, half the detection limit was used to conservatively overestimate the mass flux to the river. Based on the calculations provided above, Cr(VI) mass flux from the shallow groundwater unit is minimal (even in the nonbulkheaded portion of the site) and no material impact has been observed in pore water or surface water collected during the Sediment and Surface Water Study (CH2M HILL and Environ, 2009).

Chromium mass flux through the shallow groundwater system warrants comparison to sediment concentrations near storm drain outfalls. For example, Sample J-1 near the outfall of 15th Street presents concentrations of 2,730 ppm total chromium, compared to a total mass flux from the entire nonbulkheaded shoreline of 1.48 pounds per year. As previously discussed, chromium impacts to the sediments from groundwater discharge are insignificant. Table 6-2 presents the groundwater fluxes and concentrations used in the Cr(III) flux calculations for each zone. The total estimated rate of Cr(III) at the edge of the site within the shallow fill unit is approximately 12.84 pounds per year. The Cr(III) mass flux across the bulkhead constitutes approximately 0.08 pounds per year while 12.76 pounds per year is transported through the nonbulkheaded portion of the site. It should be noted that Cr(III) has a very low solubility and has an affinity for sorbing to aquifer materials and sediment and is therefore, not very mobile. The Cr(III) mass flux calculations are provided to illustrate the conditions at the river's edge, the actual mass flux would be considerably lower.

6.3 Upper Sand Groundwater Flux

Mass flux of Cr(VI) from the upper sands to the river were also calculated as the product of simulated volumetric groundwater flux from model layer 2 and the measured Cr(VI) concentrations in the upper sand (US) wells near the river. The calculation for Cr(VI) in this stratigraphic unit was simpler because all of the upper sand (US) wells have non-detected concentrations of dissolved Cr(VI). The total simulated flux of groundwater to the river in the upper sands was 13.60 gpm, which is comprised of 10.78 gpm through the bulkheads and 2.82 gpm east of the bulkheads (see Section 4.1.7 and Appendix B for more detail). At a concentration of 2.5 µg/L (half the detection limit) this flow transports Cr(VI) to the river at a rate of 0.15 pounds per year. This includes approximately 0.12 pound per year through the bulkhead and 0.03 pounds per year through the nonbulkheaded shoreline (Table 6-3). This miniscule mass flux is the result of using half the detection limit at wells that didn't detect Cr(VI); furthermore, this mass flux is not sufficient to materially impact the river.

The mass flux of Cr(III) to the river was also calculated using the zones provided on Figure 6-2. The total mass flux of Cr(III) through the upper sands to the river is approximately 0.1 pound per year, which breaks down into 0.08 pound per year through the bulkhead and 0.02 pound per year through the nonbulkheaded area of the site. It should be noted that Cr(III) has a very low solubility and has an affinity for sorbing to aquifer materials and sediment and is therefore, not very mobile. The Cr(III) mass flux calculations are provided to illustrate the conditions at the river's edge, the actual mass flux would be considerably lower.

6.4 Intermediate Groundwater Flux

Based on the data available from multiple phases of groundwater investigation, Cr(VI) is not known to be present in the intermediate (Patapsco) aquifer. Further, it is has not been demonstrated that groundwater in this zone beneath the DMT discharges to the Patapsco River. Therefore, the analytical data and modeling results were used to estimate the magnitude of potential downward Cr(VI) migration into the intermediate groundwater zone from the upper sands. The total simulated rate of groundwater inflow to the Patapsco Aquifer from the upper sands was 0.63 gpm. Using half the detection limit as the concentration estimate, potential Cr(VI) flux into the Patapsco Aquifer over the area of the DMT model is calculated as approximately 0.007 pound per year. The resultant mass flux for Cr(III), if it were to remain mobile, would be approximately 0.005 pound per year. This miniscule mass flux is based on assuming half the detection limit so no mass flux is believed to occur in the intermediate zone.

SECTION 7

Conclusions

This report documents the findings of the CTS prepared pursuant to the requirements of the April 2006 Consent Decree entered into by and among Honeywell, MPA, and MDE. The report assesses the transport and fate of chromium in groundwater, stormwater, overland flow/runoff, and air.

Hexavalent chromium transport via direct groundwater flow (1.64 lbs/year) from the shallow aquifer does not constitute a major transport pathway to the river. Impacts to the sediments from groundwater discharge are insignificant. Surface water runoff and air are not transport pathways because COPR is contained beneath the surface cover present at DMT. The surface cover also isolates COPR from contact with overland flow/runoff. The surface cover inspection and maintenance program includes a rigorous inspection and repair program for surface cover which ensures that COPR remains contained, thereby limiting the potential for chromium transport via air and overland flow. The primary pathway of chromium flux from the Dundalk Marine Terminal is storm drain discharge—primarily from the 12th through 15th Streets' drains, the priority drains. This finding is consistent with EA's (1987) SCA. The magnitude of the resulting impact to the river is rapidly attenuated due to geochemical processes that act to reduce the hexavalent chromium in the estuarine environment. Sampling results over a one-year period found no Cr(VI) detections above EPA NRWQC in surface water transects located at the storm drain outfalls (CH2M and Environ, 2009).

Reliable quantification of stormwater discharge is not possible under current site conditions. MPA and Honeywell have implemented a pilot program at the 15th Street and 13th Street drains to quantify mass flux and isolate and contain groundwater infiltration into these storm drains. The 13th Street vault includes a tidal exclusion device that enables measurement of dry-weather flow and acquisition of water samples. The pilot program demonstrates that chromium flux can be reliably quantified after tidal exclusion and cleanout of the drain. The 13th Street pilot program to quantify flow is being expanded to include the remaining priority drains (12th, 12.5th, and 13.5th Streets) where exact quantification of discharge is not presently possible. The pilot program for relining the 13th and 15th Streets' storm drains is scheduled to be completed by the end of 2009 and will be followed by a postrelining sampling program. While site conditions prevented exact quantification of chromium mass flux in stormwater, the CTS data are extensive and sufficient to support an assessment of corrective measures and an evaluation of risk to human health and the environment.

SECTION 8

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TABLE 2-1
Stratigraphy and Physical Properties of Subsurface Soils at DMT
Chromium Transport Study
Dundalk Marine Terminal, Baltimore, Maryland

SOIL UNIT		SOIL SUB-UNIT		CLASSIFICATION	GEOTECHNICAL PROPERTIES								CPT CHARACTERISTICS		
					Water Content (%)	Specific Gravity (20℃)	Average Grain Size (%)	Blow Count (N)	Average Permeability (cm/s)	Compressive Strength (tsf)	Consolidation Test	Average Unit Weight (pcf)	Tip Stress (qt)	Resistivity (ohm-m)	Pore Pressure (u)
ANTHROPOGENIC FILL	FILL	TYPE I	⬛	Asphalt Silty Gravel with Sand (GW)	Average = 11.05 Range = 2.06 - 85.79 Standard Deviation = 11.12	Average = 2.76 Range = 2.70 - 2.86 Standard Deviation = 0.07	Gravel = 29.9 Sand = 56.2 Fines = 13.9	Average = 50+ Range = 50+ Standard Deviation = NA	--	--	--	--	>500 tsf	> 50 ohm-m	--
		TYPE IIA	🟧	Silty Sand (SM) Silty Sand with Gravel (SM) Poorly-Graded Sand with Silt (SP-SM)	Average = 22.89 Range = 32.8 - 117.32 Standard Deviation = 16.61	Average = 2.68 Range = 2.20 - 2.92 Standard Deviation = 0.20	Gravel = 12.8 Sand = 75.5 Fines = 11.6	Average = 31 Range = 4 - 50+ Standard Deviation = 20	--	--	--	--	100-400 tsf	> 40 ohm-m	<20 feet (Hydrostatic)
		TYPE IIB		Clayey Sand (SC) SIlt (ML) Clay (CL) Silty Sand with Gravel (SM)	Average = 43.56 Range = 5.93 - 124.62 Standard Deviation = 28.36	Average = 2.72 Range = 2.65 - 2.78 Standard Deviation = 0.07	Gravel = 3.7 Sand = 44.7 Fines = 37.2	Average = 13 Range = 2 - 36 Standard Deviation = 9	5.40E-07*	--	--	94.7*	<50 tsf	>25 ohm-m	<20 feet (Variable)
	COPR	HB	🟫	Well-Graded Sand (SW) Gravelly Sand (SW)	Average = 24.1 Range = 7.48 - 79.63 Standard Deviation = 11.89	Average = 2.8 Range = 2.18 - 3.01 Standard Deviation = 0.12	Gravel = 17.9 Sand = 62.7 Fines = 19.4	Average = 50 Range = 17 - 50+ Standard Deviation = 16	3.05E-05	4.42	--	117.65	250 - 500 tsf	> 50 ohm-m	Variable
		GB	⬜	Poorly-Graded Sand (SP) Silty Sand (SM)	Average = 26.4 Range = 1.26 - 77.48 Standard Deviation = 9.2	Average = 3.1 Range = 2.67 - 3.41 Standard Deviation = 0.2	Gravel = 13.5 Sand = 69.3 Fines = 17.2	Average = 24 Range = 4 - 50+ Standard Deviation = 19	--	3.26, 1.82**	--	124.8, 136.1	50 - 250 tsf	10 - >50 ohm-m (unsturated) ≤5 ohm-m (saturated)	Variable or Hydrostatic
ALLUVIAL SEDIMENTS		Upper Silt	🟩	Organic Silt (OL) Clay (CL) Silt (ML)	Average = 48.0 Range = 6.70 - 120.23 Standard Deviation = 27.6	Average = 2.8 Range = 2.77 - 2.85 Standard Deviation = 0.04	Gravel = 0.0 Sand = 7.8 Fines = 92.2	Average = 5 Range = 2 - 12 Standard Deviation = 3	1.62E-07	1.18	Average C_C = 0.88 Average C_R = 0.18	78.3	<10 tsf	≥5 ohm-m	45-50 feet
		Sand	🟨	Silty Sand (SM) Poorly-Graded Sand (SP) Poorly-Graded Sand with Silt (SP-SM)	Average = 21.1 Range = 0.94 - 47.62 Standard Deviation = 9.6	NA	Gravel = 3.2 Sand = 81.0 Fines = 15.8	Average = 36 Range = 4 - 50+ Standard Deviation = 22	--	--	--	--	50 - 250 tsf	10 - 40 ohm-m	Hydrostatic
		Lower Silt	🟩	Lean Clay (CL) Silt (ML)	Average = 54.05 Range = 26.79 - 78.19 Standard Deviation = 11.61	NA	Gravel = 0.1 Sand = 10 Fines = 89.9	Average = 3 Range = 0 - 11 Standard Deviation = 3	9.77E-08	1.43, 2.34**	Average CC = 1.1, 0.71** Average CR = 0.23, 0.19**	105.7	5 - 10 tsf	5 - 20 ohm-m	>250 feet
POTOMAC GROUP SEDIMENTS	SAND	Sand	🟥	Poorly-Graded Sand (SP) Poorly-Graded Sand with Gravel (SP) Poorly-Graded Sand with Silt (SP-SM)	Average = 16.68 Range = 8.75 - 21.54 Standard Deviation = 6.35	NA	Gravel = 18.2 Sand = 73.9 Fines = 7.9	Average = 50+ Range = 4 - 50+ Standard Deviation = 21	--	--	--	--	100 - 500 tsf	>50 ohm-m	Hydrostatic
	CLAY	Clay	🟪	Clay (CL or CH)	Average = 15.75 Range = 11.2 - 22.1 Standard Deviation = 3.55	NA	Gravel = 0.2 Sand = 19.9 Fines = 79.9	Average = 50+ Range = 39 - 50+ Standard Deviation = 18	9.20E-08	--	--	121.7	Undefined		

Notes:
NA = Not Analyzed
* = Result is derived from one test and does not represent an average
** = Results are derived from two tests and do not represent an average
Compressive Strength and Consolidation Test data for COPR represent Consolidated Undrained Triaxial Compresstion Tests
Compressive Strength and Consolidation Test data for Alluvial Silt represent Unconsolidated Undrained Triaxial Compresstion Tests
C_C = Compression Index
C_R = Recompression Index

TABLE 3-1
Summary of Well Construction Details
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Dundalk Marine Terminal, Baltimore, Maryland

	Well Depth	Status	Installation Date	Northing NAD 83/91	Easting NAD 83/91	Man Hole Elevation (feet BCD[a])	Top of Casing Elevation (feet BCD[a])	Well Diameter (inches)	Well Depth (feet)	Well Bottom Elevation (feet BCD)	Top of Screen Depth (feet)	Top of Screen Elevation (feet BCD)	Borehole Depth (feet)	Borehole Bottom (feet BCD)
CSG-1A	S	Active	8/9/2007	574512.2	1447561.8	10.93	10.71	1.5	13.5	-2.79	11.8	-1.09	32	-21.29
CSG-1B	S	Active	8/9/2007	574512.1	1447561.8	10.93	10.70	1.5	8	2.70	6.2	4.50	32	-21.30
CSG-2	S	Active	8/8/2007	574459.5	1447511.9	10.67	10.27	1.5	9.5	0.77	7.8	2.47	32	-21.73
DMT-01S	S	Active	12/11/2005	573664.6	1444877.0	11.04	10.35	2	25	-14.65	5	5.35	25.5	-15.15
DMT-02S	S	Active	12/10/2005	573811.2	1445281.8	10.50	10.20	2	25	-14.80	5	5.20	25.5	-15.30
DMT-03S	S	Active	12/10/2005	573901.4	1445506.9	9.25	8.90	2	40	-31.10	5	3.90	40.5	-31.60
DMT-04S	S	Active	12/11/2005	574215.4	1445992.1	9.67	9.26	2	20	-10.74	5	4.26	22	-12.74
DMT-05S	S	Active	12/11/2005	574307.5	1446253.5	9.77	9.50	2	15	-5.50	5	4.50	18	-8.50
DMT-06S	S	Active	12/9/2005	574422.8	1446439.9	11.24	10.65	2	30	-19.35	5	5.65	30.5	-19.85
DMT-07S	S	Active	12/9/2005	574475.5	1446656.6	10.91	10.66	2	30	-19.34	5	5.66	30.5	-19.84
DMT-08S	S	Active	12/8/2005	574542.4	1446804.0	11.06	10.80	2	35	-24.20	5	5.80	35.5	-24.70
DMT-09S	S	Active	12/7/2005	574733.7	1447236.1	12.13	11.63	2	35	-23.37	5	6.63	35.5	-23.87
DMT-10S	S	Active	12/6/2005	574911.4	1447826.2	12.44	12.18	2	30	-17.82	4	8.18	30.5	-18.32
DMT-11S	S	Active	1/6/2006	574430.5	1448175.9	22.10	21.70	2	45	-23.30	25	-3.30	45.5	-23.80
DMT-12S	S	Active	12/12/2005	574286.1	1447479.8	8.65	8.26	2	29	-20.74	4	4.26	29.5	-21.24
DMT-13S	S	Active	12/19/2005	574461.5	1447357.4	11.31	10.90	2	24	-13.10	4	6.90	24.5	-13.60
DMT-14S	S	Active	12/10/2005	574108.4	1446859.2	8.65	8.27	2	30	-21.73	5	3.27	30	-21.73
DMT-15S	S	Active	12/20/2005	573813.2	1446162.5	9.19	8.59	2	26	-17.41	4	4.59	26.5	-17.91
DMT-16S	S	Active	12/19/2005	573496.5	1445419.1	9.59	9.05	2	24	-14.95	4	5.05	24.5	-15.45
DMT-17S	S	Active	12/12/2005	573651.8	1444341.8	8.45	8.06	2	25	-16.94	5	3.06	25.5	-17.44
DMT-18S	S	Active	12/12/2005	574010.5	1444148.0	9.57	8.86	2	29	-20.14	4	4.86	29.5	-20.64
DMT-19S	S	Active	12/13/2005	575157.7	1444188.9	11.58	10.71	2	15	-4.29	5	5.71	15.5	-4.79
DMT-20S	S	Active	1/7/2006	575421.7	1445408.5	9.53	9.15	4	40	-30.85	20	-10.85	72	-62.85
DMT-21S	S	Active	1/8/2006	575422.9	1445388.9	9.36	8.87	4	44.5	-35.63	24.5	-15.63	44.5	-35.63
DMT-22S	S	Active	12/12/2005	573838.9	1444447.7	9.29	9.15	2	29	-19.85	4	5.15	29.5	-20.35
DMT-23S	S	Active	1/5/2006	573822.8	1445303.2	10.17	9.95	4	25	-15.05	5	4.95	25.5	-15.55
DMT-24S	S	Active	1/5/2006	574549.1	1446821.3	10.84	10.49	4	35	-24.51	5	5.49	35.5	-25.01
DMT-25S	S	Active	1/4/2006	574904.2	1447807.8	12.27	11.94	4	30	-18.06	4	7.94	30.5	-18.56
DMT-26S	S	Active	12/1/2006	575486.9	1443757.4	9.63	9.24	2	40	-30.76	20	-10.76	40	-30.76
DMT-27S	S	Active	12/19/2006	574688.4	1444313.1	10.75	10.29	2	40	-29.71	20	-9.71	40	-29.71
DMT-28S	S	Active	12/5/2006	575463.1	1446206.2	10.58	10.21	2	25	-14.79	5	5.21	25	-14.79
DMT-29S	S	Active	11/19/2006	574346.9	1444924.1	10.73	10.49	2	25	-14.51	5	5.49	42	-31.51
DMT-30S	S	Active	12/2/2006	574669.7	1445674.6	10.21	9.88	2	25	-15.12	5	4.88	34	-24.12
DMT-31S	S	Active	11/20/2006	573459.2	1445298.4	9.92	9.60	2	30	-20.40	10	-0.40	30	-20.40
DMT-32S	S	Active	12/5/2006	573725.1	1445927.9	8.83	8.55	2	34	-25.45	14	-5.45	34	-25.45
DMT-33S	S	Active	11/30/2006	575001.2	1446802.3	12.88	12.56	2	30	-17.44	10	2.56	30	-17.44
DMT-01M	M	Active	12/23/2005	574770.6	1447035.8	12.24	11.86	4	113	-101.14	103	-91.14	113.5	-101.64
DMT-02M	M	Active	1/11/2006	576330.4	1444803.7	12.73	12.56	2	76	-63.44	66	-53.44	78.5	-65.94
DMT-34M	M	Active	12/15/2006	574040.9	1444176.3	9.57	9.21	2	79	-69.79	69	-59.79	82	-72.79
DMT-35M	M	Active	12/6/2006	575965.8	1448016.3	14.14	14.01	2	82	-67.99	72	-57.99	93	-78.99
DMT-36M	M	Active	12/18/2006	574811.4	1448423.6	14.61	14.32	2	110	-95.68	100	-85.68	113.2	-98.88
DMT-37M	M	Active	1/4/2007	574351.2	1446365.0	10.60	10.35	2	110	-99.65	100	-89.65	113.1	-102.75
DMT-38M	M	Active	12/13/2006	575364.3	1449385.1	--	20.67	2	120	-104.37	110	-94.37	120	-104.37
DMT-39S	S	Active	2/16/2007	574255.2	1449326.5	17.97	17.75	2	30	-12.25	20	-2.25	30	-12.25
DMT-40S	S	Active	6/18/2007	574200.3	1443901.5	9.11	8.94	2	15	-6.06	5	3.94	16	-7.06
DMT-41S	S	Active	6/16/2007	574915.4	1444974.8	10.54	10.16	2	15	-4.84	5	5.16	16	-5.84
DMT-42S	S	Active	7/27/2007	573892.0	1444084.8	9.12	8.90	2	14	-5.10	4	4.90	14	-5.10
DMT-43S	S	Active	7/17/2007	574699.7	1446285.6	12.30	11.67	2	30	-18.33	10	1.67	34	-22.33
DMT-44S	S	Active	8/6/2007	574790.8	1447033.0	11.82	11.51	2	20	-8.49	10	1.51	22	-10.49

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DMT-45S	S	Active	6/18/2007	573949.3	1448477.3	15.81	15.56	2	33	-17.44	23	-7.44	30	-14.44
DMT-46S	S	Abandoned	6/19/2007	574160.5	1449000.9	18.28	17.61	2	26	-8.39	16	1.61	26	-8.39
DMT-47S	S	Active	8/1/2007	576768.8	1447942.1	18.95	18.58	2	13	5.58	3	15.58	14	4.58
DMT-48S	S	Active	11/2/2007	575841.5	1449021.9	15.69	15.37	2	17	-1.63	7	8.37	20	-4.63
DMT-49US	US	Active	7/24/2007	573684.1	1444881.1	10.97	10.74	2	41	-30.26	31	-20.26	44	-33.26
DMT-50US	US	Active	7/25/2007	573229.6	1444756.7	9.03	8.69	2	38	-29.31	33	-24.31	47	-38.31
DMT-51US	US	Active	8/25/2007	574716.0	1446278.2	11.97	11.73	2	43	-31.28	33	-21.28	46	-34.28
DMT-52US	US	Active	8/25/2007	574779.0	1447042.2	12.14	11.58	2	35	-23.42	25	-13.42	36	-24.42
DMT-53US	US	Active	7/30/2007	575403.9	1448411.1	15.72	15.47	2	34	-18.53	24	-8.53	34	-18.53
DMT-54US	US	Active	8/10/2007	576771.3	1447937.4	18.87	18.45	2	34	-15.56	24	-5.56	34	-15.56
DMT-55S	S	Active	11/2/2007	575628.9	1449259.5	14.38	13.89	2	17	-3.11	7	6.89	20	-6.11
DMT-56S	S	Active	9/4/2007	574170.4	1447839.8	13.11	12.69	2	30	-17.31	20	-7.31	30	-17.31
DMT-57S	S	Active	8/28/2007	573989.4	1447911.5	14.03	13.68	2	33	-19.32	23	-9.32	34	-20.32
DMT-58S	S	Active	8/27/2007	573760.0	1447991.8	13.46	13.15	2	34	-20.85	24	-10.85	34	-20.85
DMT-59S	S	Active	10/20/2007	576829.5	1448021.4	19.96	19.67	2	27	-7.33	17	2.67	27	-7.33
DMT-60M	M	Active	10/26/2007	576826.9	1448014.9	20.01	19.76	2	95	-75.24	85	-65.24	190	-170.24
DMT-61S	S	Active	10/18/2007	574452.2	1450148.7	18.28	18.04	2	20	-1.97	10	8.04	20	-1.97
DMT-62S	S	Active	10/17/2007	574321.9	1449790.3	21.73	21.36	2	26	-4.64	16	5.36	28	-6.64
DMT-63S	S	Active	10/22/2008	574138.3	1448936.4	17.14	16.93	2	27	-10.07	22	-5.07	37	-20.07
DMT-64US	US	Active	10/25/2008	573896.9	1444081.9	9.30	8.86	2	44	-35.14	34	-25.14	46	-37.14
DMT-65US	US	Active	10/15/2008	573642.7	1444349.9	8.35	7.93	2	40	-32.07	35	-27.07	46	-38.07
DMT-66US	US	Not Installed	10/26/2008	573455.6	1445300.2	9.89	--	--	--	--	--	--	50	-40.11
DMT-67US	US	Active	11/7/2008	573652.2	1445753.4	9.25	8.91	2	39	-30.09	34	-25.09	42	-33.09
DMT-68US	US	Not Installed	11/8/2008	573787.1	1446106.9	9.13	--	--	--	--	--	--	46	-36.88
DMT-69US	US	Not Installed	11/5/2008	573928.8	1446444.3	9.07	--	--	--	--	--	--	46	-36.93
DMT-70US	US	Active	10/25/2008	574074.9	1446788.2	8.61	8.31	2	44	-35.69	34	-25.69	46	-37.69
DMT-71US	US	Active	10/12/2008	574230.4	1447123.2	8.87	8.52	2	43	-34.48	38	-29.48	44	-35.48
DMT-72US	US	Active	10/25/2008	574234.0	1447425.6	8.47	8.11	2	41	-32.89	36	-27.89	44	-35.89
DMT-73US	US	Active	10/13/2008	574262.4	1449319.1	18.08	17.81	2	52	-34.19	42	-24.19	52	-34.19
DMT-74US	US	Active	10/28/2008	575272.4	1449598.6	16.58	16.38	2	47	-30.62	37	-20.62	47	-30.62
DMT-75US	US	Active	10/27/2008	575902.4	1448919.4	17.97	17.77	2	40	-22.23	30	-12.23	40	-22.23
DMT-77M	M	Active	10/13/2008	574267.2	1449334.6	18.34	17.89	2	110	-92.11	100	-82.11	157	-139.11
DMT-78M	M	Active	10/9/2008	574921.2	1444894.8	10.73	10.42	2	85	-74.58	75	-64.58	97	-86.58
DMT-79M	M	Active	10/7/2008	576098.1	1448701.1	18.25	18.02	2	108	-89.98	98	-79.98	117	-98.98
DMT-80M	M	Active	10/8/2008	574856.3	1449819.0	15.32	15.08	2	108	-92.92	98	-82.92	137	-121.92
DMT-81D	D	Active	10/22/2008	574329.1	1449734.8	21.34	21.01	2	227	-205.99	217	-195.99	227	-205.99
DMT-82D	D	Active	10/26/2008	576795.2	1448072.4	19.75	19.23	2	196	-176.77	186	-166.77	247	-227.77
DMT-83D	D	Active	11/25/2008	573215.0	1444734.4	9.15	8.95	2	228	-219.05	218	-209.05	267	-258.05
LYS-1	S	Active	8/11/2007	574510.7	1447555.7	10.89	10.66	1.9	5.65	5.01	4.65	6.01	6	4.66
LYS-2	S	Active	8/11/2007	574455.6	1447516.7	10.40	10.27	1.9	5.35	4.92	4	5.92	6	4.27
TPZ-A	S	Active	11/28/2006	574755.7	1446740.1	11.08	10.80	2	26	-15.20	6	4.80	26	-15.20
TPZ-B	S	Active	11/15/2006	574981.5	1447764.4	12.51	12.13	2	40	-27.87	20	-7.87	40	-27.87
TPZ-C	S	Active	12/18/2006	NS	NS	NS	NS	1	6.5	--	2.5	--	6.5	--
TPZ-01	M	Active	1/9/2006	574780.5	1447051.6	12.24	11.97	1	51	-39.03	48	-36.03	51	-39.03
TPZ-02	M	Active	1/11/2006	574771.9	1447053.9	12.37	11.91	1	66	-54.09	63	-51.09	66	-54.09
TPZ-03	M	Active	1/10/2006	574763.8	1447052.8	12.41	11.76	1	88	-76.24	85	-73.24	88	-76.24
TPZ-04	S	Active	12/4/2006	574354.1	1447269.6	9.44	9.13	1.5	16	-6.87	11	-1.87	16	-6.87
TPZ-05	S	Active	12/4/2006	574361.9	1447289.2	9.60	9.09	1.5	16	-6.91	11	-1.91	16	-6.91
TPZ-06	S	Active	12/4/2006	574373.2	1447315.7	9.87	9.38	1.5	16	-6.62	11	-1.62	16	-6.62

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TPZ-07	S	Active	12/3/2006	574413.7	1447407.5	10.78	10.43	1.5	16	-5.57	11	-0.57	16	-5.57
TPZ-08	S	Active	12/16/2006	574395.2	1446849.0	10.26	10.07	1.5	18	-7.93	13	-2.93	18	-7.93
TPZ-09	S	Active	12/16/2006	574403.5	1446866.7	10.01	9.83	1.5	18	-8.17	13	-3.17	18	-8.17
TPZ-10	S	Active	12/16/2006	574415.4	1446894.2	10.06	9.77	1.5	18	-8.23	13	-3.23	18	-8.23
TPZ-11	S	Active	12/13/2006	574454.5	1446986.9	11.30	10.80	1.5	18	-7.20	13	-2.20	18	-7.20
TPZ-12	S	Active	11/21/2006	574198.8	1446913.9	9.07	8.76	1.5	17	-8.24	12	-3.24	17	-8.24
TPZ-13	S	Active	11/21/2006	574191.7	1446898.7	8.66	8.22	1.5	17	-8.78	12	-3.78	17	-8.78
TPZ-14	S	Active	11/21/2006	574179.6	1446871.0	8.22	7.85	1.5	17	-9.15	12	-4.15	17	-9.15
TPZ-15	S	Active	11/21/2006	574139.0	1446775.5	8.13	7.76	1.5	17	-9.24	12	-4.24	17	-9.24
TPZ-16	S	Active	11/29/2006	574046.9	1446560.2	8.26	8.09	1.5	17	-8.91	12	-3.91	17	-8.91
TPZ-17	S	Active	11/29/2006	574040.2	1446543.5	8.43	8.01	1.5	17	-8.99	12	-3.99	17	-8.99
TPZ-18	S	Active	11/29/2006	574026.5	1446511.7	8.84	8.28	1.5	17	-8.72	12	-3.72	17	-8.72
TPZ-19	S	Active	11/29/2006	573988.6	1446420.8	9.27	8.91	1.5	17	-8.09	12	-3.09	17	-8.09
TPZ-20	S	Active	11/5/2006	574100.2	1446152.0	9.50	9.21	1.5	19	-9.79	14	-4.79	19	-9.79
TPZ-21	S	Active	11/5/2006	574108.1	1446169.8	8.93	8.76	1.5	19	-10.24	14	-5.24	19	-10.24
TPZ-22	S	Active	11/5/2006	574120.8	1446197.9	8.81	8.56	1.5	19	-10.44	14	-5.44	19	-10.44
TPZ-23	S	Active	11/5/2006	574159.1	1446288.4	9.73	9.26	1.5	19	-9.74	14	-4.74	19	-9.74
TPZ-24	S	Active	11/2/2006	575441.1	1445398.2	9.70	9.37	2	40	-30.63	20	-10.63	40.5	-31.13
TPZ-25	S	Not Installed	2/13/2007	--	--	--	--	--	--	--	--	--	--	--
TPZ-26	S	Not Installed	2/13/2007	--	--	--	--	--	--	--	--	--	--	--
TPZ-27A	S	Active	2/14/2007	575280.2	1449587.6	16.60	16.42	1	25	-8.58	15	1.42	25	-8.58
TPZ-27B	S	Active	2/14/2007	575278.8	1449589.6	16.56	16.30	1	11	5.30	6	10.30	11	5.30
TPZ-28B	S	Active	2/14/2007	574834.8	1449841.1	16.08	15.88	1	18	-2.12	3	12.88	18	-2.12
TPZ-29	S	Active	2/15/2007	574647.2	1449446.6	17.61	17.17	1	25	-7.83	15	2.17	25	-7.83
TPZ-30A	S	Active	2/15/2007	574331.0	1449504.9	19.60	19.41	1	28	-8.59	18	1.41	28	-8.59
TPZ-30B	S	Active	2/15/2007	574333.4	1449504.8	19.55	19.19	1	17	2.19	2	17.19	17	2.19
TPZ-31	S	Not Installed	2/16/2007	--	--	--	--	--	--	--	--	--	--	--
TPZ-32	S	Not Installed	2/17/2007	--	--	--	--	--	--	--	--	--	--	--
TPZ-33	S	Active	7/9/2007	574915.3	1445455.0	9.73	9.27	1.5	16	-6.73	6	3.27	16	-6.73
TPZ-34	S	Active	7/16/2007	574676.1	1445516.5	9.43	8.97	1.5	24	-15.03	4	4.97	24	-15.03
TPZ-35	S	Active	7/16/2007	574956.2	1446261.6	10.07	9.63	1.5	23	-13.37	3	6.63	24	-14.37
TPZ-36	S	Active	7/29/2007	575130.6	1446425.2	9.58	9.31	1.5	16	-6.69	6	3.31	16	-6.69
TPZ-37	S	Active	7/16/2007	575090.2	1446693.4	11.72	11.48	1.5	23	-11.52	3	8.48	24	-12.52
TPZ-38	S	Active	7/15/2007	575372.8	1447010.8	10.48	10.19	1.5	16	-5.81	6	4.19	31	-20.81
TPZ-39	S	Active	6/17/2007	574602.5	1448330.5	22.75	22.47	1.5	18	4.47	8	14.47	22	0.47
TPZ-40	S	Active	6/17/2007	574342.3	1448095.6	21.69	21.37	1.5	19	2.37	9	12.37	21	0.37
TPZ-41	S	Active	6/13/2007	574101.9	1447940.5	20.13	19.83	1.5	18	1.83	8	11.83	20	-0.17
TPZ-42	S	Active	6/14/2007	573928.5	1448110.8	19.76	19.47	1.5	14	5.47	4	15.47	19	0.47
TPZ-43	S	Active	6/15/2007	573866.0	1448178.6	19.76	19.49	1.5	18	1.49	8	11.49	20	-0.51
TPZ-44	S	Active	6/19/2007	575030.2	1448964.8	17.49	17.09	1.5	18	-0.91	8	9.09	20	-2.91
TPZ-45	S	Active	6/20/2007	575474.8	1449329.6	--	22.85	1.5	18	4.85	8	14.85	14	8.85
TPZ-46	S	Active	6/16/2007	574804.9	1448372.6	14.02	13.67	1.5	15	-1.33	5	8.67	16	-2.33
TPZ-47	S	Active	8/7/2007	574373.5	1445773.5	10.08	9.63	1.5	14	-4.37	4	5.63	14	-4.37
TPZ-48	US	Active	3/6/2009	573947.4	1448470.2	14.16	13.86	2	42	-28.14	37	-23.14	86	-72.14
TPZ-49	US	Active	3/12/2009	573774.0	1447992.1	11.66	11.28	2	43	-31.72	38	-26.72	88	-76.72
EA-02S	S	Active	NA	575400.6	1448431.6	15.70	14.73	4	15	-0.27	5	9.73	16	-1.27
EA-03S	S	Active	NA	576019.2	1447972.4	13.96	13.59	4	15	-1.41	5	8.59	16	-2.41
EA-04S	S	Abandoned	6/7/1996	574215.7	1445992.4	--	--	4	13.5	--	6	--	14.5	--
EA-05S	S	Abandoned	6/5/1996	574215.7	1445992.4	--	--	4	15	--	5	--	16	--

TABLE 3-1
Summary of Well Construction Details
COPR Investigation Report
Dundalk Marine Terminal, Baltimore, Maryland

	Well Depth	Status	Installation Date	Northing NAD 83/91	Easting NAD 83/91	Man Hole Elevation (feet BCD[a])	Top of Casing Elevation (feet BCD[a])	Well Diameter (inches)	Well Depth (feet)	Well Bottom Elevation (feet BCD)	Top of Screen Depth (feet)	Top of Screen Elevation (feet BCD)	Borehole Depth (feet)	Borehole Bottom (feet BCD)
EA-06S	S	Active	12/10/1987	574464.0	1447668.2	10.35	9.86	4	19	-9.14	9	0.86	19	-9.14
EA-07S	S	Active	2/20/1987	573748.8	1447988.1	12.98	12.54	4	9.5	3.04	6	6.54	10	2.54
EA-08S	S	Active	NA	575608.3	1447535.7	12.55	12.31	4	15	-2.69	5	7.31	16	-3.69
EA-10S	S	Active	NA	574131.5	1446213.7	8.92	8.60	4	15	-6.40	5	3.60	15.5	-6.90
EA-11S	S	Active	2/19/1987	573237.9	1444779.9	8.84	8.62	4	15	-6.38	5	3.62	15	-6.38
EA-12S	S	Active	NA	574050.2	1445770.9	9.78	9.69	4	15	-5.31	5	4.69	15.5	-5.81
EA-14S	S	Active	NA	573660.3	1445559.6	9.79	9.25	4	14.8	-5.55	4.8	4.45	15	-5.75
EA-15S	S	Active	1/27/1987	574206.3	1445153.8	11.11	10.63	4	15	-4.37	5	5.63	15.5	-4.87
EA-16S	S	Active	--	573786.4	1444998.6	10.64	9.64	4	20	-10.36	10	-0.36	20	-10.36
EA-17S	S	Active	2/20/1987	574284.5	1447651.3	8.66	8.06	4	20	-11.94	10	-1.94	20	-11.94
EA-18S	S	Active	NA	577790.1	1446073.501	9.76*	NS	4	20	--	5	--	20	--
EA-19S	S	Abandoned	NA	NS	NS	--	--	4	20	--	10	--	20	--
EA-20S	S	Abandoned	1/4/2001	NS	NS	--	--	4	20	--	10	--	20	--
EA-21S	S	Active	NA	576121.0	1446277.2	10.25	9.87	4	20	-10.13	5	4.87	20	-10.13
EA-22S	S	Active	NA	576209.5	1443950.5	8.21*	NS	4	20	--	5	--	20	--
EA-02M	M	Active	NA	575394.0	1448438.4	15.47	15.23	4	62	-46.77	52	-36.77	64	-48.77
EA-03M	M	Active	NA	576005.0	1447974.0	13.60	13.22	4	47	-33.78	37	-23.78	48	-34.78
EA-05M	M	Active	NA	574787.2	1448359.0	13.67	13.27	4	97	-83.73	87	-73.73	98	-84.73
EA-06M	M	Active	12/10/1987	574465.5	1447657.1	10.37	9.92	4	93	-83.08	83	-73.08	102	-92.08
EA-07M	M	Active	2/20/1987	573745.7	1448007.3	13.26	13.13	4	109.5	-96.37	99.5	-86.37	110.5	-97.37
EA-08M	M	Active	NA	575613.3	1447540.8	12.61	12.37	4	69.95	-57.58	59.5	-47.13	71.5	-59.13
EA-09M	M	Active	1/8/2006	574756.6	1447023.4	12.20	12.00	4	108.5	-96.50	98.0	-86.00	108.5	-96.50
EA-10M	M	Active	NA	574127.8	1446210.8	8.75	8.52	4	96	-87.48	86	-77.48	98	-89.48
EA-11M	M	Active	NA	573254.5	1444766.6	9.40	8.85	4	100	-91.15	90	-81.15	101	-92.15
EA-13M	M	Active	NA	574686.1	1446040.3	10.69	10.45	4	105	-94.55	95	-84.55	106	-95.55
EA-14M	M	Active	NA	573654.2	1445562.3	9.74	9.46	4	95	-85.54	85	-75.54	95	-85.54
EA-15M	M	Active	2/3/1987	574196.5	1445153.5	11.18	10.67	4	111	-100.33	101	-90.33	112	-101.33
EAS-01A	S	Active	3/10/1987	574719.5	1447526.1	10.20	10.04	4	15.5	-5.46	4.5	5.54	15.5	-5.46
EAS-01B	S	Active	3/10/1987	574723.7	1447519.4	10.07	9.63	4	14.5	-4.87	4.5	5.13	15	-5.37
EAS-01C	S	Abandoned	NA	574724.9	1447524.1	10.01	NS	4	14.5	--	4.5	--	15	--
EAS-02A	S	Active	3/11/1987	574962.3	1447416.3	10.08	9.36	4	14.5	-5.14	4.5	4.86	15	-5.64
EAS-02B	S	Active	3/12/1987	574963.9	1447421.9	10.08	9.08	4	14.5	-5.42	4.5	4.58	15	-5.92
EAS-02C	S	Abandoned	NA	NS	NS	--	--	NA	14.5	--	4.4	--	14.5	--
EAC-01S	S	Active	NA	574847.1	1449846.8	15.93	15.65	4	20	-4.35	10	5.65	21	-5.35
EAC-02S	S	Active	12/30/1986	575581.7	1447003.5	9.49	9.30	4	32	-22.55	22	-12.55	32	-22.55
EAC-03S	S	Active	1/8/1987	574313.6	1446994.1	10.47	9.67	4	15	-5.33	5	4.67	16.5	-6.83
EAC-04S	S	Active	1/6/1987	574085.0	1444219.8	9.35	NS	4	14	--	4	--	14.5	--
EAC-01M	M	Abandoned	NA	574852.3	1449854.5	15.91	15.49	4	50	-34.51	40	-24.51	50	-34.51
EAC-02M	M	Active	1/16/1987	575580.8	1446990.4	9.32	9.32	4	90	-80.55	80	-70.55	120	-110.55
EAC-03M	M	Active	1/12/1987	574315.9	1446980.3	10.39	9.41	4	110	-100.59	100	-90.59	112	-102.59
EAC-04M	M	Active	1/6/1987	574093.5	1444215.9	NS	8.98	4	50	-41.02	40	-31.02	50	-41.02
MW-23	S	Active	NA	576307.4	1444841.9	11.6*	NS	2	NA	--	NA	--	NA	--
EW-1	S	Active	7/22/1993	574482.4	1447616.0	10.39	9.22	4	15	-5.78	5	4.22	15	-5.78
EW-2	S	Active	7/22/1993	574719.6	1447519.8	10.21	9.53	4	15	-5.47	5	4.53	15	-5.47
EW-3	S	Active	7/23/1993	574954.9	1447417.3	10.26	9.46	4	15	-5.55	5	4.46	15	-5.55
EW-4	S	Active	7/23/1993	575136.4	1447337.2	10.95	9.75	4	15	-5.25	5	4.75	15	-5.25
EW-5	S	Active	7/24/1993	575332.1	1447254.7	10.92	10.21	4	15	-4.79	5	5.21	15	-4.79
EW-6	S	Active	7/24/1993	575435.0	1447270.7	11.08	10.07	4	15	-4.93	5	5.07	15	-4.93
P-01	S	Active	NA	575605.0	1448698.7	16.84	16.57	2	15	1.57	5	11.97	15	1.57

TABLE 3-1

Summary of Well Construction Details

COPR Investigation Report

Dundalk Marine Terminal, Baltimore, Maryland

	Well Depth	**Status**	**Installation Date**	**Northing NAD 83/91**	**Easting NAD 83/91**	**Man Hole Elevation (feet BCD[a])**	**Top of Casing Elevation (feet BCD[a])**	**Well Diameter (inches)**	**Well Depth (feet)**	**Well Bottom Elevation (feet BCD)**	**Top of Screen Depth (feet)**	**Top of Screen Elevation (feet BCD)**	**Borehole Depth (feet)**	**Borehole Bottom (feet BCD)**
P-03	S	Active	NA	574710.4	1446896.5	12.21	11.79	2	15.3	-3.51	5	6.49	15.3	-3.51
P-04	S	Active	NA	574684.0	1446036.3	10.60	10.25	2	16.5	-6.25	7	3.45	16.5	-6.25
P-05	S	Active	NA	575422.0	1447211.7	10.57	10.24	2	20.1	-9.86	NA	--	NA	--
P-06	S	Active	NA	575195.3	1447180.8	11.75	11.43	2	18.7	-7.27	NA	--	NA	--
P-07	S	Active	NA	575160.5	1447366.4	10.48	10.05	2	20	-9.95	NA	--	NA	--
P-08	S	Active	NA	574959.5	1447318.3	9.73	9.30	2	20	-10.70	NA	--	NA	--
P-09	S	Active	NA	574730.2	1447478.4	10.26	9.91	2	20	-10.09	NA	--	NA	--
P-10	S	Active	NA	574482.1	1447546.7	10.54	10.27	2	18.6	-8.33	NA	--	NA	--
P-11	S	Active	NA	575094.2	1447989.1	14.04	13.64	2	19.8	-6.16	NA	--	NA	--
P-12	S	Active	NA	574659.1	1448959.3	19.97	19.65	2	14.4	5.25	10	10.15	NA	--

Notes:

Elevations surveyed by Greenhorn and O'Mera, Inc. January and February 2007, October through December 2007, November 2008, and March 2009.

NA = Not Available

NS= Well Not Surveyed in 2007

Not Installed = Well/Piezometers were not installed due to subsurface condition:

Depths measured in feet below ground surface.

[a] Elevation (ft BCD) is in Baltimore City Datum (NAVD88 + 1.7)

Created by: CH 3/13/2009

Checked by: LGC 3/27/09

Approved by:

TABLE 4-1
Soil Analytical Results
Chromium Transport Study
Dundalk Marine Terminal, Baltimore, Maryland

Location	Date	Field Sample ID	Start Depth (feet)	End Depth (feet)	*Chromium (mg/kg)*	*Chromium (VI) (mg/kg)*	*Aluminum (mg/kg)*	*Calcium (mg/kg)*	*Iron (mg/kg)*	*Magnesium (mg/kg)*	*Manganese (mg/kg)*	*pH (std. units)*	*Potassium (mg/kg)*	*Redox Potential Vs H2*	*Sodium (mg/kg)*	*Titanium (mg/kg)*	*Vanadium (mg/kg)*
B-100	11/17/2006	B-100-SOI-3134	31	34	89.4 J	1.5 U	26400	1660	38100	6110	880	8.48	3190 J	239	3450	--	55.5 J
B-101	11/3/2006	B-101-SOI-2527	25	27	423 J	1.2 U	9240	5280	17700 J	3460 J	359	8.45	1380 L	238	1710	--	56.3 J
B-105	11/27/2006	B-105-SOI-2224	22	23	58 J	1.4 U	19700	1860	33200	4520	437	8.06	2590	257	2910	265	44.1
B-127	2/8/2007	**B-127-SOI-0406**	**4**	**5**	**17100**	**6090 L**	**47600**	**204000**	**120000**	**39400**	**994**	**11.83**	--	**176**	--	--	**1110**
	2/8/2007	**B-127-SOI-0610**	**6**	**10**	**22800**	**5120 L**	**64200**	**267000**	**163000**	**53100**	**1360**	**11.93**	--	**165**	--	--	**1490**
	2/8/2007	B-127-SOI-1417	14	17	27.6	1.2 UL	20700	1630	17300	2100	122	7.14	--	224	--	--	38.9
	2/8/2007	B-127-SOI-2122	20	21	9.9	0.6 J	3710	211	2320	380	13.2	7.16	--	342	--	--	9.3
B-128	2/12/2007	**B-128-SOI-0204**	**2**	**4**	**4560**	**1250 L**	**16200**	**189000**	**33500**	**61700**	**335**	**11.27**	--	**192**	--	--	**330**
	2/12/2007	**B-128-SOI-0406**	**4**	**5**	**16800**	**4000**	**39100**	--	**96400**	**41500**	**895**	**11.4**	--	**193**	--	--	**985**
	2/12/2007	B-128-SOI-1014	10	14	31.4	2 L	10500	2620	10100	2160	56.3	5.21	--	380	--	--	22.1
	2/12/2007	B-128-SOI-1820	18	20	4.2	2.5	571	632	1830	797	63.7	8.77	--	341	--	--	1.8
CSG-1	8/10/2007	CSG-1-SOI-020030-A	2	3	--	347	--	--	--	--	--	11.09	--	178	--	--	--
	8/10/2007	**CSG-1-SOI-030040-A**	**3**	**4**	--	**1060**	--	--	--	--	--	**10.96**	--	**228**	--	--	--
	8/10/2007	**CSG-1-SOI-040045-A**	**4**	**4**	--	**1370**	--	--	--	--	--	**10.93**	--	**207**	--	--	--
	8/10/2007	**CSG-1-SOI-045050-A**	**4**	**5**	**21200**	**4310**	**35800**	**160000**	**85200**	**30700**	**779**	**10.97**	**323 B**	**228**	**1630 B**	**1440**	**762**
	8/10/2007	**CSG-1-SOI-055065-A**	**5**	**6**	**14300**	**4350**	**37600**	**142000**	**87900**	**32100**	**883**	**11.02**	**553 B**	**254**	**1130 B**	**1520**	**804**
	8/10/2007	**CSG-1-SOI-080100-A**	**8**	**10**	--	**6080**	--	--	--	--	--	**11.79**	--	**132**	--	--	--
	8/10/2007	**CSG-1-SOI-100110-A**	**10**	**11**	--	**4110**	--	--	--	--	--	**11.62**	--	**214**	--	--	--
	8/10/2007	**CSG-1-SOI-110120-A**	**11**	**12**	--	**5820**	--	--	--	--	--	**11.57**	--	**216**	--	--	--
	8/10/2007	**CSG-1-SOI-120125-A**	**12**	**12**	--	**3340**	--	--	--	--	--	**11.37**	--	**225**	--	--	--
	8/10/2007	**CSG-1-SOI-145150-A**	**14**	**15**	--	**3980**	--	--	--	--	--	**11.38**	--	**229**	--	--	--
	8/10/2007	CSG-1-SOI-150180-A	15	18	--	809	--	--	--	--	--	10.94	--	182	--	--	--
CSG-2	8/9/2007	CSG-2-SOI-020035-A	2	3	2580	184	8740	41900	21000	24100	267	11.05	786 B	248	320 B	338	151
	8/9/2007	**CSG-2-SOI-035040-A**	**3**	**4**	**22700**	**6870**	**41100**	**179000**	**112000**	**41800**	**1040**	**11.43**	**12000 U**	**165**	**2000 B**	**2070**	**1050**
	8/9/2007	**CSG-2-SOI-050060-A**	**5**	**6**	**18700**	**5230**	**37700**	**153000**	**94500**	**31500**	**890**	**11.63**	**12000 U**	**239**	**1220 B**	**1620**	**928**
	8/9/2007	**CSG-2-SOI-085115-A**	**8**	**11**	**18700**	**9480**	**48000**	**190000**	**121000**	**41300**	**1090**	**12.17**	**13000 U**	**262**	**1350 B**	**2250**	**1090**
	8/9/2007	**CSG-2-SOI-120140-AD**	**12**	**14**	**18300**	**5760**	**52800**	**215000**	**133000**	**46100**	**1220**	**12.16**	**12000 U**	**261**	**1610 B**	**2500**	**1220**
	8/9/2007	**CSG-2-SOI-120140-A**	**12**	**14**	**16300**	**6040**	**49700**	**203000**	**124000**	**43400**	**1150**	**12.1**	**12000 U**	**243**	**1790 B**	**2340**	**1140**
	8/9/2007	CSG-2-SOI-140160-A	14	16	--	156	--	--	--	--	--	10.89	--	219	--	--	--
	8/9/2007	CSG-2-SOI-170190-A	17	19	--	19.9	--	--	--	--	--	10.99	--	181	--	--	--
	8/9/2007	CSG-2-SOI-210215-A	21	21	--	4.9	--	--	--	--	--	9.79	--	126	--	--	--
	8/9/2007	CSG-2-SOI-215230-A	21	23	--	60.7	--	--	--	--	--	10.25	--	174	--	--	--
	8/9/2007	CSG-2-SOI-240260-A	24	26	--	28.1	--	--	--	--	--	11.22	--	165	--	--	--
	8/9/2007	CSG-2-SOI-280300-A	28	30	--	4.4	--	--	--	--	--	9.31	--	251	--	--	--
DMT-01S	12/11/2005	SODMT1S-0608	6	8	3.4	0.939 J	--	--	--	--	--	--	--	--	--	--	--
DMT-03S	12/10/2005	SODMT3S-1416	14	16	157	1.86 J	--	--	--	--	--	--	--	--	--	--	--
	12/10/2005	SODMT3S-2426	24	26	353	1.76 J	--	--	--	--	--	--	--	--	--	--	--
	12/13/2005	SODMT3SDUP-2426	24	26	253	5.27 J	--	--	--	--	--	--	--	--	--	--	--
DMT-05S	12/11/2005	**SODMT5S-1112**	**11**	**12**	**7760**	**372 J**	--	--	--	--	--	--	--	--	--	--	--
DMT-06S	12/9/2005	**SODMT6S-0810**	**8**	**10**	**32800**	**3980 J**	--	--	--	--	--	--	--	--	--	--	--
	12/9/2005	SODMT6S-2527	25	27	6560	12.2 J	--	--	--	--	--	--	--	--	--	--	--
DMT-07S	12/9/2005	**SODMT7S-1213**	**12**	**13**	**28700**	**4480 J**	--	--	--	--	--	--	--	--	--	--	--
	12/9/2005	**SODMT7S-1617**	**16**	**17**	**25100**	**2510 J**	--	--	--	--	--	--	--	--	--	--	--
DMT-08S	12/8/2005	**SODMT8S-1012**	**10**	**12**	**20900**	**3680 J**	--	--	--	--	--	--	--	--	--	--	--
	12/8/2005	SODMT8S-2426	24	26	8.5	6.99 J	--	--	--	--	--	--	--	--	--	--	--
DMT-09S	12/7/2005	**SODMT9S-0608**	**6**	**8**	**23500**	**10000**	--	--	--	--	--	--	--	--	--	--	--
	12/7/2005	**SODMT9S-1517**	**15**	**17**	**15200**	**7150**	--	--	--	--	--	--	--	--	--	--	--
	12/7/2005	**SODMT9SDUP-1517**	**15**	**17**	**17800**	**5630 J**	--	--	--	--	--	--	--	--	--	--	--
DMT-10S	12/6/2005	**SODMT10S-0810**	**8**	**10**	**31700**	**5260**	--	--	--	--	--	--	--	--	--	--	--
	12/6/2005	SODMT10S-1416	14	16	976	84 J	--	--	--	--	--	--	--	--	--	--	--
DMT-12S	12/12/2005	SODMT12S-1517	15	17	86.7	0.913 J	--	--	--	--	--	--	--	--	--	--	--
	12/12/2005	SODMT12S-2628	26	28	37.3	1.4 J	--	--	--	--	--	--	--	--	--	--	--
DMT-14S	12/10/2005	SODMT14S-2324	23	24	19.8	1.47 J	--	--	--	--	--	--	--	--	--	--	--
DMT-18S	12/12/2005	**SODMT18S-1416**	**14**	**16**	**26000**	**3550 J**	--	--	--	--	--	--	--	--	--	--	--
DMT-19S	12/13/2005	SODMT19S-1416	14	16	21.3	1.19 J	--	--	--	--	--	--	--	--	--	--	--
DMT-20S	12/13/2005	SODMT20S-1012	10	12	12.2	0.754 J	--	--	--	--	--	--	--	--	--	--	--
	12/13/2005	SODMT20S-1820	18	20	40.6	1.17 J	--	--	--	--	--	--	--	--	--	--	--

TABLE 4-1
Soil Analytical Results
Chromium Transport Study
Dundalk Marine Terminal, Baltimore, Maryland

Location	Date	Field Sample ID	Start Depth (feet)	End Depth (feet)	*Chromium (mg/kg)*	*Chromium (VI) (mg/kg)*	*Aluminum (mg/kg)*	*Calcium (mg/kg)*	*Iron (mg/kg)*	*Magnesium (mg/kg)*	*Manganese (mg/kg)*	*pH (std. units)*	*Potassium (mg/kg)*	*Redox Potential Vs H2*	*Sodium (mg/kg)*	*Titanium (mg/kg)*	*Vanadium (mg/kg)*
DMT-22S	12/11/2005	**SODMT22S-1012**	**10**	**12**	**10000**	**2920 J**	--	--	--	--	--	--	--	--	--	--	--
	12/11/2005	**SODMT22S-2224**	**22**	**24**	**25500**	**4080 J**	--	--	--	--	--	--	--	--	--	--	--
DMT-29S	11/18/2006	**DMT-29S-SOI-1414**	**14**	**14**	**21900 J**	**9500**	**51200**	**233000**	**142000**	**43700**	**1210**	**12.35**	**3200 UJ**	**127**	**6300 U**	--	**1600 J**
	11/18/2006	**DMT-29S-SOI-1417-D**	**14**	**17**	**21200 J**	**4220**	**63500**	**272000**	**159000**	**53600**	**1390**	**12.46**	**3200 UJ**	**117**	**6400 U**	--	**1570 J**
	11/18/2006	**DMT-29S-SOI-1417**	**14**	**17**	**20500 J**	**4290**	**62300**	**259000**	**152000**	**51500**	**1340**	**12.44**	**3300 UJ**	**112**	**6600 U**	--	**1530 J**
	11/18/2006	DMT-29S-SOI-3032	30	32	45.8 J	6	14000	658	10800	2190	89.3	8.97	1430 J	185	1200 U	--	29.3 J
	11/22/2006	**DMT-29S-SOI-1414-1**	**14**	**14**	**21400 J**	**8550**	**51300**	**221000**	**135000**	**42800**	**1180**	**12.33**	**3300 U**	**137**	**1030 B**	**2490**	**1510**
	11/22/2006	**DMT-29S-SOI-1414-2**	**14**	**14**	**22000 J**	**3690**	**65200**	**269000**	**162000**	**52500**	**1410**	**12.42**	**3100 U**	**126**	**4040 B**	**2930**	**1610**
	11/22/2006	**DMT-29S-SOI-1414-3**	**14**	**15**	**21300 J**	**4530**	**63800**	**263000**	**159000**	**52100**	**1410**	**12.57**	**3200 U**	**122**	**4810 B**	**2920**	**1580**
DMT-30S	12/3/2006	**DMT-30S-SOI-1013**	**10**	**13**	**19800**	**4500**	**59400**	**259000**	**145000**	**51200**	**1260**	**12.45**	**3400 U**	**103**	**6180 B**	**2660**	**1400**
	12/3/2006	DMT-30S-SOI-1718	17	18	137	0.87 B	12400	1470	22700	3260	587	11.32	1920	-120	10500	245	30
DMT-31S	11/20/2006	DMT-31S-SOI-2224	22	24	24.7 J	1.3	4990	590 U	52000	590 U	128	8.09	644 J	270	1200 U	--	38.6 J
DMT-32S	12/6/2006	DMT-32S-SOI-0406	4	6	11.4	1.4	1700	201 B	3970	49.6 B	3.4	6.28	173 B	421	494 B	36.3	19.8
	12/6/2006	DMT-32S-SOI-1012	10	12	6.2	0.9	889	48.6 B	3310	31.8 B	4.4	4.82	68.4 B	466	157 B	20.1	9.4
DMT-33S	12/2/2006	**DMT-33S-SOI-1214**	**12**	**14**	**19000**	**3890**	**59000**	**256000**	**145000**	**65400**	**1340**	**12.36**	**3200 U**	**150**	**4770 B**	**2420**	**1160**
	12/2/2006	**DMT-33S-SOI-1518**	**15**	**18**	**17100**	**3600**	**57800**	**251000**	**127000**	**67000**	**1650**	**12.34**	**3300 U**	**152**	**2980 B**	**1940**	**863**
DMT-34M	12/1/2006	**DMT-34M-SOI-1314-D**	**13**	**14**	**26800**	**3760**	**51100**	**255000**	**133000**	**47500**	**1280**	**12.39**	**69.5 B**	**146**	**3180 B**	--	**1330**
	12/1/2006	**DMT-34M-SOI-1314**	**13**	**14**	**25500**	**4440**	**49200**	**245000**	**126000**	**47500**	**1270**	**12.46**	**78.5 B**	**145**	**3180 B**	--	**1160**
	12/1/2006	DMT-34M-SOI-2324	23	24	43.1	1.2 U	13700	1200	27100	2680	215	8.3	1880	232	1460 B	--	32.6
	12/14/2006	DMT-34M-SOI-6364	63	64	87	1.2 U	12400	21300	50400	2260	1220	7.86	1510	252	1100 B	--	47.6
	12/15/2006	DMT-34M-SOI-7273	72	73	44.1	1.1	5950	320 B	47500	229 B	165	9.3	839 B	269	299 B	--	73.9
	12/15/2006	DMT-34M-SOI-8283	82	83	29.6	0.73 J	1130	3630	1800	186 B	15	5.31	71 B	480	328 B	--	5.6 B
DMT-35M	12/4/2006	**DMT-35M-SOI-0809**	**8**	**9**	**3720**	**768**	**28700**	**127000**	**11400**	**40500**	**692**	**11.62**	**472 B**	**156**	**874 B**	**705**	**102**
	12/5/2006	DMT-35M-SOI-2223	22	23	23.7	2.8	2000	299 B	1940	166 B	8.8	8.22	110 B	308	223 B	40.1	9
	12/5/2006	DMT-35M-SOI-3233-D	32	33	2.8	0.66 J	388	46.3 B	573	33.2 B	5.2	8.48	620 U	358	156 B	45	3.4 B
	12/5/2006	DMT-35M-SOI-3233	32	33	25.9	3.8	545	381 B	728	97.8 B	8.2	8.88	17.1 B	333	160 B	29.7	3.9 B
	12/5/2006	DMT-35M-SOI-4243	42	43	18.9	1.7	713	176 B	4960	64.4 B	5.1	7.73	49.4 B	434	120 B	16	12.7
	12/5/2006	DMT-35M-SOI-5253	52	53	5.3	1.9	584	78.2 B	649	42.7 B	12.1	7.6	32.6 B	438	88.1 B	29.4	5.1 B
	12/5/2006	DMT-35M-SOI-6263	62	63	7.8	7.9	194	72.5 B	2220	19.4 B	3.1	7.9	580 U	428	1200 U	9.5	2.8 B
	12/5/2006	DMT-35M-SOI-7273	72	73	5.7	0.59 J	1330	140 B	432	56.1 B	2.8	4.74	167 B	521	96.9 B	88.8	8.9
	12/5/2006	DMT-35M-SOI-8283	82	83	8.3	1.9	274	95.7 B	3350	23.6 B	3.5	8.28	570 U	442	105 B	15.9	39
	12/6/2006	DMT-35M-SOI-9293	92	93	9.5	0.96 U	1440	100 B	611	43.4 B	2.9	4.92	265 B	519	101 B	57	16.4
DMT-36M	11/29/2006	**DMT-36M-SOI-1314**	**13**	**14**	**27500**	**4810**	**45700**	**200000**	**124000**	**37200**	**986**	**12.01**	**81.8 B**	**135**	**2660 B**	--	**1070**
	11/29/2006	DMT-36M-SOI-1819	18	19	492	24 U	30400	159000	4070	35800	1370	10.86	1850	132	1250 B	--	16.8
	12/16/2006	DMT-36M-SOI-4446	44	46	44.6	1.3 UJ	18500	6970	43100	4710	1250	7.21	2510	257	597 B	--	40.4
	12/17/2006	DMT-36M-SOI-5456	54	56	51.1	1.3 UJ	17900	2280	42800	3920	605	6.69	2110	324	459 B	--	52.9
	12/17/2006	DMT-36M-SOI-6264-D	62	64	50	0.85 J	14200	1640	37300	2820	718	6.42	1540	389	193 B	--	41.2
	12/17/2006	DMT-36M-SOI-6264	62	64	46.1	1.2 UJ	15400	1760	38700	3180	701	6.44	1660	337	229 B	--	46.5
	12/17/2006	DMT-36M-SOI-7476	74	76	57.6	0.95 UJ	2150	545 B	2830	273 B	36.5	7.2	141 B	277	106 B	--	7.4
	12/17/2006	DMT-36M-SOI-8284	82	83	6.9	1.2 J	785	80.2 B	389	48.4 B	7.6	6.9	91.8 B	4130	101 B	--	3.2 B
	12/17/2006	DMT-36M-SOI-9293	92	93	5.5	1.3 K	252	71.7 B	284	26 B	3.9	7.16	41.3 B	363	127 B	--	1.6 B
	12/17/2006	DMT-36M-SOI-102103	102	103	27.2	4.2 J	492	113 B	8160	41.2 B	11.3	7.19	43.8 B	428	107 B	--	20
	12/18/2006	DMT-36M-SOI-112113	112	113	37.2	1.3 J	4650	89.9 B	42800	123 B	98.2	4.81	815	554	122 B	--	94.8
DMT-37M	12/2/2006	**DMT-37M-SOI-1314**	**13**	**14**	**39100 L**	--	**58600**	**258000**	**148000**	**48400**	**1140**	--	**102 B**	--	**4240**	**2610**	**1420**
	12/2/2006	DMT-37M-SOI-2324	23	24	10500 L	--	20900	8360	28500	6040	380	--	2610	--	22900	449	63.7
	1/2/2007	DMT-37M-SOI-4749	47	49	53.5 L	1.4 U	20600	4300	44000	5160	1250	6.71	2560	347	899 B	279	38.3
	1/3/2007	DMT-37M-SOI-5759	57	59	48.5 L	1.2 U	16500	2280	39300	4240	663	6.41	2000	437	421 B	521	44.7
	1/3/2007	DMT-37M-SOI-6769	67	69	50 L	1.2 U	13900	1770	29400	3800	530	6.37	1580	438	251 B	753	45.7
	1/3/2007	DMT-37M-SOI-7779	77	79	73.2 L	1.2 U	15000	1730	31500	3170	265	6.12	1190	413	234 B	509	51.4
	1/3/2007	DMT-37M-SOI-8789	87	87	11.3 L	0.94 J	557	113 B	1170	106 B	12.8	6.8	64.8 B	401	158 B	42.9	5.7 B
	1/3/2007	DMT-37M-SOI-9799	97	97	135 L	4.5	1800	1190	3300	520 B	43.7	8.24	187 B	400	182 B	95.3	11.2
	1/4/2007	DMT-37M-SOI-107109	107	108	14.9 L	1.9	988	114 B	5190	102 B	17.6	6.65	71.6 B	417	148 B	43.7	5.6 B
	1/4/2007	DMT-37M-SOI-112114	112	113	32.2 L	0.96 U	4610	242 B	48400	218 B	95.9	5.16	717	467	159 B	276	47.4

TABLE 4-1
Soil Analytical Results
Chromium Transport Study
Dundalk Marine Terminal, Baltimore, Maryland

Location	Date	Field Sample ID	Start Depth (feet)	End Depth (feet)	Chromium (mg/kg)	Chromium (VI) (mg/kg)	Aluminum (mg/kg)	Calcium (mg/kg)	Iron (mg/kg)	Magnesium (mg/kg)	Manganese (mg/kg)	pH (std. units)	Potassium (mg/kg)	Redox Potential Vs H2	Sodium (mg/kg)	Titanium (mg/kg)	Vanadium (mg/kg)
DMT-38M	11/28/2006	DMT-38M-SOI-0810	8	10	54.9	2.8	5950	830	5610	522 B	42.7	9.37	552 B	270	208 B	70.9	17.1
	11/28/2006	DMT-38M-SOI-3839	38	39	3.6	0.95 U	691	109 B	896	55 B	2.7	7.6	28.8 B	277	133 B	27.4	6.1
	11/28/2006	DMT-38M-SOI-4848	48	48	5.3	0.67 J	295	88 B	3230	36.1 B	4.8	7.6	620 U	292	141 B	15.2	9.4
	12/12/2006	DMT-38M-SOI-5759	57	59	3.2	0.9 U	489	123 B	615	46.9 B	1.6 B	8.8	20.5 B	264	98.2 B	14	3.4 B
	12/12/2006	DMT-38M-SOI-6769	67	69	14.8	1.5	2660	153 B	3300	54.8 B	1.1 B	6.31	352 B	191	95.7 B	14.7	20.5
	12/12/2006	DMT-38M-SOI-7777	77	77	10	1.4	2240	644	2280	101 B	5.3	8.23	286 B	361	1200 U	25	21.9
	12/13/2006	DMT-38M-SOI-8787	87	87	2.9	1 U	336	322 B	702	21.4 B	2.3	11.02	19.3 B	188	114 B	23.2	6 B
	12/13/2006	DMT-38M-SOI-107107	107	107	7.2	0.57 J	1840	144 B	688	53.9 B	2.1	5.85	273 B	378	1200 U	30.6	6.3
	12/13/2006	DMT-38M-SOI-117118	117	118	2.9	0.95 U	425	196 B	2920	19.3 B	2.1	9.11	60.5 B	317	123 B	--	23.4
	12/13/2006	DMT-38M-SOI-120121	120	121	12.6	0.76 J	2800	129 B	1500	99.9 B	4	5.05	871	548	106 B	--	9
DMT-39S	2/16/2007	DMT-39S-SOI-0407	4	7	64.8 L	10	12100	1080	14600	780	8.8	7.31	--	398	--	--	32.2
	2/16/2007	DMT-39S-SOI-1011	10	11	72.5 L	6.3 L	12000	262	70900	781	18.3	4.23	--	536	--	--	36.6
	2/16/2007	DMT-39S-SOI-1719	17	19	10.3 L	1.2 L	2270	82.4	9650	165	12.4	4.26	--	557	--	--	8.9
DMT-49US	7/24/2007	DMT-49US-SOI-210220-A	21	22	50.1	1.7 U	28900	3040	39700	7640	1380	8.5	4770	141	3640	271	59.7
DMT-50US	7/25/2007	DMT-50US-SOI-280290-A	28	29	89.5	1.3 U	27400	6010	32400	5010	641	7.8	2970	40.1	2540	464	56
DMT-51US	8/14/2007	DMT-51US-SOI-350355-A	35	35	2720	654	6920	22200	16300	4670	141	11.3	357 B	258	887 B	236	123
DMT-52US	8/13/2007	DMT-52US-SOI-220225-A	22	22	2790	851	19100	28500	36700	11100	767	11.82	2420	242	5260	424	218
DMT-53US	7/26/2007	DMT-53US-SOI-080090-A	8	9	521	21.6	17500	796	22300	2070	120	10.15	981 B	-78	2600	316	39.3
DMT-63S	10/20/2008	DMT-63S-SOI-1718	17	18	50.6	1.2	--	--	--	--	--	5.75	--	416	--	--	--
	10/20/2008	DMT-63S-SOI-2324	23	24	218	2.3	--	--	--	--	--	11.4	--	259	--	--	--
	10/20/2008	DMT-63S-SOI-2324-D	23	24	181	2.4	--	--	--	--	--	11.5	--	245	--	--	--
	10/20/2008	DMT-63S-SOI-2930	29	30	35.4	0.28 U	--	--	--	--	--	5.86	--	256	--	--	--
	10/20/2008	DMT-63S-SOI-3536	35	36	40.1	0.30 U	--	--	--	--	--	5.71	--	256	--	--	--
DMT-64US	10/23/2008	DMT-64US-SOI-0610	6	10	2.76 L	0.23 U	--	--	--	--	--	8.83	--	442	--	--	--
	10/23/2008	DMT-64US-SOI-1418	14	18	7.25 L	0.23 U	--	--	--	--	--	9.83	--	492	--	--	--
	10/23/2008	DMT-64US-SOI-2226	22	26	760 L	2.1	--	--	--	--	--	8.48	--	14.8	--	--	--
	10/23/2008	DMT-64US-SOI-3034	30	34	81.5 L	2.1	--	--	--	--	--	7.91	--	327	--	--	--
	10/23/2008	DMT-64US-SOI-3842	38	42	7.17 L	0.66 J	--	--	--	--	--	8.18	--	319	--	--	--
DMT-65US	10/14/2008	DMT-65US-SOI-0610	6	10	23.2 J	1.8 J	--	--	--	--	--	8.88	--	342	--	--	--
	10/14/2008	DMT-65US-SOI-1418	14	18	51.2 J	1.4 J	--	--	--	--	--	10.4	--	257	--	--	--
	10/14/2008	DMT-65US-SOI-2226	22	26	271 J	1.9 J	--	--	--	--	--	10.7	--	204	--	--	--
	10/14/2008	DMT-65US-SOI-3034	30	34	69.1 J	2.6	--	--	--	--	--	8.39	--	287	--	--	--
	10/14/2008	DMT-65US-SOI-3842	38	42	20.8 J	0.25 U	--	--	--	--	--	8.56	--	291	--	--	--
DMT-66US	10/26/2008	DMT-66US-SOI-0610	6	10	30.2	0.61 J	--	--	--	--	--	5.33	--	524	--	--	--
	10/26/2008	DMT-66US-SOI-1418	14	18	29.7	0.82 J	--	--	--	--	--	4.84	--	404	--	--	--
	10/26/2008	DMT-66US-SOI-2226	22	26	21.7	1.2	--	--	--	--	--	7.56	--	356	--	--	--
	10/26/2008	DMT-66US-SOI-3034	30	34	24.5	0.27 U	--	--	--	--	--	8.29	--	189	--	--	--
	10/26/2008	DMT-66US-SOI-3034-D	30	34	21.9	0.50 J	--	--	--	--	--	8.38	--	-7.9	--	--	--
	10/26/2008	DMT-66US-SOI-3842	38	42	36.0	2.4	--	--	--	--	--	7.09	--	157	--	--	--
	10/26/2008	DMT-66US-SOI-4650	46	50	36.2	0.29 U	--	--	--	--	--	6.7	--	194	--	--	--
DMT-67US	11/7/2008	DMT-67US-SOI-0206	2	6	27.4 J	0.50 J	--	--	--	--	--	6.86	--	435	--	--	--
	11/7/2008	DMT-67US-SOI-1014	10	14	13.5 J	0.26 J	--	--	--	--	--	7.26	--	417	--	--	--
	11/7/2008	DMT-67US-SOI-1822	18	22	27.5 J	0.36 J	--	--	--	--	--	4.85	--	424	--	--	--
	11/7/2008	DMT-67US-SOI-2630	26	30	34.3 U	0.27 J	--	--	--	--	--	7.49	--	289	--	--	--
	11/7/2008	DMT-67US-SOI-2630-D	26	30	27.3 J	0.33 J	--	--	--	--	--	7.71	--	315	--	--	--
	11/7/2008	DMT-67US-SOI-3438	34	38	20.2 J	0.84 J	--	--	--	--	--	7.48	--	261	--	--	--
DMT-68US	11/8/2008	DMT-68US-SOI-0206	2	6	10.9 U	0.22 J	--	--	--	--	--	10.1	--	249	--	--	--
	11/8/2008	DMT-68US-SOI-1014	10	14	6.88 J	0.32 J	--	--	--	--	--	5.48	--	370	--	--	--
	11/8/2008	DMT-68US-SOI-1822	18	22	8.63 J	0.52 J	--	--	--	--	--	5.29	--	360	--	--	--
	11/8/2008	DMT-68US-SOI-2630	26	30	26.2 J	0.28 J	--	--	--	--	--	6.42	--	48.2	--	--	--
	11/8/2008	DMT-68US-SOI-2630-D	26	30	17.3 J	1.1 J	--	--	--	--	--	6.94	--	206	--	--	--
	11/8/2008	DMT-68US-SOI-3438	34	38	25.4 J	0.42 J	--	--	--	--	--	6.82	--	252	--	--	--
	11/8/2008	DMT-68US-SOI-4246	42	46	38.5 U	0.33 J	--	--	--	--	--	6.04	--	186	--	--	--

TABLE 4-1
Soil Analytical Results
Chromium Transport Study
Dundalk Marine Terminal, Baltimore, Maryland

Location	Date	Field Sample ID	Start Depth (feet)	End Depth (feet)	*Chromium (mg/kg)*	*Chromium (VI) (mg/kg)*	*Aluminum (mg/kg)*	*Calcium (mg/kg)*	*Iron (mg/kg)*	*Magnesium (mg/kg)*	*Manganese (mg/kg)*	*pH (std. units)*	*Potassium (mg/kg)*	*Redox Potential Vs H2*	*Sodium (mg/kg)*	*Titanium (mg/kg)*	*Vanadium (mg/kg)*
DMT-69US	11/5/2008	DMT-69US-SOI-0206	2	6	25.0 J	0.71 J	--	--	--	--	--	5.38	--	521	--	--	--
	11/5/2008	DMT-69US-SOI-1014	10	14	18.7 J	0.39 J	--	--	--	--	--	5.83	--	393	--	--	--
	11/5/2008	DMT-69US-SOI-1822	18	22	18.1 J	0.49 J	--	--	--	--	--	5.06	--	468	--	--	--
	11/5/2008	DMT-69US-SOI-2630	26	30	191 J	8.4	--	--	--	--	--	7.96	--	325	--	--	--
	11/5/2008	DMT-69US-SOI-3438	34	38	27.1 J	0.45 J	--	--	--	--	--	7.11	--	237	--	--	--
	11/5/2008	DMT-69US-SOI-4248	42	48	39.5 J	0.33 U	--	--	--	--	--	6.21	--	183	--	--	--
DMT-70US	10/25/2008	DMT-70US-SOI-0610	6	10	25.0 L	0.47 J	--	--	--	--	--	7.28	--	355	--	--	--
	10/25/2008	DMT-70US-SOI-1418	14	18	22.2 L	0.30 J	--	--	--	--	--	5.29	--	416	--	--	--
	10/25/2008	DMT-70US-SOI-2226	22	26	57.9 L	3.3	--	--	--	--	--	8.31	--	73.2	--	--	--
	10/25/2008	DMT-70US-SOI-3039	30	39	67.2 L	0.28 U	--	--	--	--	--	8.19	--	39.0	--	--	--
	10/25/2008	DMT-70US-SOI-3842	38	42	35.3 L	1.9	--	--	--	--	--	6.65	--	173	--	--	--
DMT-71US	10/12/2008	DMT-71US-SOI-0104	1	4	66.7 J	8.4	--	--	--	--	--	8.6	--	542	--	--	--
	10/12/2008	DMT-71US-SOI-0812	8	12	14.5 J	0.65 J	--	--	--	--	--	5.06	--	542	--	--	--
	10/12/2008	DMT-71US-SOI-1620	16	20	17.2	0.88 J	--	--	--	--	--	5.41	--	437	--	--	--
	10/12/2008	DMT-71US-SOI-2428	24	28	1850	0.35 J	--	--	--	--	--	10.3	--	114	--	--	--
	10/12/2008	DMT-71US-SOI-3236	32	36	43.6	0.32 J	--	--	--	--	--	6.5	--	270	--	--	--
	10/12/2008	DMT-71US-SOI-4044	40	44	4.93	0.65 J	--	--	--	--	--	6.27	--	352	--	--	--
DMT-72US	9/25/2008	DMT-72US-SOI-1216	12	16	250 J	0.65 B	--	--	--	--	--	10.5	--	369	--	--	--
	9/25/2008	DMT-72US-SOI-1620	16	20	206 J	1.7 J	--	--	--	--	--	10.5	--	245	--	--	--
	9/25/2008	DMT-72US-SOI-2428	24	28	2.96 J	0.36 B	--	--	--	--	--	10.6	--	279	--	--	--
	9/25/2008	DMT-72US-SOI-3236	32	36	55.0 J	0.29 U	--	--	--	--	--	6.29	--	316	--	--	--
	9/25/2008	DMT-72US-SOI-3840	38	40	6.09 J	0.65 J	--	--	--	--	--	6.46	--	436	--	--	--
DMT-73US	9/27/2008	DMT-73US-SOI-0812	8	12	55.8 J	3.0	--	--	--	--	--	4.9	--	564	--	--	--
	10/13/2008	DMT-73US-SOI-1719	17	19	38.4	0.28 U	--	--	--	--	--	5.47	--	328	--	--	--
	10/13/2008	DMT-73US-SOI-1719-D	17	19	32.4	0.28 U	--	--	--	--	--	5.77	--	296	--	--	--
	10/13/2008	DMT-73US-SOI-2426	24	26	40.6	0.42 J	--	--	--	--	--	5.19	--	268	--	--	--
	10/13/2008	DMT-73US-SOI-3133	31	33	3.00	0.50 J	--	--	--	--	--	5.46	--	386	--	--	--
	10/13/2008	DMT-73US-SOI-3840	38	40	27.6	2.1	--	--	--	--	--	5.18	--	475	--	--	--
	10/13/2008	DMT-73US-SOI-4547	45	47	1.59 J	0.33 J	--	--	--	--	--	6.31	--	443	--	--	--
DMT-74US	10/13/2008	DMT-74US-SOI-0812	8	12	23.8	1.4	--	--	--	--	--	6.3	--	355	--	--	--
	10/13/2008	DMT-74US-SOI-1620	16	20	12.9	1.8	--	--	--	--	--	6.05	--	304	--	--	--
	10/28/2008	DMT-74US-SOI-2527	25	27	83.8	5.4	--	--	--	--	--	5.8	--	283	--	--	--
	10/28/2008	DMT-74US-SOI-3234	32	34	7.02	1.0 J	--	--	--	--	--	7.42	--	395	--	--	--
	10/28/2008	DMT-74US-SOI-3841	38	41	2.75	0.23 U	--	--	--	--	--	7.38	--	424	--	--	--
	10/28/2008	DMT-74US-SOI-3841-D	38	41	2.18	0.23 U	--	--	--	--	--	7.36	--	406	--	--	--
	10/28/2008	DMT-74US-SOI-4647	46	47	1.94	0.24 U	--	--	--	--	--	7.5	--	307	--	--	--
DMT-75US	10/13/2008	DMT-75US-SOI-1216	12	16	27.3	3.4	--	--	--	--	--	5.83	--	449	--	--	--
	10/27/2008	DMT-75US-SOI-2123	21	23	17.1	0.54 J	--	--	--	--	--	6.07	--	281	--	--	--
	10/27/2008	DMT-75US-SOI-2831	28	31	2.91	0.22 U	--	--	--	--	--	7.02	--	383	--	--	--
	10/27/2008	DMT-75US-SOI-3537	35	37	1.14 J	0.25 U	--	--	--	--	--	7.21	--	455	--	--	--
	10/27/2008	DMT-75US-SOI-3537-D	35	37	2.03	0.24 U	--	--	--	--	--	7.16	--	448	--	--	--
INC-1	11/17/2006	**INC-1-SOI-1921**	**19**	**21**	**17100 J**	**2930**	**43500**	**189000**	**109000**	**37400**	**978**	**12.55**	**2900 UJ**	**113**	**5900 U**	--	**1150 J**
	11/17/2006	**INC-1-SOI-2122**	**21**	**22**	**26300 J**	**2240**	**52500**	**246000**	**137000**	**46100**	**1220**	**12.76**	**3300 UJ**	**95.2**	**7620**	--	**1370 J**
INC-10	12/4/2006	**INC-10-SOI-1113**	**11**	**13**	**18800**	**2500**	**64100**	**258000**	**156000**	**56000**	**1370**	**12.46**	**3200 U**	**136**	**3650 B**	**2850**	**1450**
	12/4/2006	**INC-10-SOI-1314**	**13**	**14**	**19800**	**8580**	**52100**	**210000**	**140000**	**47300**	**1180**	**12.53**	**1400 U**	**141**	**309 B**	**2590**	**1620**
INC-11	10/22/2006	**INC-11-SOI-0810**	**8**	**10**	**22900**	**3880**	**50100**	**266000**	**131000**	**46200**	**1150**	**12.53**	**590 U**	**134**	**4160**	**2490**	**1320**
	10/22/2006	**INC-11-SOI-2527**	**25**	**27**	**31000 J**	**12600**	**49800**	**217000**	**122000**	**50000**	**1090**	**12.41**	**710 U**	**121**	**7230**	**2280**	**1260**
INC-12	11/14/2006	**INC-12-SOI-1314**	**13**	**14**	**21100**	**5150**	**42000**	**175000**	**103000**	**36400**	**930**	**12.49**	**3100 U**	**115**	**6300 U**	--	**996**
	11/14/2006	**INC-12-SOI-1618**	**16**	**18**	**26800**	**6130**	**42100**	**185000**	**107000**	**34400**	**942**	**12.39**	**3200 U**	**99.9**	**6500 U**	--	**996**
	11/14/2006	INC-12-SOI-3638	36	38	25.1	5.4	938	600 U	980	600 U	4.1	8.78	600 U	219	1200 U	--	6 U
	11/22/2006	INC-12-SOI-1111	11	11	25600 J	6040	49200	215000	124000	42800	1090	12.26	61.7 B	131	2150 B	2280	1140
	11/22/2006	INC-12-SOI-1414	14	14	28700 J	7050	51700	227000	130000	44700	1140	12.33	3300 U	133	2400 B	2420	1210
	11/22/2006	INC-12-SOI-1515	15	15	25500	5160	43800	187000	106000	34500	948	12.03	289 B	206	2410 B	--	1100
	12/14/2006	INC-12-SOI-1515-2	15	15	26500 J	5700	46800	208000	118000	40100	1070	12.32	203 B	130	2680 B	2170	1110
	12/15/2006	INC-12-SOI-1616-2	16	16	27000	4770	57500	253000	141000	49300	1270	12.18	5900 U	154	4810 B	--	1440

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Chromium Transport Study
Dundalk Marine Terminal, Baltimore, Maryland

Location	Date	Field Sample ID	Start Depth (feet)	End Depth (feet)	*Chromium (mg/kg)*	*Chromium (VI) (mg/kg)*	*Aluminum (mg/kg)*	*Calcium (mg/kg)*	*Iron (mg/kg)*	*Magnesium (mg/kg)*	*Manganese (mg/kg)*	*pH (std. units)*	*Potassium (mg/kg)*	*Redox Potential Vs H2*	*Sodium (mg/kg)*	*Titanium (mg/kg)*	*Vanadium (mg/kg)*
INC-13	10/22/2006	**INC-13-SOI-0709**	**7**	**9**	**25400 J**	**2950**	**49000**	**240000**	**116000**	**56700**	**1260**	**12.42**	**760 U**	**145**	**2620**	**1890**	**963**
INC-14	11/7/2006	**INC-14-SOI-0608**	**6**	**8**	**24900 J**	**6180**	**59100**	**249000**	**147000**	**47600**	**1200**	**12.41**	**610 U**	**113**	**4680**	**2650**	**1330**
	11/7/2006	INC-14-SOI-3335	33	35	24.3 J	2.1	7630	919	14800	1280	223	7.66	777	243	1200 U	152	26.4
INC-15	10/22/2006	**INC-15-SOI-1415**	**14**	**15**	**6810 J**	**708**	**23400**	**79500**	**48000**	**16200**	**417**	**12.32**	**560 U**	**160**	**1100 U**	--	**458**
INC-16	10/22/2006	**INC-16-SOI-0808**	**8**	**8**	**22100 J**	**3330**	**44100**	**205000**	**108000**	**40500**	**1040**	**12.1**	**560 U**	**136**	**3640**	**1830**	**1010**
	10/22/2006	**INC-16-SOI-0911**	**9**	**11**	**41100 J**	**7330**	**48200**	**255000**	**92700**	**58800**	**1610**	**12.41**	**740 U**	**140**	**2680**	**1260**	**537**
INC-17	10/25/2006	**INC-17-SOI-0406**	**4**	**6**	**9350**	**604**	**30200**	**110000**	**70400**	**24000**	**766**	**11.82**	**3200 U**	**126**	**6400 U**	--	**545**
	10/25/2006	**INC-17-SOI-1214**	**12**	**14**	**26100**	**6210 J**	**47800**	**212000**	**123000**	**35300**	**1030**	**12.37**	**3300 U**	**93.9**	**7010**	--	**1270**
INC-18	10/25/2006	**INC-18-SOI-0508**	**5**	**8**	**23800**	**6840**	**48000**	**207000**	**119000**	**41900**	**1030**	**12.2**	**2900 U**	**145**	**5900 U**	--	**1090**
	10/25/2006	**INC-18-SOI-0810-D**	**8**	**10**	**22000**	**6650**	**42500**	**178000**	**103000**	**34800**	**951**	**12.02**	**2900 U**	**163**	**5900 U**	--	**991**
	10/25/2006	**INC-18-SOI-0810**	**8**	**10**	**22100**	**7270 J**	**41300**	**177000**	**102000**	**34500**	**938**	**12.04**	**3000 U**	**157**	**6000 U**	--	**978**
	12/15/2006	**INC-18-SOI-0808**	**8**	**8**	**26300**	**9420**	**50900**	**222000**	**125000**	**43900**	**1100**	**11.18**	**116 B**	**166**	**2330 B**	--	**1160**
	12/15/2006	**INC-18-SOI-0909**	**9**	**9**	**28300**	**15100**	**45800**	**220000**	**121000**	**41700**	**1070**	**12.27**	**109 B**	**146**	**2460 B**	--	**1170**
	12/15/2006	**INC-18-SOI-101-2**	**10**	**10**	**32700**	**5920**	**53600**	**251000**	**133000**	**43300**	**1210**	**12.17**	**157 B**	**188**	**3820 B**	--	**1300**
	12/15/2006	**INC-18-SOI-1111-2**	**11**	**11**	**32400**	**9770**	**46100**	**220000**	**119000**	**38800**	**1060**	**12.14**	**199 B**	**179**	**3090 B**	--	**1180**
	12/15/2006	**INC-18-SOI-1212-2**	**12**	**12**	**34000**	**5690**	**53700**	**265000**	**140000**	**46300**	**1250**	**12.12**	**91 B**	**178**	**4200 B**	--	**1350**
	12/15/2006	**INC-18-SOI-1313**	**13**	**13**	**24400**	**1830**	**42300**	**193000**	**104000**	**32700**	**899**	**12.12**	**287 B**	**173**	**2290 B**	--	**1000**
INC-19	10/31/2006	**INC-19-SOI-1618**	**16**	**18**	**16100**	**3220 J**	**34300**	**137000**	**79500**	**27300**	**708**	**12**	**2900 U**	**108**	**6660**	--	**800**
INC-20	11/7/2006	**INC-20-SOI-0506**	**5**	**6**	**21700 J**	**4130**	**61700**	**272000**	**147000**	**45300**	**1260**	**12.37**	**2900 U**	**118**	**5700 U**	**3240**	**1560**
INC-21	10/22/2006	**INC-21-SOI-0506**	**5**	**6**	**25700 J**	**19500**	**53900**	**190000**	**111000**	**37400**	**910**	**12.18**	**620 U**	**167**	**1200 U**	**2020**	**1120**
	10/22/2006	**INC-21-SOI-1213**	**12**	**13**	**13800 J**	**3020**	**56300**	**233000**	**138000**	**47700**	**1110**	**12.27**	**690 U**	**146**	**4950**	**2420**	**1290**
INC-22	10/22/2006	**INC-22-SOI-0102**	**1**	**2**	**22400 J**	**6850**	**43800**	**192000**	**112000**	**38700**	**899**	**11.5**	**570 U**	**164**	**1100 U**	**2070**	**1000**
INC-23	11/3/2006	**INC-23-SOI-0608**	**6**	**8**	**23400 J**	**4860 L**	**65400**	**268000**	**153000 J**	**49400 J**	**1340**	**12.38**	**580 UL**	**85.9**	**6710**	--	**1600 J**
	11/3/2006	INC-23-SOI-0811	8	11	283 J	0.99 U	15400	580 U	18700 J	1500 J	40	9.78	629 L	194	3920	--	36.8 J
INC-3	12/3/2006	**INC-3-SOI-1113**	**11**	**13**	**35400**	**6010**	**61200**	**265000**	**152000**	**52100**	**1330**	**12.39**	**3200 U**	**111**	**4020 B**	**2710**	**1420**
	12/3/2006	**INC-3-SOI-1819**	**18**	**19**	**28200**	**5310**	**52300**	**228000**	**131000**	**45100**	**1150**	**12.41**	**45.2 B**	**103**	**3370 B**	**2420**	**1330**
INC-4	12/4/2006	**INC-4-SOI-0809**	**8**	**9**	**24100**	**5650**	**44300**	**214000**	**112000**	**39400**	**1050**	**12.19**	**2900 U**	**122**	**1210 B**	**2100**	**1030**
	12/4/2006	**INC-4-SOI-1214-D**	**12**	**14**	**24800**	**5430**	**65100**	**267000**	**158000**	**52900**	**1380**	**12.61**	**3100 U**	**122**	**4740 B**	**2880**	**1500**
	12/4/2006	**INC-4-SOI-1214**	**12**	**14**	**24700**	**5510**	**63400**	**262000**	**152000**	**51400**	**1330**	**12.56**	**3100 U**	**116**	**4660 B**	**2770**	**1470**
INC-5	11/7/2006	**INC-5-SOI-0507**	**5**	**7**	**23300 J**	**4230**	**61000**	**268000**	**151000**	**53800**	**1350**	**12.42**	**3200 U**	**121**	**6300 U**	**2750**	**1520**
	11/7/2006	**INC-5-SOI-0810**	**8**	**10**	**22400 J**	**3560**	**60700**	**269000**	**150000**	**53400**	**1340**	**12.38**	**3000 U**	**118**	**6000 U**	**2720**	**1530**
INC-6	11/3/2006	INC-6-SOI-1718	17	18	1460 J	1.8 U	20200	2130	78700 J	5380 J	485	7.75	2410 L	186	3980	--	178 J
INC-8	12/16/2006	**INC-8-SOI-0708**	**7**	**8**	**20100**	**3800 K**	**62600**	**251000**	**164000**	**49100**	**1300**	**12.52**	**3000 U**	**146**	**4270 B**	--	**1330**
	12/16/2006	**INC-8-SOI-1214**	**12**	**14**	**20500**	**5390 J**	**54000**	**221000**	**145000**	**44200**	**1150**	**12.57**	**84.9 B**	**179**	**4640 B**	--	**1170**
INC-9	11/7/2006	**INC-9-SOI-1012-D**	**10**	**12**	**17200**	**5020**	**56500**	**241000**	**128000**	**60500**	**1550**	**12.82**	**3200 U**	**111**	**6300 U**	--	**1060**
	11/7/2006	**INC-9-SOI-1012**	**10**	**12**	**18000**	**5090**	**62300**	**260000**	**142000**	**66200**	**1720**	**12.76**	**3000 U**	**112**	**6100 U**	--	**1170**
	11/7/2006	INC-9-SOI-2324	23	24	69.6	7.5	14300	1430	25300	3840	488	11.84	2350	-39	5920	--	33.6
	11/21/2006	INC-9-SOI-1010	10	10	16200 J	3320	64500	271000	148000	71400	1740	12.5	3200 U	121	2970 B	2260	1100
	1/8/2007	INC-9-SOI-0505-2	5	5	--	10200	--	--	--	--	--	11.8	--	167	--	--	--
	1/8/2007	INC-9-SOI-0505-3	5	5	16000	3860	44700	229000	123000	39100	1120	11.83	3000 U	171	1200 B	2110	1250
	1/8/2007	INC-9-SOI-0606	5	5	27900	2180	53500	244000	134000	43800	1320	12.05	6000 U	170	4660 B	2510	1630
INC-I-1	8/6/2007	**INC-I-1-SOI-090100-A**	**9**	**10**	**20000**	**8600**	**50500**	**199000**	**135000**	**42700**	**1200**	**10.89**	**283 B**	**170**	**1350 B**	**2470**	**1620**
SBA-D-1	7/10/2007	SBA-D-1-SOI-060070-A	6	7	1380	37.3 J	3860	39200	11100	5400	190	10.31	1100 U	397	426 B	180	94.3
	7/10/2007	**SBA-D-1-SOI-080090-A**	**8**	**9**	**26500**	**3620 J**	**51300**	**238000**	**126000**	**47700**	**1360**	**12.03**	**12000 U**	**113**	**3340 B**	**2180**	**1180**
	7/10/2007	**SBA-D-1-SOI-120130-A**	**12**	**13**	**24000**	**2970 J**	**47900**	**224000**	**118000**	**52500**	**1380**	**12.29**	**13000 U**	**171**	**4530 B**	**1970**	**943**
	7/10/2007	**SBA-D-1-SOI-170180-A**	**17**	**18**	**22400**	**4220 J**	**50900**	**233000**	**123000**	**53700**	**1340**	**12.13**	**12000 U**	**138**	**4420 B**	**2030**	**1120**
	7/10/2007	**SBA-D-1-SOI-220230-A**	**22**	**23**	**25500**	**3790 J**	**50500**	**230000**	**124000**	**42400**	**1190**	**12.28**	**12000 U**	**174**	**3820 B**	**2330**	**1280**
	7/10/2007	**SBA-D-1-SOI-250260-A**	**25**	**26**	**21100**	**2440 J**	**47500**	**213000**	**114000**	**40100**	**1140**	**12.07**	**13000 U**	**177**	**3870 B**	**2030**	**1110**
	7/10/2007	SBA-D-1-SOI-290300-A	29	30	147	1.3 UJ	23400	2370	32900	5140	834	9.51	3100	-47	3550	358	50.1
SBA-D-4	7/12/2007	SBA-D-4-SOI-060070-A	6	7	5.5	0.9 U	1010	19800	839	1350	39.9	8.83	495 B	296	247 B	36.4	6.5
	7/12/2007	SBA-D-4-SOI-080090-A	8	9	99.4	2.2	775	12100	2080	2370	47.8	9.1	170 B	152	128 B	61.2	9.8
	7/12/2007	SBA-D-4-SOI-110120-A	11	12	7.7	0.94 U	2320	21000	2110	164 B	57.2	9.06	89.4 B	189	292 B	32.5	9.4
	7/12/2007	SBA-D-4-SOI-170180-A	17	18	11.6	1	208	3490	200	42.8 B	9.1	9.28	39.6 B	205	192 B	26.1	2.7 B
	7/12/2007	SBA-D-4-SOI-220230-A	22	23	20.5	1 U	5670	10800	14400	1610	127	10.79	1080 B	129	1250	308	21.1
	7/12/2007	SBA-D-4-SOI-270280-A	27	28	68.2	1.2 J	24900	1970	37300	5610	370	8.07	2950	176	3090	530	53.5

TABLE 4-1
Soil Analytical Results
Chromium Transport Study
Dundalk Marine Terminal, Baltimore, Maryland

Location	Date	Field Sample ID	Start Depth (feet)	End Depth (feet)	Chromium (mg/kg)	Chromium (VI) (mg/kg)	Aluminum (mg/kg)	Calcium (mg/kg)	Iron (mg/kg)	Magnesium (mg/kg)	Manganese (mg/kg)	pH (std. units)	Potassium (mg/kg)	Redox Potential Vs H2	Sodium (mg/kg)	Titanium (mg/kg)	Vanadium (mg/kg)
SBA-D-5	7/12/2007	SBA-D-5-SOI-060070-A	6	7	59.7	0.92	588	27600	3280	451 B	87.9	9.01	108 B	215	291 B	35.8	11.3
	7/12/2007	SBA-D-5-SOI-070080-A	7	8	15.7	0.94 U	218	5190	298	60.9 B	15.4	9.08	39.2 B	228	141 B	30.7	4 B
	7/12/2007	SBA-D-5-SOI-110120-A	11	12	4.6	0.93 U	218	30400	323	151 B	100	8.94	56.3 B	267	300 B	32.1	3.6 B
	7/12/2007	SBA-D-5-SOI-150160-A	15	16	15	0.97 U	192	16200	233	102 B	104	8.93	36.6 B	265	286 B	30.1	2.5 B
	7/12/2007	SBA-D-5-SOI-200210-A	20	21	322	2.3	1350	5320	2940	1230	45.4	11.31	172 B	104	565 B	206	17.7
	7/12/2007	SBA-D-5-SOI-250260-AD	25	26	59.4	1.3 U	29900	1810	31900	4950	782	7.74	2710	140	1920	605	55.3
	7/12/2007	SBA-D-5-SOI-250260-A	25	26	81.6	1.6 U	27200	3010	37400	5670	397	7.78	3130	152	3090	509	55.8
	7/12/2007	SBA-D-5-SOI-270280-AD	27	28	78.5	1.5 U	28000	2270	37100	5950	429	7.68	3430	177	2930	475	55.7
	7/12/2007	SBA-D-5-SOI-270280-A	27	28	74.7	1.5 U	24600	2110	31700	5720	464	7.51	2740	143	2930	697	45.7
SBA-F-1	6/28/2007	SBA-F-1-SOI-050060-A	5	6	58.4	1.7	274	7930	772	355 J	25.8	9.15	27.8 J	324	1100 R	23	6.7
	6/28/2007	**SBA-F-1-SOI-065075-A**	**6**	**7**	**23300**	**4370**	**49800**	**211000**	**119000**	**52000**	**1270**	**12.36**	**13000 UJ**	**228**	**2300 J**	**1880**	**1000**
	6/28/2007	**SBA-F-1-SOI-100110-A**	**10**	**11**	**22000**	**2380**	**36300**	**163000**	**86400**	**33200**	**945**	**12.72**	**276 J**	**160**	**3000 J**	**1330**	**717**
	6/28/2007	**SBA-F-1-SOI-130140-A**	**13**	**14**	**22000**	**4810**	**44500**	**217000**	**104000**	**56900**	**1340**	**12.32**	**123 J**	**167**	**3830 J**	**1500**	**853**
	6/28/2007	**SBA-F-1-SOI-270280-A**	**27**	**28**	**27400**	**3910**	**54300**	**243000**	**141000**	**49700**	**1380**	**12.32**	**12000 UJ**	**215**	**4370 J**	**2380**	**1320**
	6/28/2007	SBA-F-1-SOI-280290-A	28	29	1560	34.9 J	24900	17700	40400	7970	778	11.97	3540 J	-27	6970 J,L	468	108
SBA-F-3	7/2/2007	SBA-F-3-SOI-040050-A	4	5	7.9	1.4	301	1450	450	61.9 B	8.8	9.28	59.9 B	294	160 B	29.2	5.2 B
	7/2/2007	SBA-F-3-SOI-090100-A	9	10	16.5	1.8	261	3050	442	77.8 B	14.7	8.48	37.8 B	318	111 B	19.1	3.9 B
	7/2/2007	SBA-F-3-SOI-160170-A	16	17	14.7	0.8 J	128	21200	317	129 B	54.1	9.71	46.1 B	277	289 B	14.5	4.5 B
	7/2/2007	SBA-F-3-SOI-220230-A	22	23	3.9	1 U	110	4640	290	43.8 B	15.6	9.66	22.6 B	270	523 B	9.2	2.8 B
	7/2/2007	SBA-F-3-SOI-320330-A	32	33	75.1	1.6 UJ	27600	1910	40300	6680	1060	7.75	4070	195	4000	317	57.8
SBA-F-5	7/13/2007	SBA-F-5-SOI-040080-A	4	8	13.1 J	1.1	680	22200	825	810	92.7	7.69	60.2 B	312	317 B	35.8	5.1 B
	7/13/2007	SBA-F-5-SOI-090100-A	9	10	5.6 J	0.91 U	79.9	9190	253	72 B	25	8.09	1200 U	291	97.5 B	13.7	1.6 B
	7/13/2007	SBA-F-5-SOI-160170-A	16	17	111 J	2.1	22300	1710	35300	5450	882	9.45	3550	57.3	3140	287	48
	7/13/2007	SBA-F-5-SOI-170180-AD	17	18	19.5 J	1 U	136	3850	590	69.2 B	15.3	8.27	1200 U	275	260 B	12.4	5.1 B
	7/13/2007	SBA-F-5-SOI-170180-A	17	18	10.1 J	1 U	84	7620	330	59.3 B	28	8.22	1300 U	253	300 B	13.3	3 B
	7/13/2007	SBA-F-5-SOI-230240-A	23	24	2.1 J	0.87 U	42.5	13500	180	70.5 B	29.3	8.84	1100 U	259	531 B	9.1	2.7 B
	7/13/2007	SBA-F-5-SOI-310320-A	31	32	43.2	1.2 U	14000	1240	30600	2810	414	7.66	1680	166	1900	157	45.6
SBA-F-6	9/8/2007	SBA-F-6-SOI-020060-A	2	6	2.5 J	0.9 U	195	4160	242	37.7 B	13.5	9.61	53.4 B	138	181 B	26.1	2.8 B
	9/8/2007	SBA-F-6-SOI-085100-A	8	10	14 J	1.8	1720	2550	351	46.9 B	26.1	8.84	428 B	233	139 B	20.5	12.9
	9/8/2007	SBA-F-6-SOI-130135-A	13	13	48.4 J	1.3 U	15100	1950	20800	3440	544	9.57	2290	-25	1090 B	201	33.3
	9/8/2007	SBA-F-6-SOI-145180-AD	14	18	244 J	5.9	3340	6710	4640	1080	126	10.43	640 B	142	485 B	67.7	15.8
	9/8/2007	SBA-F-6-SOI-145180-A	14	18	215 J	6.5	2300	38500	3260	861	161	10.4	495 B	147	491 B	53.6	11.2
	9/8/2007	SBA-F-6-SOI-220260-A	22	26	112 J	1.2	417	7110	1010	477 B	26.6	10.52	57.8 B	159	819 B	26.5	9.5
	9/8/2007	SBA-F-6-SOI-290300-A	29	30	101 J	1.1 U	17600	4590	23000	2940	296	9.12	2070	38.4	2290	159	50.8
SBA-H-1	6/30/2007	SBA-H-1-SOI-020030-A	2	3	51.4	6.7 J	1480	12100	3390	5100	20.6	8.97	306 B	267	101 B	51	15.3
	6/30/2007	**SBA-H-1-SOI-040050-A**	**4**	**5**	**12500**	**2640**	**30200**	**113000**	**67600**	**23000**	**747**	**11.85**	**988 B**	**178**	**2100 B**	**990**	**584**
	6/30/2007	**SBA-H-1-SOI-055060-A**	**5**	**6**	**19500**	**8890**	**44400**	**181000**	**104000**	**36000**	**1000**	**11.97**	**12000 U**	**188**	**2040 B**	**1880**	**999**
	6/30/2007	**SBA-H-1-SOI-060080-A**	**6**	**8**	**28500**	**5320**	**58900**	**247000**	**146000**	**50500**	**1350**	**12.18**	**13000 U**	**161**	**4380 B**	**2540**	**1450**
	6/30/2007	**SBA-H-1-SOI-190200-A**	**19**	**20**	**19400**	**2660**	**53900**	**227000**	**132000**	**46600**	**1230**	**12.63**	**14000 U**	**113**	**7830 B**	**2320**	**1250**
	6/30/2007	**SBA-H-1-SOI-250260-A**	**25**	**26**	**26300**	**606**	**57600**	**14300**	**42600**	**7810 B**	**590**	**12.49**	**3280 B**	**46.2**	**54100**	**487**	**79.7 B**
	6/30/2007	**SBA-H-1-SOI-260270-A**	**26**	**27**	**21400**	**2320**	**52500**	**220000**	**134000**	**46000**	**1270**	**12.36**	**12000 U**	**161**	**5630 B**	**2370**	**1230**
	6/30/2007	SBA-H-1-SOI-310320-A	31	32	619	1.2 UJ	17400	3020	33500	3540	195	10.28	2030	96.6	5190	179	63.9
SBA-H-4	7/13/2007	SBA-H-4-SOI-060070-A	6	7	23.5 J	0.85 J	2130	1180	5590	487 B	9.5	7.51	201 B	330	1100 U	51.8	23.7
	7/13/2007	SBA-H-4-SOI-080090-AD	8	9	15.7 J	1.6	1650	299 B	4120	135 B	5.1	8.22	151 B	320	193 B	41	18.2
	7/13/2007	SBA-H-4-SOI-080090-A	8	9	22.9 J	1.6	1690	139 B	5290	102 B	4.7	8.11	123 B	314	150 B	41.3	25.2
	7/13/2007	SBA-H-4-SOI-120130-A	12	13	807 J	1 U	9580	5420	21900	6690	811	10.77	1300	-29	4310	216	58.2
	7/13/2007	SBA-H-4-SOI-160170-A	16	17	8640 J	87.9	5320	6940	18900	1560	138	10.28	831 B	146	5700	657	22.1
	7/13/2007	SBA-H-4-SOI-190200-A	19	20	3500 J	1.7 U	29900	18100	60700	22400	1200	10.1	3460	88.4	9690	649	219
	7/13/2007	SBA-H-4-SOI-230240-A	23	24	48.3 J	1.3 U	19800	2350	30500	4860	612	7.85	2720	140	2440	257	44.2
SBA-H-6	7/13/2007	SBA-H-6-SOI-060070-A	6	7	13.5	1.6	3380	657	5480	292 B	12.8	7.88	122 B	302	125 B	52	14.3
	7/13/2007	SBA-H-6-SOI-080090-A	8	9	282 J	9.8	2530	53200	14300	6940	115	8.86	731 B	287	486 B	134	11.3
	7/13/2007	SBA-H-6-SOI-140150-A	14	15	599 J	27.4	1490	13600	4100	1470	65.2	9.94	10.9 B	224	391 B	73.1	32.6
	7/13/2007	SBA-H-6-SOI-180190-A	18	19	151 J	1.4 J	23800	2180	38100	7960	1010	9.6	3960	134	6150	316	57.7
	7/13/2007	SBA-H-6-SOI-230240-A	23	24	46.2 J	0.99 J	21600	1470	36800	5810	714	7.8	3410	161	3010	233	44.5

TABLE 4-1
Soil Analytical Results
Chromium Transport Study
Dundalk Marine Terminal, Baltimore, Maryland

Location	Date	Field Sample ID	Start Depth (feet)	End Depth (feet)	Chromium (mg/kg)	Chromium (VI) (mg/kg)	Aluminum (mg/kg)	Calcium (mg/kg)	Iron (mg/kg)	Magnesium (mg/kg)	Manganese (mg/kg)	pH (std. units)	Potassium (mg/kg)	Redox Potential Vs H2	Sodium (mg/kg)	Titanium (mg/kg)	Vanadium (mg/kg)
SBA-H-7	9/8/2007	SBA-H-7-SOI-020080-A	2	8	12.9 J	1.9	2160	652	4540	261 B	4.9	8.27	216 B	319	152 B	42.4	18.4
	9/8/2007	SBA-H-7-SOI-120130-A	12	13	110 J	5.3	4430	25500	7910	8840	121	10.76	322 B	130	814 B	73.4	19.5
	9/8/2007	SBA-H-7-SOI-130150-A	13	15	473 J	1.1 U	7100	4920	14400	3950	443	11.26	1020 B	-350	2900	234	40.8
	9/8/2007	SBA-H-7-SOI-150180-A	15	18	1820 J	21	3250	3390	4920	1360	89.5	11.18	466 B	112	2070	91.2	16.2
	9/8/2007	SBA-H-7-SOI-220260-A	22	26	69.6 J	1.3 U	29700	1420	32600	4890	378	7.99	2820	-55	2340	554	59.5
	9/8/2007	SBA-H-7-SOI-260300-A	26	30	42.8 J	1.2 U	15700	824	27800	2980	227	7.79	1740	106	1330 B	188	51.6
SBA-I-1	8/6/2007	**SBA-I-1-SOI-090095-A**	**9**	**9**	**13900**	**2770**	**41600**	**182000**	**101000**	**37400**	**976**	**12.13**	**291 B**	**170**	**1780 B**	**1780**	**970**
	8/6/2007	**SBA-I-1-SOI-095100-A**	**9**	**10**	**19200**	**3150**	**58100**	**234000**	**144000**	**51200**	**1310**	**12.17**	**132 B**	**175**	**2850 B**	**2510**	**1400**
	8/6/2007	**SBA-I-1-SOI-140150-A**	**14**	**15**	**19200**	**6710**	**48700**	**197000**	**130000**	**42200**	**1150**	**12.26**	**265 B**	**233**	**1670 B**	**2300**	**1570**
SBA-I-2	8/6/2007	**SBA-I-2-SOI-080090-A**	**8**	**9**	**18200**	**6170**	**46300**	**183000**	**123000**	**38900**	**1090**	**12.47**	**151 B**	**171**	**1400 B**	**2220**	**1520**
	8/6/2007	**SBA-I-2-SOI-140150-A**	**14**	**15**	**21200**	**5730**	**54100**	**219000**	**140000**	**46700**	**1260**	**12.42**	**229 B**	**171**	**2850 B**	**2530**	**1520**
TPZ-25	2/13/2007	**TPZ-25-SOI-0405**	**5**	**5**	**19600**	**1580**	**47100**	**212000**	**120000**	**44700**	**1130**	**10.92**	--	**218**	--	--	**1130**
	2/13/2007	**TPZ-25-SOI-0506**	**5**	**6**	**9380**	**538**	**27700**	**103000**	**64900**	**22600**	**618**	**10.12**	--	**301**	--	--	**573**
	2/13/2007	TPZ-25-SOI-1116	11	16	22.1	1.1	7920	254	10500	1160	33.1	5.25	--	506	--	--	26.1
	2/13/2007	TPZ-25-SOI-1618	16	18	35.9	1	11900	506	5770	1560	39.2	4.85	--	540	--	--	13.9
	2/13/2007	TPZ-25-SOI-1822	18	22	699	374	942	9020	11300	24	16.4	11.17	--	214	--	--	9.1
TPZ-26	2/13/2007	**TPZ-26-SOI-0405**	**3**	**5**	**26600**	**4150**	**48600**	**228000**	**123000**	**45600**	**1220**	**11.49**	--	**194**	--	--	**1060**
	2/13/2007	TPZ-26-SOI-0813	8	13	37.2	3.6	8990	341	18200	1050	26.1	4.99	--	469	--	--	20.4
	2/13/2007	TPZ-26-SOI-1617	16	17	15	1	5450	162	3820	863	25.3	5.65	--	458	--	--	10.2
	2/13/2007	TPZ-26-SOI-1718	17	18	5.9	1.7	657	51.8	2660	56.9	2.2	7.3	--	410	--	--	7.8
TPZ-27	2/14/2007	TPZ-27-SOI-0510	4	9	125	5.6	2330	794	3700	231	16	8.15	--	421	--	--	11.5
	2/14/2007	TPZ-27-SOI-1113	11	12	20.3	1 U	8920	745	7790	1680	59	6.69	--	279	--	--	21.5
	2/14/2007	TPZ-27-SOI-1318	13	18	16.8	0.6 J	2260	433	2940	338	12.9	6.05	--	324	--	--	13
TPZ-28	2/14/2007	TPZ-28-SOI-0304	3	3	39.3	1	5930	130000	3800	31900	200	8	--	325	--	--	39.8
	2/14/2007	TPZ-28-SOI-0611	6	11	45.8	4.7	2730	351	2900	280	22	7.38	--	377	--	--	6.2
	2/14/2007	TPZ-28-SOI-1112	11	12	24.5	1.8	8650	510	6670	1510	53.2	5.43	--	489	--	--	12.3
	2/14/2007	TPZ-28-SOI-1418	13	18	12.9	0.99	3200	163	3130	483	26.3	4.28	--	451	--	--	16.8
TPZ-29	2/15/2007	TPZ-29-SOI-0305-D	3	5	16.8 L	0.97	9750	287	13000	935	130	5.51	--	504	--	--	18.3
	2/15/2007	TPZ-29-SOI-0305	3	5	10.4	0.95	7010	213	6200	769	71	4.23	--	442	--	--	15
	2/15/2007	TPZ-29-SOI-0507	5	6	27.9	0.92	11600	1260	9600	1200	106	4.93	--	444	--	--	19.6
	2/15/2007	TPZ-29-SOI-1417-D	14	17	22.8 L	0.72 J	13900	462	12600	2920	127	11.04	--	380	--	--	25.2
	2/15/2007	TPZ-29-SOI-1417	14	17	19.3	1 U	10300	376	10500	2410	106	5.01	--	408	--	--	21.7
	2/15/2007	TPZ-29-SOI-1718	17	18	6.9	1.1	1600	64.9	1630	215	8.6	5.3	--	509	--	--	9.4
TPZ-30	2/15/2007	TPZ-30-SOI-0406-D	3	6	202 L	17.7 L	16700	27700	10400	2140	79.6	4.69	--	226	--	--	112
	2/15/2007	TPZ-30-SOI-0406	3	6	110 L	17.9 L	17400	28500	9760	2650	71.3	7.57	--	204	--	--	103
	2/15/2007	TPZ-30-SOI-1012	10	12	186 L	7.6	3230	397	13300	443	54.2	4.67	--	333	--	--	16.1
	2/15/2007	TPZ-30-SOI-1218-D	12	18	23 L	1 UL	13100	305	13000	2170	85.1	11.06	--	398	--	--	31.1
	2/15/2007	TPZ-30-SOI-1218	12	18	25.4 L	1 UL	12500	428	13400	2210	90.1	4.48	--	355	--	--	27.1
	2/15/2007	TPZ-30-SOI-1819	18	19	28.3 L	1.2 L	2190	224	3540	335	20.6	10.93	--	504	--	--	9.7
TPZ-31	2/16/2007	**TPZ-31-SOI-0506**	**5**	**6**	**1500 L**	**78.3**	**10800**	**17000**	**16700**	**4500**	**133**	**10.89**	--	**173**	--	--	**102**
	2/16/2007	**TPZ-31-SOI-0610**	**6**	**10**	**22800 L**	**4490**	**56400**	**266000**	**140000**	**50800**	**1220**	**12.21**	--	**155**	--	--	**1260**
	2/16/2007	TPZ-31-SOI-1012	10	12	5140 L	122	14700	23600	25100	5860	381	12.02	--	208	--	--	109
	2/16/2007	**TPZ-31-SOI-1214**	**12**	**14**	**26200 L**	**6400**	**56000**	**251000**	**138000**	**49000**	**1190**	**11.29**	--	**167**	--	--	**1290**
	2/16/2007	TPZ-31-SOI-1618	16	18	625 L	17.7 L	560	1090	2170	67.1	12.1	11.07	--	219	--	--	2.7
TPZ-32	2/17/2007	**TPZ-32-SOI-0405**	**4**	**5**	**24600 L**	**5720**	**53100**	**229000**	**123000**	**48100**	**1110**	**11.78**	--	**179**	--	--	**1130**
	2/17/2007	**TPZ-32-SOI-0507**	**5**	**7**	**27300 L**	**2980**	**59800**	**265000**	**144000**	**54200**	**1240**	**11.65**	--	**198**	--	--	**1320**
	2/17/2007	TPZ-32-SOI-1013	9	12	347 L	21.4	11700	198	9160	1660	53.2	8.51	--	398	--	--	17.2
	2/17/2007	TPZ-32-SOI-1618	16	18	619 L	26.8 L	13300	342	6500	1660	47.5	8.01	--	370	--	--	21.2

TABLE 4-1
Soil Analytical Results
Chromium Transport Study
Dundalk Marine Terminal, Baltimore, Maryland

Location	Date	Field Sample ID	Start Depth (feet)	End Depth (feet)	Chromium (mg/kg)	Chromium (VI) (mg/kg)	Aluminum (mg/kg)	Calcium (mg/kg)	Iron (mg/kg)	Magnesium (mg/kg)	Manganese (mg/kg)	pH (std. units)	Potassium (mg/kg)	Redox Potential Vs H2	Sodium (mg/kg)	Titanium (mg/kg)	Vanadium (mg/kg)
TPZ-48	3/4/2009	TPZ-48-SOI-020021	20	21	24.9	2.7	--	--	--	--	--	10.3	--	185	--	--	--
	3/4/2009	TPZ-48-SOI-025026	25	26	1.31 J	0.25 U	--	--	--	--	--	10.4	--	242	--	--	--
	3/4/2009	TPZ-48-SOI-030031	30	31	29.9	0.26 U	--	--	--	--	--	6.43	--	192	--	--	--
	3/4/2009	TPZ-48-SOI-035036	35	36	46.7	0.30 U	--	--	--	--	--	6.13	--	157	--	--	--
	3/4/2009	TPZ-48-SOI-041042	41	42	45.2	0.31 U	--	--	--	--	--	6.12	--	219	--	--	--
	3/4/2009	TPZ-48-SOI-045046	45	46	38.8	0.48 J	--	--	--	--	--	6.29	--	235	--	--	--
	3/5/2009	TPZ-48-SOI-055056	55	56	49.0	0.47 J	--	--	--	--	--	6.92	--	271	--	--	--
	3/5/2009	TPZ-48-SOI-060061	60	61	59.5	1.0 J	--	--	--	--	--	6.84	--	222	--	--	--
	3/5/2009	TPZ-48-SOI-063064	63	64	64.6	0.32 U	--	--	--	--	--	6.7	--	181	--	--	--
	3/5/2009	TPZ-48-SOI-069070	69	70	59.9	0.48 J	--	--	--	--	--	6.84	--	170	--	--	--
	3/5/2009	TPZ-48-SOI-073074	73	74	52.6	0.30 U	--	--	--	--	--	6.76	--	182	--	--	--
	3/5/2009	TPZ-48-SOI-073074-D	73	74	53.7	0.34 J	--	--	--	--	--	6.64	--	190	--	--	--
	3/5/2009	TPZ-48-SOI-080081	80	81	60.2	0.30 U	--	--	--	--	--	6.67	--	147	--	--	--
	3/5/2009	TPZ-48-SOI-085086	85	86	12.1	0.49 J	--	--	--	--	--	6.82	--	207	--	--	--
TPZ-49	3/9/2009	TPZ-49-SOI-025026	25	26	11.8 K	0.67 B	--	--	--	--	--	6.42	--	312	--	--	--
	3/9/2009	TPZ-49-SOI-030031	30	31	37.2 K	0.76 B	--	--	--	--	--	6.03	--	251	--	--	--
	3/9/2009	TPZ-49-SOI-035036	35	36	65.8 K	1.6	--	--	--	--	--	6.18	--	231	--	--	--
	3/9/2009	TPZ-49-SOI-040041	40	41	19.4 K	1.2 B	--	--	--	--	--	6.11	--	311	--	--	--
	3/9/2009	TPZ-49-SOI-045046	45	46	39.8 K	0.32 U	--	--	--	--	--	6.75	--	154	--	--	--
	3/9/2009	TPZ-49-SOI-050051	50	51	46.1 K	0.33 U	--	--	--	--	--	7.06	--	157	--	--	--
	3/10/2009	TPZ-49-SOI-050051-D	50	51	44.8 K	0.62 J	--	--	--	--	--	7.04	--	160	--	--	--
	3/10/2009	TPZ-49-SOI-055056	55	56	59.4 K	0.34 U	--	--	--	--	--	6.89	--	173	--	--	--
	3/11/2009	TPZ-49-SOI-060061	60	61	62.4 K	0.34 U	--	--	--	--	--	6.82	--	180	--	--	--
	3/11/2009	TPZ-49-SOI-065066	65	66	59.5 K	0.62 J	--	--	--	--	--	6.83	--	195	--	--	--
	3/11/2009	TPZ-49-SOI-070071	70	71	61.1 K	0.32 U	--	--	--	--	--	6.75	--	186	--	--	--
	3/11/2009	TPZ-49-SOI-075076	75	76	71.8	0.33 U	--	--	--	--	--	6.81	--	149	--	--	--
	3/11/2009	TPZ-49-SOI-075076-D	75	76	75.4	0.32 U	--	--	--	--	--	6.8	--	159	--	--	--
	3/11/2009	TPZ-49-SOI-080081	80	81	50.6	0.31 U	--	--	--	--	--	6.88	--	138	--	--	--
	3/11/2009	TPZ-49-SOI-086087	86	87	2.38	0.25 U	--	--	--	--	--	6.52	--	268	--	--	--

Data Validation Qualifiers:
B = Not detected substantially above the level reported in laboratory or field blank. Analyte also detected in the associated
J = Reported result is estimated
L = The analyte is present. The reported values may be biased low. The actual value is expected to be higher than reported.
U = Analyte was not detected above the reported detection limit.
UJ = Analyte was not detected and the associated detection limit is estimated.
UL = Analyte was not detected and the reported quantitation limit is probably higher.

Notes:
1) Bold Sample IDs, depths, and values indicate that the sample was described as COPR.
2) Duplicate samples are identified by "-D" and -AD" appended to the end of the field sample ID
3) The notation "-A" appended to the end of a field sample ID is used only to identify the analytical laboratory that analyzed the sample
4) -- = Sample not analyzed

TABLE 4-2
Comparison of Average Cr and Cr(VI) Concentrations in COPR and Non-COPR Fill
Chromium Transport Study
Dundalk Marine Terminal, Baltimore, Maryland

Sample Population	***N***	**Average Cr Concentration (mg/kg)**[a]	**Average Cr(VI) Concentration (mg/kg)**[a]
COPR	123	22,048	4,894
All non-COPR soils	281	258	16
All non-COPR soils (outliers removed)[b]	261	90	2
Non-COPR fill	72	71	2

N, number of samples.

[a] All non-detect values were assigned a concentration equal to one-half the MDL.

[b] The outliers are samples that were collected within approximately 3 feet of the COPR limits or samples that were collected from a soil horizon that was potentially exposed during the time of COPR placement.

TABLE 4-3
Groundwater Analytical Results—Wet Chemistry
Chromium Transport Study
Dundalk Marine Terminal, Baltimore, Maryland

Location ID	Sample ID	Sample Date	Alkalinity to pH 4.5 mg/L	Alkalinity to pH 8.3 mg/L	Alkalinity, Total as CaCO3 mg/L	Bicarbonate mg/L	Bromide mg/L	Carbon Dioxide mg/L	Chloride mg/L	Fluoride mg/L	Nitrogen, Nitrate mg/L	Nitrogen, Nitrate + Nitrite mg/L	Nitrogen, Nitrite mg/L	Silica, Dissolved mg/L	Sulfate mg/L	Total Dissolved Solids mg/L	Total Suspended mg/L
	Shallow Wells																
DMT-21S	DMT-21S-GRW-100406	10/04/06	NA	NA	1020	NA	NA	52.4	3410	NA	NA	NA	NA	NA	89.4	6270	4 U
DMT-23S	DMT-23S-GRW-100406	10/04/06	NA	NA	215	NA	NA	5 U	957	NA	NA	NA	NA	NA	22.5	1820	4 U
DMT-23S	DMT-23S-GRW-100406-D	10/04/06	NA	NA	212	NA	NA	5 U	1230	NA	NA	NA	NA	NA	18.8	2010	165
DMT-24S	DMT-24S-GRW-100406	10/04/06	NA	NA	1490	NA	NA	5 U	3260	NA	NA	NA	NA	NA	9.1	6970	5.9
DMT-25S	DMT-25S-GRW-100406	10/04/06	NA	NA	5110	NA	NA	5 U	576	NA	NA	NA	NA	NA	36.3	7990	4 U
DMT-25S	DMT-25S-GRW-120406	12/04/06	NA	NA	2030	NA	0.39 B	5	84.3	1.5 B	0.11 U	0.1 U	0.089	11.1	30.1	NA	NA
EA-6S	EA-6S-GRW-112906	11/29/06	NA	NA	1530	NA	0.085 B	5 UB	54.7	0.2 U	0.11 UB	0.0081 B	0.0087 B	1.8	9.4	NA	NA
EA-11S	EA-11S-GRW-120106	12/01/06	NA	NA	150	NA	0.067 B	6.8	172	0.8	0.11 U	0.1 U	0.01 U	12.9	92.9	NA	NA
EA-15S	EA-15S-GRW-113006	11/30/06	NA	NA	5700	NA	0.31	5 UB	83.3	3.3	0.75	1.1	0.35	0.92 B	4.4 B	NA	NA
EAC-1S	EAC-1S-GRW-112806	11/28/06	NA	NA	133	NA	0.24	9.4 L	15.1	0.39	0.16	0.17	0.01	5.1	34.3 L	NA	NA
EAC-4S	EAC-4S-GRW-113006	11/30/06	NA	NA	2420	NA	0.31	5 UB	184	0.1 U	0.2 U	0.82	0.75	0.79 B	3.7 B	NA	NA
EAC-4S	EAC-4S-GRW-113006-D	11/30/06	NA	NA	2410	NA	0.22	5 UB	182	0.1 U	0.2 U	0.82	0.82	1 U	3.4 B	NA	NA
P-4	P-4-GRW-120506	12/05/06	NA	NA	2740	NA	0.25	0.11 B	77.3	0.35 B	0.2 U	0.12	1.1	1 U	5.4 B	NA	NA
	M-Series Wells																
DMT-1M	DMT-01M-062106	06/21/06	13.7	0.46 U	NA	13.7	NA	NA	136	NA	NA	NA	NA	NA	176	490	3 U
EA-5M	EA-5M-GRW-120406-01	12/04/06	NA	NA	55.9	NA	0.08 B	6.1	41.2	0.061 B	1.2	1.3	0.11	1	19.4	NA	NA
EA-5M	EA-5M-GRW-120406-02	12/04/06	NA	NA	141	NA	0.89	60.3	325	0.12	0.11 U	0.1 U	0.01 U	15.4	77.9	NA	NA
EA-5M	EA-5M-GRW-120406-02-D	12/04/06	NA	NA	146	NA	0.88	40.3	313	0.12	0.3	0.3	0.01 U	13.7	78.8	NA	NA
EA-6M	EA-6M-GRW-112906-01	11/29/06	NA	NA	87.6	NA	1.2	133	289	0.07 B	0.11 UB	0.1 U	0.01 U	21.1	176	NA	NA
EA-6M	EA-6M-GRW-112906-02	11/29/06	NA	NA	87.6	NA	1.2	76.5	288	0.086 B	0.11 UB	0.1 U	0.01 U	24.1	179	NA	NA
EA-6S	EA-6S-GRW-112906	11/29/06	NA	NA	1530	NA	0.085 B	5 UB	54.7	0.2 U	0.11 UB	0.0081 B	0.0087 B	1.8	9.4	NA	NA
EA-11M	EA-11M-GRW-120106-01	12/01/06	NA	NA	88.7	NA	1.4	35.4	354	0.1	0.11 U	0.023 B	0.01 U	13.5	191	NA	NA
EA-11M	EA-11M-GRW-120106-02	12/01/06	NA	NA	145	NA	1.4	68	357	0.1	0.11 U	0.083 B	0.01 U	16.5	190	NA	NA
EA-11S	EA-11S-GRW-120106	12/01/06	NA	NA	150	NA	0.067 B	6.8	172	0.8	0.11 U	0.1 U	0.01 U	12.9	92.9	NA	NA
EA-13M	EA-13M-GRW-120506-1	12/05/06	NA	NA	121	NA	2.3	192	580	0.087 B	0.11 U	0.1 U	0.01 U	18.7	221	NA	NA
EA-13M	EA-13M-GRW-120506-2	12/05/06	NA	NA	125	NA	2.2	151	537	0.075 B	0.11 U	0.1 U	0.01 U	20.6	215	NA	NA
EA-15M	EA-15M-GRW-120106-01	12/01/06	NA	NA	235	NA	4.1	139	1210	0.13	0.15 U	0.1 U	0.05 U	16.7	226	NA	NA
EA-15M	EA-15M-GRW-120106-02	12/01/06	NA	NA	237	NA	4.1	125	1200	0.13	0.15 U	0.035 B	0.05 U	18.2	226	NA	NA
EA-15S	EA-15S-GRW-113006	11/30/06	NA	NA	5700	NA	0.31	5 UB	83.3	3.3	0.75	1.1	0.35	0.92 B	4.4 B	NA	NA
EAC-1M	EAC-1M-GRW-112806-01	11/28/06	NA	NA	11.3	NA	0.29	84 L	187	0.017 J	0.11 U	0.048 J	0.0078 J	23.4	260 L	NA	NA
EAC-1M	EAC-1M-GRW-112806-02	11/28/06	NA	NA	15.1	NA	0.32	83.2 L	199	0.018 J	0.11 U	0.036 J	0.01 U	21.8	266 L	NA	NA
EAC-1S	EAC-1S-GRW-112806	11/28/06	NA	NA	133	NA	0.24	9.4 L	15.1	0.39	0.16	0.17	0.01	5.1	34.3 L	NA	NA
EAC-4M	EAC-4M-GRW-113006-01	11/30/06	NA	NA	401	NA	5.2	5 B	2140	0.16	0.11	0.11	0.0047 B	9.8	10 U	NA	NA
EAC-4M	EAC-4M-GRW-113006-02	11/30/06	NA	NA	682	NA	12.9	25.9	3560	0.26	0.11 U	0.1 U	0.01 U	16.3	10 U	NA	NA
EAC-4S	EAC-4S-GRW-113006	11/30/06	NA	NA	2420	NA	0.31	5 UB	184	0.1 U	0.2 U	0.82	0.75	0.79 B	3.7 B	NA	NA
EAC-4S	EAC-4S-GRW-113006-D	11/30/06	NA	NA	2410	NA	0.22	5 UB	182	0.1 U	0.2 U	0.82	0.82	1 U	3.4 B	NA	NA
P-4	P-4-GRW-120506	12/05/06	NA	NA	2740	NA	0.25	0.11 B	77.3	0.35 B	0.2 U	0.12	1.1	1 U	5.4 B	NA	NA

Notes:
Results in mg/L
A "D" appended to a sample ID indicates a duplicate sample
U = Analyte not detected above reported MDL
J = Analyte present. Reported value may or may not be accurate or precise.
UJ = estimated non-detect due to associated inaccurate or imprecise spike recoveries, calibration issues, blank
B = Not detected substantially above the level reported in the laboratory or field blank
L = Analyte is present but flagged as a low bias, usually associated with MS/MSD, LCS, LCSD spike recoveries
NA = Not Analyzed

TABLE 4-4

Round 1 Storm Drain Analytical Data

Chromium Transport Study, Dundalk Marine Terminal, Baltimore, Maryland

Storm Drain Street	**Date**	**Sample Collection Location**	**Chromium (ppm)**		**Flow Rate (gpm)**	**TI?[a]**	**SI?[b]**
			Total	**Hexavalent**			
9	12/21/7	M-I2	1.39	0.74	8–10	No	Yes
9	12/21/7	M-M1	0.0807	0.090	Sample collected from ponded water; no flow was observed or measured.	No	Yes
9	12/21/7	M-M2	0.189	Not detected above limit of quantitation	Unquantifiable; very small flow (< 1)	No	Yes
9	12/21/7	M-M3	0.117	Not detected above limit of quantitation	2–3	No	Yes
9	12/21/7	M-M4	0.0538	0.039	Sample collected from ponded water; no flow was observed or measured.	No	Yes
9	12/21/7	M-M6	0.0883	Not detected above limit of quantitation	Sample collected from ponded water; no flow was observed or measured.	No	Yes
9	12/21/7	M-O53	0.0533	Not detected above limit of quantitation	100	No	Yes
9.5	4/30/07	I-17	*Did not sample—inlet too small for entry*				
9.5	4/30/07	I-18	*Did not sample—inlet too small for entry*				
9.5	4/30/07	I-19	*Did not sample—inlet too small for entry*				
10	11/30/7	M-M1	0.0180	Not detected above limit of quantitation	Sample collected from ponded water; no flow was observed or measured.	No	No
10	11/30/7	M-M2	0.0109	Not detected above limit of quantitation	7	No	No
10	11/30/7	M-M5	0.171	Not detected above limit of quantitation	Sample collected from ponded water; no flow was observed or measured.	No	No
10	11/30/7	M-S1	0.0171	Not detected above limit of quantitation	Sample collected from ponded water; no flow was observed or measured.	No	No

TABLE 4-4

Round 1 Storm Drain Analytical Data

Chromium Transport Study, Dundalk Marine Terminal, Baltimore, Maryland

Storm Drain Street	Date	Sample Collection Location	Chromium (ppm)		Flow Rate (gpm)	TI?[a]	SI?[b]
			Total	Hexavalent			
10.5	5/12/07	I-116	0.021	Not detected above limit of quantitation	Sample collected from ponded water; no flow was observed or measured.	Yes	Yes
10.5	5/12/07	I-123	0.003	Not detected above limit of quantitation	Sample collected from ponded water; no flow was observed or measured.	Yes	Yes
11	4/30/07	M-117	0.505	0.51	Sample collected from ponded water; no flow was observed or measured.	Yes	Yes
11	4/30/07	M-118	0.497	0.46	Sample collected from ponded water; no flow was observed or measured.	Yes	Yes
11	10/12/07	M-115	0.103	Not detected above limit of quantitation	5	No	Yes
11	10/12/07	M-116	0.0747	Not detected above limit of quantitation	5	No	Yes
11	10/12/07	M-117	0.155	0.14	Sample collected from ponded water; no flow was observed or measured.	No	Yes
11	10/12/07	M-118	0.920	1.0	Sample collected from ponded water; no flow was observed or measured.	No	Yes
11.5	5/9/07	I-136	0.008	Not detected above limit of quantitation	Sample collected from ponded water; no flow was observed or measured.	Yes	Yes
12	4/26/07	M-122	11.1	10	Sample collected from ponded water; no flow was observed or measured.	Yes	Yes
12	4/26/07	M-124	7.66	7.4	Sample collected from ponded water; no flow was observed or measured.	Yes	Yes
12	10/4/07	M-120	10.5	9.2	6.7	No	Yes
12	10/8/07	M-120	3.82[c]	3.0[c]	Not available; conditions precluded measurement	Yes	Yes
12	10/8/07	M-121	15.3[c]	13[c]	Not available; conditions precluded measurement	Yes	Yes

TABLE 4-4

Round 1 Storm Drain Analytical Data

Chromium Transport Study, Dundalk Marine Terminal, Baltimore, Maryland

Storm Drain Street	Date	Sample Collection Location	Chromium (ppm)		Flow Rate (gpm)	TI?[a]	SI?[b]
			Total	Hexavalent			
12	10/8/07	M-122	30.6[c]	21[c]	Not available; conditions precluded measurement	No	Yes
12	10/8/07	M-123	28.9[c]	24[c]	Not available; conditions precluded measurement	No	Yes
12	10/8/07	M-124	37.1[c]	44[c]	Not available; conditions precluded measurement	No	Yes
12.5	3/28/07	M-124	7.66	4.8	11.4	Yes	Yes
12.5	3/28/07	M124B	12.8	8.7	11.3	Yes	Yes
12.5	4/30/07	M-124	45.5	45	Sample collected from ponded water; no flow was observed or measured.	Yes	Yes
13	4/26/07	M-127	26.4	27	Sample collected from ponded water; no flow was observed or measured.	Yes	Yes
13	4/26/07	M-128	27.9	27	Sample collected from ponded water; no flow was observed or measured.	Yes	Yes
13	5/16/07	M125A	21.9	20	Sample collected from ponded water; no flow was observed or measured.	Yes	Yes
13	5/16/07	M-126	29.2	26	Sample collected from ponded water; no flow was observed or measured.	Yes	Yes
13	5/16/07	M128	30.2	25	3.2	Yes	Yes
13	5/24/07	M-128	30.3	33	2.2	Yes	Yes
13	6/6/07	M-128	29.6	31	3.2	Yes	Yes
13	10/5/07	M-125	23.7	24	Unquantifiable; very small flow (< 1)	No	Yes
13	10/5/07	M-126	32.8	25	Unquantifiable; very small flow (< 1)	No	Yes
13	10/5/07	M-128	36.6	32	3.2	No	Yes

TABLE 4-4
Round 1 Storm Drain Analytical Data
Chromium Transport Study, Dundalk Marine Terminal, Baltimore, Maryland

Storm Drain Street	Date	Sample Collection Location	Chromium (ppm)		Flow Rate (gpm)	TI?[a]	SI?[b]
			Total	Hexavalent			
13	10/8/07	M-125	14.5[c]	12[c]	Not available; conditions precluded measurement	No	Yes
13	10/8/07	M125A	25.1[c]	22[c]	Not available; conditions precluded measurement	No	Yes
13	10/8/07	M-126	26.2[c]	22[c]	Not available; conditions precluded measurement	No	Yes
13	10/8/07	M-127	25.7[c]	22[c]	Not available; conditions precluded measurement	No	Yes
13	10/8/07	M-128	5.32[c]	5.6[c]	Not available; conditions precluded measurement	No	Yes
13	10/8/07	M-129	5.47[c]	5.4[c]	Not available; conditions precluded measurement	No	Yes
13.5	4/11/07	I-169	0.097	0.031	Sample collected from ponded water; no flow was observed or measured.	Yes	Yes
13.5	4/11/07	I-172	0.088	Not detected above limit of quantitation	Sample collected from ponded water; no flow was observed or measured.	Yes	Yes
13.5	5/16/07	I-169	0.136	0.049	Sample collected from ponded water; no flow was observed or measured.	Yes	Yes

[a] Sample was tidally influenced, indicating the isolation plate or plug was not fully sealed. Tidal dilution may have altered analytical results.
[b] Sample was influenced by sediment due to the storm drains not being cleaned prior to sampling. Suspended sediment may have altered analytical results.
[c] Sampling holding time was not met.

TABLE 4-5A
Groundwater Analytical Results - Shallow Wells - Dissolved Metals
Chromium Transport Study
Dundalk Marine Terminal, Baltimore, Maryland

Location ID	Sample ID	Sample Date	Chromium (µg/L)	Chromium (VI) (µg/L)	Alumium (µg/L)	Iron (µg/L)	Magnesium (µg/L)	Manganese (µg/L)	Potassium (µg/L)	Sodium (µg/L)	Titanium (µg/L)	Vanadium (µg/L)	Calcium (µg/L)
DMT-1S	DMT01S-052306	05/23/06	16.7	5 U	168	98.7	399	4.6	NA	NA	NA	55.9	21400
	DMT01S-052306-D	05/23/06	19.2	5 U	164	110	401	4.9	NA	NA	NA	57.8	21900
DMT-2S	DMT02S-052306	05/23/06	11.2 J	5 U	80.2	61.7	89	1.7	NA	NA	NA	36	5460
DMT-3S	DMT03S-052306	05/23/06	60.6	20 J	80.2	52.2	1590	15	NA	NA	NA	5.4	322000
DMT-4S	DMT04S-052306	05/23/06	16	50 U	136	52.2	33.3	1.1	NA	NA	NA	78.3	26600
DMT-5S	**DMT05S-052306**	**05/23/06**	**182**	**50 U**	**774**	**196**	**33.3**	**1.7**	**NA**	**NA**	**NA**	**297**	**9300**
DMT-6S	**DMT06S-052306**	**05/23/06**	**13700**	**2500 U**	**32100**	**6460**	**238**	**20.5**	**NA**	**NA**	**NA**	**1180**	**35300**
DMT-7S	**DMT07S-052406**	**05/24/06**	**70400**	**70000**	**707**	**52.2**	**33.3**	**0.52**	**NA**	**NA**	**NA**	**35.7**	**175000**
DMT-8S	**DMT08S-052406**	**05/24/06**	**14100**	**17000**	**4060**	**62.7**	**290**	**0.36**	**NA**	**NA**	**NA**	**210**	**66400**
DMT-9S	**DMT09S-052406**	**05/24/06**	**1370**	**500 U**	**2950**	**1330**	**33.3**	**2.8**	**NA**	**NA**	**NA**	**1500**	**7370**
	DMT09S-052406-D	**05/24/06**	**1300**	**500 U**	**3370**	**1280**	**33.3**	**2.7**	**NA**	**NA**	**NA**	**1470**	**7210**
DMT-10S	**DMT10S-052406**	**05/24/06**	**6060**	**250 U**	**14800**	**926**	**33.3**	**9**	**NA**	**NA**	**NA**	**384**	**12500**
DMT-11S	DMT11S-052406	05/24/06	16.9	20 U	80.2	285	106000	42.9	NA	NA	NA	21	51400
DMT-12S	**DMT12S-052206**	**05/22/06**	**4 J**	**5 UR**	**1850**	**75.7**	**33.3**	**0.36**	**NA**	**NA**	**NA**	**5.6**	**2240**
	DMT-12S-GRW-022607	**02/26/07**	**11.2 J**	**5 U**	**1480**	**52.2**	**32.2**	**0.69**	**NA**	**NA**	**NA**	**11.9**	**4750**
	DMT-12S-GRW-060509-F	**06/05/09**	**4 J**	**5 U**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
DMT-13S	**DMT13S-052406**	**05/24/06**	**18100**	**21000**	**349**	**52.2**	**33.3**	**0.36**	**NA**	**NA**	**NA**	**7.9**	**564000**
DMT-14S	DMT14S-052206	05/22/06	2.3 U	5 UR	133	76300	114000	3110	NA	NA	NA	1.5	411000
	DMT-14S-GRW-022607	02/26/07	2.7 J	5 U	80.2	70900	125000	2830	NA	NA	NA	1.5	390000
	DMT-14S-GRW-060809-F	06/08/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-15S	DMT15S-052206	05/22/06	2.3 U	50 UR	702	122000	12900	3020	NA	NA	NA	1.5	78200
	DMT-15S-GRW-022807	02/28/07	2.3 U	5 U	300	103000	14300	2860	NA	NA	NA	1.5	87700
	DMT-15S-GRW-060809-F	06/08/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-16S	DMT16S-052206	05/22/06	2.3 U	5 U	130	423	8200	236	NA	NA	NA	1.5	90600
	DMT-16S-GRW-030107	03/01/07	2.3 U	5 U	80.2	52.2	10500	37.4	NA	NA	NA	1.8	85400
DMT-17S	DMT17S-052306	05/23/06	2.3 U	50 U	108	52.2	539	0.9	NA	NA	NA	2.7	62800
	DMT-17S-GRW-022707	02/27/07	2.3 U	5 U	80.2	52.2	62.8	1.6	NA	NA	NA	2.5	36300
	DMT-17S-GRW-060409-F	06/04/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA
	DMT-17S-GRW-060409-D-F	06/04/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-18S	**DMT18S-052306**	**05/23/06**	**1930**	**1900**	**2780**	**993**	**232**	**13.1**	**NA**	**NA**	**NA**	**624**	**54300**
	DMT-18S-GRW-022807	**02/28/07**	**3210**	**2580**	**2160**	**3060**	**174**	**18.2**	**NA**	**NA**	**NA**	**1480**	**27800**
	DMT-18S-GRW-022807-D	**02/28/07**	**2410**	**3200**	**1690**	**4840**	**252**	**28.3**	**NA**	**NA**	**NA**	**2200**	**27600**
DMT-19S	DMT19S-052406	05/24/06	2.3 U	5 U	80.2	97700	64600	3310	NA	NA	NA	1.5	37200
	DMT-19S-GRW-022807	02/28/07	2.3 U	5 U	80.2	57400	41400	1950	NA	NA	NA	1.5	77300
DMT-20S	DMT20S-052406	05/24/06	2.3 U	50 U	80.2	14200	281000	1390	NA	NA	NA	1.7	71900
	DMT-20S-GRW-030207	03/02/07	2.3 U	5 U	80.2	5520	93700	1410	NA	NA	NA	1.5	51200
DMT-21S	DMT21S-052506	05/24/06	2.3 U	5 U	80.2	9650	204000	2010	NA	NA	NA	1.5	87600
	DMT-21S-GRW-100406	10/04/06	10 U	NA	200 U	21900	276000	2090	NA	NA	NA	50	86800
DMT-22S	**DMT22S-052306**	**05/23/06**	**24400**	**23000**	**1770**	**77.7**	**33.3**	**1.8**	**NA**	**NA**	**NA**	**1.5**	**121000**
DMT-23S	DMT23S-052306	05/23/06	7.2 J	5 U	80.2	61.1	1160	2	NA	NA	NA	25.8	24100
	DMT-23S-GRW-100406	10/04/06	10 U	NA	200 U	100 U	5000 U	15 U	NA	NA	NA	50	45700
	DMT-23S-GRW-100406-D	10/04/06	10.4	NA	200 U	100 U	5000 U	15 U	NA	NA	NA	50	25700
DMT-24S	**DMT24S-052406**	**05/24/06**	**11400**	**14000**	**1890**	**52.2**	**33.3**	**0.36**	**NA**	**NA**	**NA**	**7.1**	**230000**
	DMT-24S-GRW-100406	**10/04/06**	**1630**	**NA**	**1450**	**1430**	**25700**	**21.5**	**NA**	**NA**	**NA**	**772**	**27900**
DMT-25S	**DMT25S-052406**	**05/24/06**	**1070**	**25 U**	**14400**	**155**	**33.3**	**0.85**	**NA**	**NA**	**NA**	**152**	**22800**
	DMT-25S-GRW-100406	**10/04/06**	**10700**	**NA**	**19100**	**2460**	**5000 U**	**15 U**	**NA**	**NA**	**NA**	**1670**	**24000**
	DMT-25S-GRW-120406	**12/04/06**	**3040**	**2500 L**	**6950**	**111**	**38.8 B**	**2 B**	**NA**	**NA**	**NA**	**55.4**	**84700**
DMT-26S	DMT-26S-GRW-022807	02/28/07	2.3 U	5 U	80.2	20700	258000	483	NA	NA	NA	2	73900
DMT-27S	DMT-27S-GRW-022707	02/27/07	34.8 J	5 U	4300	10800	295000	699	NA	NA	NA	12.1	77900
	DMT-27S-GRW-060409-F	06/04/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA

TABLE 4-5A

Groundwater Analytical Results - Shallow Wells - Dissolved Metals
Chromium Transport Study
Dundalk Marine Terminal, Baltimore, Maryland

Location ID	Sample ID	Sample Date	Chromium (µg/L)	Chromium (VI) (µg/L)	Alumium (µg/L)	Iron (µg/L)	Magnesium (µg/L)	Manganese (µg/L)	Potassium (µg/L)	Sodium (µg/L)	Titanium (µg/L)	Vanadium (µg/L)	Calcium (µg/L)
DMT-28S	DMT-28S-GRW-030207	03/02/07	2.3 U	5 U	80.2	15500	214000	1860	NA	NA	NA	1.5	73900
DMT-29S	**DMT-29S-GRW-022707**	**02/27/07**	**6650**	**8480**	**1420**	**52.2**	**32.2**	**0.36**	**NA**	**NA**	**NA**	**8**	**122000**
DMT-30S	**DMT-30S-GRW-022807**	**02/28/07**	**24400 L**	**25700 J**	**2000**	**261**	**161**	**0.36**	**NA**	**NA**	**NA**	**48.1**	**132000**
	DMT-30S-GRW-100807-F	**10/08/07**	**34200 J**	**37100**	**2820**	**592**	**79.1**	**5.7**	**NA**	**NA**	**NA**	**252**	**39400**
DMT-31S	DMT-31S-GRW-030107	03/01/07	2.3 U	5 U	80.2	1080	21900	718	NA	NA	NA	3.2	37500
DMT-32S	DMT-32S-GRW-030107	03/01/07	2.3 U	5 U	80.2	22400	214000	741	NA	NA	NA	1.5	139000
DMT-33S	**DMT-33S-GRW-022707**	**02/27/07**	**24800 L**	**27100 J**	**1540**	**52.2**	**32.2**	**0.36**	**NA**	**NA**	**NA**	**3.3**	**213000**
	DMT-33S-GRW-022707-D	**02/27/07**	**25400 J**	**26500 J**	**1590**	**52.2**	**32.2**	**0.36**	**NA**	**NA**	**NA**	**4**	**207000**
DMT-39S	DMT-39S-GRW-022707	02/27/07	5.8 J	5 U	187	21800	33000	3230	NA	NA	NA	1.5	20200
	DMT-39S-GRW-061009-F	06/10/09	19	9.9 J	NA	NA	NA	NA	NA	NA	NA	NA	NA
	DMT-39S-GRW-061009-D-F	06/10/09	18.7	6.4 J	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-40S	DMT-40S-GRW-092507-F	09/25/07	2.3 U	5.2 J	80.2	8100	158000	2210	NA	NA	NA	1.5	218000
DMT-41S	DMT-41S-GRW-092607-F	09/26/07	2.3 U	5 UJ	80.2	4840	72500	359	NA	NA	NA	1.5	136000
	DMT-41S-GRW-060509-F	06/05/09	3.4 U	5 U	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-42S	DMT-42S-GRW-092607-F	09/26/07	2.3 U	5 UJ	80.2	52.2	573	0.84	NA	NA	NA	5.5	45600
	DMT-42S-GRW-060409-F	06/04/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-43S	**DMT-43S-GRW-092507-F**	**09/25/07**	**2240**	**8860**	**806**	**817**	**355**	**7**	**NA**	**NA**	**NA**	**62.4**	**79800**
DMT-44S	**DMT-44S-GRW-092507-F**	**09/25/07**	**726 J**	**623**	**16700**	**52.2**	**13.5**	**0.84**	**NA**	**NA**	**NA**	**1.5**	**150000**
	DMT-44S-GRW-060809-F	**06/08/09**	**1400 L**	**1320 J**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
	DMT-44S-GRW-060809-D-F	**06/08/09**	**1360 L**	**980 J**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
DMT-45S	DMT-45S-GRW-092607-F	09/26/07	404	39 J	32900	464	13.5	1.4	NA	NA	NA	322	4770
	DMT-45S-GRW-061109-F	06/11/09	122	124 J	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-46S	**DMT-46S-GRW-100107-F**	**10/01/07**	**15000**	**15600 J**	**7620**	**261**	**67.5**	**4.2**	**NA**	**NA**	**NA**	**73.9**	**13100**
DMT-47S	DMT-47S-GRW-100207-F	10/02/07	290	332	238	153	23600	12	NA	NA	NA	6.4	59400
DMT-48S	DMT-48S-GRW-112707-F	11/27/07	42.3	5 UJ	12500	15100	24800	630	4680	201000	NA	27	68900
DMT-55S	DMT-55S-GRW-112707-F	11/27/07	2.3 U	5 UJ	80.2 U	3280	12200	1480	1840	17700	NA	1.5 U	115000
DMT-56S	DMT-56S-GRW-092707-F	09/27/07	2.3 U	5 UJ	80.2	36200	220000	738	NA	NA	NA	1.5	269000
DMT-57S	DMT-57S-GRW-092707-F	09/27/07	2.3 U	5 UJ	80.2	9220	261000	756	NA	NA	NA	1.6	114000
	DMT-57S-GRW-060909-F	06/09/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-58S	DMT-58S-GRW-092707-F	09/27/07	2.3 U	5 UJ	80.2	748	187000	358	NA	NA	NA	2.8	107000
	DMT-58S-061109-F	06/11/09	11100	14200 J	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-59S	DMT-59S-GRW-112907-F	11/29/07	5.8 J	5 UJ	3550	3150	35000	2720	2630	124000	NA	1.5 U	18700
	DMT-59S-GRW-061009-F	06/10/09	5 J	5 U	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-61S	DMT-61S-GRW-112607-F	11/26/07	2.3 U	5 UJ	80.2 U	4610	8140	754	1310	19500	NA	1.5 U	10300
DMT-62S	DMT-62S-GRW-112607-F	11/26/07	2.3 U	5 UJ	80.2 U	23400	13500	735	1340	25000	NA	1.5 U	13400
DMT-63S	DMT-63US-GRW-112008F	11/20/08	1190	45	401 U	1270	67.5 U	4.2 U	8640	1100000	32.7 J	132	409 J
	DMT-63S-GRW-060909-F	06/09/09	740	21.9 J	NA	NA	NA	NA	NA	NA	NA	NA	NA
EA-6S	**EA-6S-GRW-112906**	**11/29/06**	**166**	**130**	**3740**	**100 U**	**5000 U**	**15 U**	**NA**	**NA**	**NA**	**50 U**	**255000**
EA-8S	**EA-8S-GRW-022807**	**02/28/07**	**30900**	**37000 R**	**401**	**261**	**161**	**0.36**	**NA**	**NA**	**NA**	**10.6**	**721000**
	EA-8S-GRW-022807-D	**02/28/07**	**31900 J**	**35200 R**	**401**	**261**	**161**	**0.36**	**NA**	**NA**	**NA**	**13.7**	**717000**
	EA-8S-GRW-092807-F	**09/28/07**	**30000**	**29000 J**	**83.9**	**52.2**	**13.5**	**0.84**	**NA**	**NA**	**NA**	**1.5**	**700000**
EA-10S	EA-10S-GRW-030107	03/01/07	26 J	5 UJ	109	52.2	425	3.4	NA	NA	NA	66.6	23600
EA-11S	EA-11S-GRW-120106	12/01/06	10 U	10 U	200 U	604	11100	788	NA	NA	NA	50 U	65300
	EA-11S-GRW-060809-F	06/08/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA
EA-15S	EA-15S-GRW-113006	11/30/06	13200	17100	373	100 U	5000 U	15 U	NA	NA	NA	50 U	301000
EAC-1S	**EAC-1S-GRW-112806**	**11/28/06**	**1.7 J**	**10 U**	**200 U**	**89.5 J**	**6230**	**58.5**	**NA**	**NA**	**NA**	**50 U**	**29900**
	EAC-01S-GRW-060409-F	**06/04/09**	**3.4 U**	**5 U**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
EAC-2S	EAC-2S-GRW-030207	03/02/07	2.3 U	5 U	80.2	960	30700	143	NA	NA	NA	1.5	29200
EAC-3S	**EAC-3S-GRW-022707**	**02/27/07**	**12400 J**	**125 J**	**167**	**52.2**	**32.2**	**0.36**	**NA**	**NA**	**NA**	**1.5**	**350000**

TABLE 4-5A

Groundwater Analytical Results - Shallow Wells - Dissolved Metals
Chromium Transport Study
Dundalk Marine Terminal, Baltimore, Maryland

Location ID	Sample ID	Sample Date	Chromium (µg/L)	Chromium (VI) (µg/L)	Alumium (µg/L)	Iron (µg/L)	Magnesium (µg/L)	Manganese (µg/L)	Potassium (µg/L)	Sodium (µg/L)	Titanium (µg/L)	Vanadium (µg/L)	Calcium (µg/L)
EAC-4S	**EAC-4S-GRW-113006**	**11/30/06**	**5280**	**5700**	**1610**	**100 U**	**5000 U**	**15 U**	**NA**	**NA**	**NA**	**50 U**	**241000**
	EAC-4S-GRW-113006-D	**11/30/06**	**5270**	**6100 L**	**1600**	**100 U**	**5000 U**	**15 U**	**NA**	**NA**	**NA**	**50 U**	**237000**
P-4	**P-4-GRW-120506**	**12/05/06**	**23400**	**26700**	**224**	**100 U**	**5000 U**	**15 U**	**NA**	**NA**	**NA**	**50 U**	**513000**
TPZ-27A	TPZ-27A-GRW-022607	02/26/07	2.3 U	5 U	80.2	19800	14400	545	NA	NA	NA	1.5	79700
TPZ-27B	TPZ-27B-GRW-022607	02/26/07	13300 J	12600 J	1630	52.2	32.2	0.36	NA	NA	NA	34.1	50400
TPZ-28	TPZ-28-GRW-022707	02/27/07	2.3 U	5 U	214	1980	12300	920	NA	NA	NA	1.5	56900
TPZ-29	TPZ-29-GRW-022707	02/27/07	2.3 U	5 U	80.2	40200	20100	838	NA	NA	NA	1.5	8930
TPZ-30A	TPZ-30A-GRW-022607	02/26/07	12.4 B	5 U	2150	40500	6700	1120	NA	NA	NA	5.4	6610
TPZ-30B	TPZ-30B-GRW-022607	02/26/07	6430	7510	23800	52.2	32.2	0.36	NA	NA	NA	280	11900
TPZ-33	TPZ-33-GRW-092607-F	09/26/07	30.8	5 UJ	80.2	1780000	416000	27400	NA	NA	NA	88.5	808000
TPZ-36	TPZ-36-GRW-092607-F	09/26/07	2.3 U	5 UJ	80.2	19800	7150	614	NA	NA	NA	1.5	18100
TPZ-38	TPZ-38-GRW-092607-F	09/26/07	2.3 U	5 UJ	80.2	9650	177000	414	NA	NA	NA	1.5	94200
TPZ-44	**TPZ-44-GRW-092807-F**	**09/28/07**	**2130**	**1750 J**	**755**	**52.2**	**22.8**	**0.84**	**NA**	**NA**	**NA**	**1.5**	**500000**
TPZ-45	TPZ-45-GRW-092807-F	09/28/07	32	5 UJ	80.2	705	22200	70.2	NA	NA	NA	3.6	31400
	TPZ-45-GRW-092807-FD	09/28/07	44.7 B	5 UJ	80.2	602	22300	73.6	NA	NA	NA	4	31000
TPZ-46	**TPZ-46-GRW-092807-F**	**09/28/07**	**4360**	**4100 J**	**20500**	**1230**	**29.5**	**2.1**	**NA**	**NA**	**NA**	**164**	**7560**

Notes:
Results in µg/L
A "D" appended to a sample ID indicates a duplicate sample
All dissolved samples were field filtered except Chromium (VI), which was lab filtered. The "F" was appended to sample IDs during later investigation phases to indicate that the sample was field filtered
U = Analyte not detected above reported MDL
J = Analyte present. Reported value may or may not be accurate or precise.
UJ = estimated non-detect due to associated inaccurate or imprecise spike recoveries, calibration issues, blank contamination, etc.
UL = Analyte not detected, but flagged as a low bias, usually associated with MS/MSD, LCS, LCSD spike recoveries
UR = Analyte not detected, but was rejected
B = Not detected substantially above the level reported in the laboratory or field blank
L = Analyte is present but flagged as a low bias, usually associated with MS/MSD, LCS, LCSD spike recoveries
R = Analyte was detected, but has been rejected
NA = Not Analyzed
BOLD values indicate that the well is screened across COPR material

TABLE 4-5B
Groundwater Analytical Results - Shallow Wells - Total Metals
Chromium Transport Study
Dundalk Marine Terminal, Baltimore, Maryland

Location ID	Sample ID	Sample Date	Chromium (µg/L)	Alumium (µg/L)	Iron (µg/L)	Magnesium (µg/L)	Manganese (µg/L)	Potassium (µg/L)	Sodium (µg/L)	Titanium (µg/L)	Vanadium (µg/L)	Calcium (ug/L)
DMT-1S	DMT01S-052306	05/23/06	43.3	893	1210	874	43.7	NA	NA	NA	59.5	21900
	DMT01S-052306-D	05/23/06	33.1	634	841	804	36.6	NA	NA	NA	54.9	21600
DMT-2S	DMT02S-052306	05/23/06	52	561	1260	405	43.1	NA	NA	NA	41.6	6980
DMT-3S	DMT03S-052306	05/23/06	654	1430	1540	2140	125	NA	NA	NA	12.7	296000
DMT-4S	DMT04S-052306	05/23/06	71.3	512	573	200	18.4	NA	NA	NA	84	24100
DMT-5S	**DMT05S-052306**	**05/23/06**	**329**	**1040**	**465**	**275**	**9.5**	**NA**	**NA**	**NA**	**313**	**10400**
DMT-6S	**DMT06S-052306**	**05/23/06**	**13600**	**30200**	**7360**	**1120**	**37**	**NA**	**NA**	**NA**	**1180**	**35400**
DMT-7S	**DMT07S-052406**	**05/24/06**	**70500**	**5640**	**10300**	**2530**	**97.2**	**NA**	**NA**	**NA**	**124**	**187000**
DMT-8S	**DMT08S-052406**	**05/24/06**	**18000**	**9400**	**1140**	**4510**	**12.9**	**NA**	**NA**	**NA**	**102**	**145000**
DMT-9S	**DMT09S-052406**	**05/24/06**	**1680**	**4210**	**3570**	**688**	**28**	**NA**	**NA**	**NA**	**1470**	**10600**
	DMT09S-052406-D	**05/24/06**	**1640**	**3860**	**3130**	**530**	**23**	**NA**	**NA**	**NA**	**1510**	**10100**
DMT-10S	**DMT10S-052406**	**05/24/06**	**7720**	**16800**	**6020**	**564**	**42.2**	**NA**	**NA**	**NA**	**406**	**15900**
DMT-11S	DMT11S-052406	05/24/06	186	7390	13500	107000	88.2	NA	NA	NA	76.6	54600
DMT-12S	**DMT12S-052206**	**05/22/06**	**59.9**	**3070**	**3760**	**582**	**48.6**	**NA**	**NA**	**NA**	**12.4**	**3600**
	DMT-12S-GRW-022607	**02/26/07**	**49.3**	**1860**	**1700**	**520**	**25.7**	**NA**	**NA**	**NA**	**16.4**	**7590**
	DMT-12S-GRW-060509	**06/05/09**	**5.5 J**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
DMT-13S	**DMT13S-052406**	**05/24/06**	**26600**	**12800**	**19200**	**6560**	**171**	**NA**	**NA**	**NA**	**246**	**617000**
DMT-14S	DMT14S-052206	05/22/06	2.3 U	256	88300	120000	3540	NA	NA	NA	1.5	393000
	DMT-14S-GRW-022607	02/26/07	81	1370	78200	126000	2980	NA	NA	NA	6.5	397000
	DMT-14S-GRW-060809	06/08/09	9.4 J	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-15S	DMT15S-052206	05/22/06	27.9	1470	126000	12400	2740	NA	NA	NA	3.8	80500
	DMT-15S-GRW-022807	02/28/07	27.1	722	104000	12800	2100	NA	NA	NA	1.5	88300
	DMT-15S-GRW-060809	06/08/09	4.4 J	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-16S	DMT16S-052206	05/22/06	24	845	2370	9910	281	NA	NA	NA	3.7	97800
	DMT-16S-GRW-030107	03/01/07	53.8	952	4490	18900	154	NA	NA	NA	4.9	117000
DMT-17S	DMT17S-052306	05/23/06	27	648	758	887	25.9	NA	NA	NA	6.1	61500
	DMT-17S-GRW-022707	02/27/07	28.2	807	1220	672	34.1	NA	NA	NA	8.7	65900
	DMT-17S-GRW-060409	06/04/09	3.4 U	NA	NA	NA	NA	NA	NA	NA	NA	NA
	DMT-17S-GRW-060409-D	06/04/09	16.3 B	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-18S	**DMT18S-052306**	**05/23/06**	**3300**	**3470**	**2730**	**460**	**24.3**	**NA**	**NA**	**NA**	**803**	**50300**
	DMT-18S-GRW-022807	**02/28/07**	**4000**	**3340**	**5610**	**1160**	**55.7**	**NA**	**NA**	**NA**	**1470**	**36400**
	DMT-18S-GRW-022807-D	**02/28/07**	**3850**	**3020**	**2650**	**767**	**32.7**	**NA**	**NA**	**NA**	**831**	**35600**
DMT-19S	DMT19S-052406	05/24/06	2.8 B	80.2	98400	63500	3190	NA	NA	NA	1.7	40300
	DMT-19S-GRW-022807	02/28/07	5.2 B	203	69700	45500	2100	NA	NA	NA	1.5	69700
DMT-20S	DMT20S-052406	05/24/06	5 B	194	15000	275000	1320	NA	NA	NA	2.4	69400
	DMT-20S-GRW-030207	03/02/07	6.7 B	803	6390	92200	1370	NA	NA	NA	2.4	49100
DMT-21S	DMT21S-052506	05/24/06	3.1 J	140	16600	214000	1920	NA	NA	NA	1.5	82200
	DMT-21S-GRW-100406	10/04/06	45.1	2960	24900	286000	2170	109000	1930000	NA	50	90000
DMT-22S	**DMT22S-052306**	**05/23/06**	**23500**	**2980**	**1260**	**851**	**13.4**	**NA**	**NA**	**NA**	**39.6**	**116000**
DMT-23S	DMT23S-052306	05/23/06	16.7	495	591	1350	36.4	NA	NA	NA	31.5	22300
	DMT-23S-GRW-100406	10/04/06	11.9	630	632	5000 U	22.9	22800	591000	NA	50	27900
	DMT-23S-GRW-100406-D	10/04/06	10.3	516	490	5000 U	17	35800	889000	NA	50	48800
DMT-24S	**DMT24S-052406**	**05/24/06**	**11300**	**2060**	**145**	**36.9**	**2**	**NA**	**NA**	**NA**	**8.9**	**229000**
	DMT-24S-GRW-100406	**10/04/06**	**1840**	**1810**	**1830**	**29700**	**26.6**	**76000**	**2490000**	**NA**	**850**	**31400**
DMT-25S	**DMT25S-052406**	**05/24/06**	**1500**	**15400**	**387**	**43.4**	**3.3**	**NA**	**NA**	**NA**	**174**	**23100**
	DMT-25S-GRW-100406	**10/04/06**	**10800**	**18500**	**2610**	**5000 U**	**15.8**	**42900**	**2380000**	**NA**	**1740**	**24600**
	DMT-25S-GRW-120406	**12/04/06**	**3450**	**6780**	**430**	**109 B**	**5.8 B**	**NA**	**NA**	**NA**	**97.6**	**84900**

TABLE 4-5B

Groundwater Analytical Results - Shallow Wells - Total Metals

Chromium Transport Study

Dundalk Marine Terminal, Baltimore, Maryland

Location ID	Sample ID	Sample Date	Chromium (µg/L)	Alumium (µg/L)	Iron (µg/L)	Magnesium (µg/L)	Manganese (µg/L)	Potassium (µg/L)	Sodium (µg/L)	Titanium (µg/L)	Vanadium (µg/L)	Calcium (ug/L)
DMT-26S	DMT-26S-GRW-022807	02/28/07	13.7 B	2180	25200	267000	495	NA	NA	NA	6.3	75800
DMT-27S	DMT-27S-GRW-022707	02/27/07	2.3 UJ	80.2	5540	296000	715	NA	NA	NA	1.5	78800
	DMT-27S-GRW-060409	06/04/09	85.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-28S	DMT-28S-GRW-030207	03/02/07	7.2 B	658	16000	208000	1790	NA	NA	NA	2.3	70600
DMT-29S	**DMT-29S-GRW-022707**	**02/27/07**	**10700**	**8550**	**13000**	**4070**	**123**	**NA**	**NA**	**NA**	**178**	**165000**
DMT-30S	**DMT-30S-GRW-022807**	**02/28/07**	**47300 L**	**51200**	**108000**	**17400**	**2370**	**NA**	**NA**	**NA**	**467**	**298000**
	DMT-30S-GRW-100807	**10/08/07**	**27100 J**	**4680**	**3610**	**479**	**47.1**	**NA**	**NA**	**NA**	**330**	**60100**
DMT-31S	DMT-31S-GRW-030107	03/01/07	31.6	2150	9810	22500	706	NA	NA	NA	16.1	37900
DMT-32S	DMT-32S-GRW-030107	03/01/07	50.1	1460	29400	223000	828	NA	NA	NA	7.2	144000
DMT-33S	**DMT-33S-GRW-022707**	**02/27/07**	**25700 L**	**2060**	**337**	**150**	**4.2**	**NA**	**NA**	**NA**	**10.3**	**224000**
	DMT-33S-GRW-022707-D	**02/27/07**	**24600 J**	**1940**	**387**	**125**	**5.3**	**NA**	**NA**	**NA**	**8.2**	**229000**
DMT-39S	DMT-39S-GRW-022707	02/27/07	66.4	1580	24700	33200	3250	NA	NA	NA	4.3	19900
	DMT-39S-GRW-061009	06/10/09	333	NA	NA	NA	NA	NA	NA	NA	NA	NA
	DMT-39S-GRW-061009-D	06/10/09	332	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-40S	DMT-40S-GRW-092507	09/25/07	35.3	1560	8660	160000	1820	NA	NA	NA	5.6	217000
DMT-41S	DMT-41S-GRW-092607	09/26/07	17 B	1800	12400	68900	462	NA	NA	NA	9.1	135000
	DMT-41S-GRW-060509	06/05/09	5.3 J	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-42S	DMT-42S-GRW-092607	09/26/07	21.2 B	382	481	1050	20.5	NA	NA	NA	9.7	43800
DMT-42S	DMT-42S-GRW-060409	06/04/09	6.7 B	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-43S	**DMT-43S-GRW-092507**	**09/25/07**	**13600**	**9810**	**13800**	**5580**	**121**	**NA**	**NA**	**NA**	**440**	**426000**
DMT-44S	**DMT-44S-GRW-092507**	**09/25/07**	**2430 J**	**22300**	**8790**	**3270**	**91.7**	**NA**	**NA**	**NA**	**101**	**160000**
	DMT-44S-GRW-060809	**06/08/09**	**1460 L**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
	DMT-44S-GRW-060809-D	**06/08/09**	**7650 L**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
DMT-45S	DMT-45S-GRW-092607	09/26/07	851	35300	4430	425	22.7	NA	NA	NA	347	7240
	DMT-45S-GRW-061109	06/11/09	136	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-46S	**DMT-46S-GRW-100107**	**10/01/07**	**15600**	**9860**	**5740**	**742**	**30.2**	**NA**	**NA**	**NA**	**89.4**	**16100**
DMT-47S	DMT-47S-GRW-100207	10/02/07	332	80.2	52.2	23500	22.2	NA	NA	NA	5.1	59800
DMT-48S	DMT-48S-GRW-112707	11/27/07	591	164000	217000	48200	1330	13700	192000	NA	436	90900
DMT-55S	DMT-55S-GRW-112707	11/27/07	20.1	422	4670	11900	1460	1550	18200	NA	1.9 J	111000
DMT-56S	DMT-56S-GRW-092707	09/27/07	585	12300	60600	226000	902	NA	NA	NA	56.9	285000
DMT-57S	DMT-57S-GRW-092707	09/27/07	334	1900	15900	243000	756	NA	NA	NA	21.4	111000
	DMT-57S-GRW-060909	06/09/09	487	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-58S	DMT-58S-GRW-092707	09/27/07	85.9	902	2530	191000	388	NA	NA	NA	9.3	111000
	DMT-58S-061109	06/11/09	11300	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-59S	DMT-59S-GRW-112907	11/29/07	415	78100	167000	37100	2880	6160	150000	NA	560	18900
	DMT-59S-GRW-061009	06/10/09	13.6 J	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-61S	DMT-61S-GRW-112607	11/26/07	2.8 J	174 J	4830	8320	806	1180	20800	NA	1.5 U	10100
DMT-62S	DMT-62S-GRW-112607	11/26/07	15.8	579	24200	13900	747	1270	26300	NA	1.9 J	13200
DMT-63S	DMT-63US-GRW-112008	11/20/08	1300	1350	3210	67.5 U	7.7 J	7540	966000	64.5	120	351 U
	DMT-63S-GRW-060909	06/09/09	893	NA	NA	NA	NA	NA	NA	NA	NA	NA
EA-6S	**EA-6S-GRW-112906**	**11/29/06**	**147**	**3800**	**73.8 B**	**45.7 B**	**2.1 B**	**NA**	**NA**	**NA**	**1.9 B**	**233000**
EA-8S	**EA-8S-GRW-022807**	**02/28/07**	**33500**	**80.2**	**52.2**	**32.2**	**0.36**	**NA**	**NA**	**NA**	**1.5**	**122000**
	EA-8S-GRW-022807-D	**02/28/07**	**31700 J**	**80.2**	**52.2**	**32.2**	**0.36**	**NA**	**NA**	**NA**	**1.5**	**20600**
	EA-8S-GRW-092807	**09/28/07**	**30800**	**306**	**408**	**385**	**7.5**	**NA**	**NA**	**NA**	**3.6**	**751000**
EA-10S	EA-10S-GRW-030107	03/01/07	23.6 J	98.1	160	1900	36	NA	NA	NA	42.6	29300
EA-11S	EA-11S-GRW-120106	12/01/06	8.4 J	1580	1970	11500	899	NA	NA	NA	4.6 B	69000
	EA-11S-GRW-060809	06/08/09	3.4 U	NA	NA	NA	NA	NA	NA	NA	NA	NA

TABLE 4-5B

Groundwater Analytical Results - Shallow Wells - Total Metals

Chromium Transport Study

Dundalk Marine Terminal, Baltimore, Maryland

Location ID	Sample ID	Sample Date	Chromium (µg/L)	Alumium (µg/L)	Iron (µg/L)	Magnesium (µg/L)	Manganese (µg/L)	Potassium (µg/L)	Sodium (µg/L)	Titanium (µg/L)	Vanadium (µg/L)	Calcium (ug/L)
EA-15S	**EA-15S-GRW-113006**	**11/30/06**	**16200**	**458**	**100 U**	**48.9 B**	**1.5 B**	**NA**	**NA**	**NA**	**50 U**	**289000**
EAC-1S	EAC-1S-GRW-112806	11/28/06	4.6 J	102 J	141	5580	56.3	NA	NA	NA	50 U	26900
	EAC-01S-GRW-060409	06/04/09	6.8 B	NA	NA	NA	NA	NA	NA	NA	NA	NA
EAC-2S	EAC-2S-GRW-030207	03/02/07	2.3 U	80.2	1870	29900	140	NA	NA	NA	1.5	28000
EAC-3S	**EAC-3S-GRW-022707**	**02/27/07**	**11400 J**	**533**	**1810**	**1240**	**41.5**	**NA**	**NA**	**NA**	**2.6**	**413000**
EAC-4S	**EAC-4S-GRW-113006**	**11/30/06**	**4980**	**1580**	**162**	**197 B**	**3.9 B**	**NA**	**NA**	**NA**	**50 U**	**239000**
	EAC-4S-GRW-113006-D	**11/30/06**	**5170**	**1660**	**112**	**216 B**	**4.8 B**	**NA**	**NA**	**NA**	**50 U**	**236000**
P-4	**P-4-GRW-120506**	**12/05/06**	**23600**	**364**	**368**	**256 B**	**4.6 B**	**NA**	**NA**	**NA**	**4.1 B**	**529000**
TPZ-27A	TPZ-27A-GRW-022607	02/26/07	3.6 B	822	20400	14700	558	NA	NA	NA	2.9	79700
TPZ-27B	TPZ-27B-GRW-022607	02/26/07	12700 J	1660	120	32.2	0.69	NA	NA	NA	35.8	48800
TPZ-28	TPZ-28-GRW-022707	02/27/07	16.7	716	2100	11900	890	NA	NA	NA	1.8	55300
TPZ-29	TPZ-29-GRW-022707	02/27/07	2.3 U	276	41900	20900	884	NA	NA	NA	1.5	9010
TPZ-30A	TPZ-30A-GRW-022607	02/26/07	6.2 B	80.2	38700	6900	1160	NA	NA	NA	1.5	7030
TPZ-30B	TPZ-30B-GRW-022607	02/26/07	6960	25500	163	32.2	0.58	NA	NA	NA	298	12200
TPZ-33	TPZ-33-GRW-092607	09/26/07	33.4 B	1620	1850000	391000	25800	NA	NA	NA	98.4	755000
TPZ-36	TPZ-36-GRW-092607	09/26/07	2.8 B	474	24500	8270	721	NA	NA	NA	2.7	21100
TPZ-38	TPZ-38-GRW-092607	09/26/07	17.4 B	1660	13700	189000	398	NA	NA	NA	4.7	105000
TPZ-44	**TPZ-44-GRW-092807**	**09/28/07**	**2880**	**3200**	**2320**	**991**	**20**	**NA**	**NA**	**NA**	**37.5**	**509000**
TPZ-45	TPZ-45-GRW-092807	09/28/07	32.3	130	904	18800	67	NA	NA	NA	3.2	26000
	TPZ-45-GRW-092807-D	09/28/07	37.7 B	119	922	21300	78.7	NA	NA	NA	4.8	29500
TPZ-46	**TPZ-46-GRW-092807**	**09/28/07**	**18000**	**55400**	**62600**	**16200**	**499**	**NA**	**NA**	**NA**	**634**	**112000**

Notes:

Results in µg/L

A "D" appended to a sample ID indicates a duplicate sample

U = Analyte not detected above reported MDL

J = Analyte present. Reported value may or may not be accurate or precise.

UJ = estimated non-detect due to associated inaccurate or imprecise spike recoveries, calibration issues, blank contamination, etc.

B = Not detected substantially above the level reported in the laboratory or field blank

L = Analyte is present but flagged as a low bias, usually associated with MS/MSD, LCS, LCSD spike recoveries

NA = Not Analyzed

BOLD values indicate that the well is screened across COPR material

TABLE 4-6A

Groundwater Analytical Results - Upper Sand Wells - Dissolved Metals

Chromium Transport Study

Dundalk Marine Terminal, Baltimore, Maryland

Location ID	Sample ID	Sample Date	Chromium (µg/L)	Chromium (VI) (µg/L)	Alumium (µg/L)	Iron (µg/L)	Magnesium (µg/L)	Manganese (µg/L)	Potassium (µg/L)	Sodium (µg/L)	Titanium (µg/L)	Vanadium (µg/L)	Calcium (µg/L)
DMT-49US	DMT-49US-GRW-100807-F	10/08/07	2.3 U	5 U	80.2	6320	217000	436	NA	NA	NA	1.5	59800
DMT-50US	DMT-50US-GRW-092507-F	09/25/07	21.6	5 U	6290	11600	154000	1320	NA	NA	NA	17.8	84400
	DMT-50US-GRW-060809-F	06/08/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-51US	DMT-51US-GRW-092507-F	09/25/07	2.3 U	5 U	80.2	25800	224000	236	NA	NA	NA	1.5	229000
DMT-52US	DMT-52US-GRW-092507-F	09/25/07	5.1 J	5 U	119	116	105000	119	NA	NA	NA	6.3	51800
	DMT-52US-GRW-060809-F	06/08/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-53US	DMT-53US-GRW-092807-F	09/28/07	2.7 B	5 UJ	80.2	4930	94300	3680	NA	NA	NA	2.1	60700
DMT-54US	DMT-54US-GRW-100107-F	10/01/07	4.9 B	5 UJ	918	59.8	33600	2010	NA	NA	NA	1.5	22200
	DMT-54US-GRW-060509-F	06/05/09	3.4 U	5 U	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-64US	DMT-64US-GRW-111808F	11/18/08	3 U	5 UJ	80.2 U	2470	152000	134	68100	1460000	3.8 U	2.5 U	26200
	DMT-64US-GRW-060409-F	06/04/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-65US	DMT-65US-GRW-111808F	11/18/08	3 U	5 UJ	80.2 U	3210	139000	848	50.3 U	1940000	4 J	2.5 U	76600
	DMT-65US-GRW-111808-DF	11/18/08	3 U	5 UJ	80.2 U	3210	144000	873	79300	1860000	4 J	2.5 U	79300
	DMT-65US-GRW-060409-F	06/04/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-67US	DMT-67US-GRW-111908F	11/19/08	3.4 J	5 U	80.2 U	27600	178000	1960	94100	4140000	3.8 U	2.5 U	102000
	DMT-67US-GRW-060809-F	06/08/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-70US	DMT-70US-GRW-111908F	11/19/08	3.5 J	5 U	80.2 U	91300	191000	3180	86300	4860000	3.8 U	2.5 J	344000
	DMT-70US-GRW-060809-F	06/08/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-71US	DMT-71US-GRW-111908F	11/19/08	3 U	5 U	80.2 U	111000	189000	3640	73400	4420000	3.8 U	2.5 U	350000
	DMT-71US-GRW-111908-DF	11/19/08	3 U	5 U	80.2 U	115000	195000	3730	75000	4650000	3.8 U	2.6 J	359000
DMT-72US	DMT-72US-GRW-111908F	11/19/08	3 U	5 U	80.2 U	83900	225000	4000	85100	2070000	3.8 U	2.5 U	362000
	DMT-72US-GRW-060509-F	06/05/09	3.4 U	5 U	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-73US	DMT-73US-GRW-111808F	11/18/08	3 U	5 UJ	80.2 U	16000	20400	1840	5320	96500	3.8 U	2.5 U	23300
	DMT-73US-GRW-061009-F	06/10/09	3.4 U	5 U	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-74US	DMT-74US-GRW-111708F	11/17/08	3 U	5 UJ	80.2 U	16800	26000	1240	6200	111000	3.8 U	2.5 U	43600
DMT-75US	DMT-75US-GRW-111708F	11/17/08	3 U	5 UJ	80.2 U	36500	29800	1800	9260	192000	3.8 U	2.5 U	47400
TPZ-48	TPZ-48-GRW-031909F	03/19/09	3 U	5 U	80.2 U	43900	61800	2760	13400	821000	3.8 U	2.5 U	190000
	TPZ-48-GRW-031909-DF	03/19/09	3 U	5 U	80.2 U	43900	59000	2670	13000	815000	3.8 U	2.5 U	182000
	TPZ-48-GRW-060909-F	06/09/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA
TPZ-49	TPZ-49-GRW-031909F	03/19/09	3 U	5 U	80.2 U	4430	29100	1130	7360	461000	3.8 U	2.5 U	109000
	TPZ-49-GRW-060909-F	06/09/09	3.9 J	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

Results in µg/L

A "D" appended to a sample ID indicates a duplicate sample

All dissolved samples were field filtered except Chromium (VI), which was lab filtered. The "F" was appended to sample IDs during later investigation phases to indicate that the sample was field filtered

U = Analyte not detected above reported MDL

J = Analyte present. Reported value may or may not be accurate or precise.

UJ = estimated non-detect due to associated inaccurate or imprecise spike recoveries, calibration issues, blank contamination, etc.

UL = Analyte not detected, but flagged as a low bias, usually associated with MS/MSD, LCS, LCSD spike recoveries

UR = Analyte not detected, but was rejected

B = Not detected substantially above the level reported in the laboratory or field blank

L = Analyte is present but flagged as a low bias, usually associated with MS/MSD, LCS, LCSD spike recoveries

R = Analyte was detected, but has been rejected

NA = Not Analyzed

TABLE 4-6B

Groundwater Analytical Results - Upper Sand Wells - Total Metals

Chromium Transport Study

Dundalk Marine Terminal, Baltimore, Maryland

Location ID	Sample ID	Sample Date	Chromium (µg/L)	Alumium (µg/L)	Iron (µg/L)	Magnesium (µg/L)	Manganese (µg/L)	Potassium (µg/L)	Sodium (µg/L)	Titanium (µg/L)	Vanadium (µg/L)	Calcium (ug/L)
DMT-49US	DMT-49US-GRW-100807	10/08/07	2.8 J	125	6590	211000	448	NA	NA	NA	1.5	58200
DMT-50US	DMT-50US-GRW-092507	09/25/07	31.8	7500	15100	146000	1500	NA	NA	NA	26.9	90400
	DMT-50US-GRW-060809	06/08/09	31.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-51US	DMT-51US-GRW-092507	09/25/07	15.9	932	32200	257000	267	NA	NA	NA	1.5	254000
DMT-52US	DMT-52US-GRW-092507	09/25/07	10.4 J	415	410	105000	128	NA	NA	NA	8.6	51700
	DMT-52US-GRW-060809	06/08/09	6.6 J	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-53US	DMT-53US-GRW-092807	09/28/07	24.6 B	541	7970	92700	3720	NA	NA	NA	3.5	60000
DMT-54US	DMT-54US-GRW-100107	10/01/07	50.1 B	4170	9630	33500	2030	NA	NA	NA	24.5	23300
	DMT-54US-GRW-060509	06/05/09	5.5 J	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-64US	DMT-64US-GRW-111808	11/18/08	3 U	256	3740	154000	138	64300	1600000	7.6 J	2.5 U	30400
	DMT-64US-GRW-060409	06/04/09	6.8 B	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-65US	DMT-65US-GRW-111808	11/18/08	11.1 B	379	4260	139000	833	138000	2270000	13.3	2.5 U	76300
	DMT-65US-GRW-111808-D	11/18/08	9.1 B	161 J	3940	138000	831	135000	2080000	8.3 J	2.5 U	77400
DMT-65US	DMT-65US-GRW-060409	06/04/09	4.8 B	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-67US	DMT-67US-GRW-111908	11/19/08	13.2 J	343	28800	183000	2010	95900	4760000	14.5	2.8 J	104000
	DMT-67US-GRW-060809	06/08/09	7.3 J	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-70US	DMT-70US-GRW-111908	11/19/08	228	10500	108000	195000	3310	87000	4300000	223	44.9	342000
	DMT-70US-GRW-060809	06/08/09	26.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-71US	DMT-71US-GRW-111908	11/19/08	7.5 J	80.2 U	112000	190000	3640	73000	4640000	3.8 U	2.8 J	351000
	DMT-71US-GRW-111908-D	11/19/08	6.2 J	80.2 U	116000	196000	3770	75800	4860000	3.8 U	2.8 J	363000
DMT-72US	DMT-72US-GRW-111908	11/19/08	4.6 J	117 J	84600	229000	4020	85900	2100000	3.8 U	2.5 U	362000
	DMT-72US-GRW-060509	06/05/09	6.2 J	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-73US	DMT-73US-GRW-111808	11/18/08	3 U	80.2 U	15200	19300	1680	4570	99900	5.9 J	2.5 U	21600
	DMT-73US-GRW-061009	06/10/09	8.2 J	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-74US	DMT-74US-GRW-111708	11/17/08	3 U	524	19400	27400	1330	6580	113000	11.4	2.5 U	45300
DMT-75US	DMT-75US-GRW-111708	11/17/08	3 U	122 J	35000	29300	1720	9220	197000	3.8 U	2.5 U	44900
TPZ-48	TPZ-48-GRW-031909	03/19/09	33.4	578	28100	46800	2120	14200	711000	23.2	3.6 J	145000
	TPZ-48-GRW-031909-D	03/19/09	31.6	570	27700	46500	2030	14100	708000	19.1	3.6 J	145000
	TPZ-48-GRW-060909	06/09/09	24.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
TPZ-49	TPZ-49-GRW-031909	03/19/09	23.5	738	6140	29900	1160	7520	472000	22	3.4 J	111000
	TPZ-49-GRW-060909	06/09/09	84.3	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

Results in µg/L

A "D" appended to a sample ID indicates a duplicate sample

U = Analyte not detected above reported MDL

J = Analyte present. Reported value may or may not be accurate or precise.

UJ = estimated non-detect due to associated inaccurate or imprecise spike recoveries, calibration issues, blank contamination, etc.

B = Not detected substantially above the level reported in the laboratory or field blank

L = Analyte is present but flagged as a low bias, usually associated with MS/MSD, LCS, LCSD spike recoveries

NA = Not Analyzed

TABLE 4-7A

Groundwater Analytical Results - M-Series Wells - Dissolved Metals

Chromium Transport Study

Dundalk Marine Terminal, Baltimore, Maryland

Location ID	Sample ID	Sample Date	Chromium (µg/L)	Chromium (VI) (µg/L)	Alumium (µg/L)	Iron (µg/L)	Magnesium (µg/L)	Manganese (µg/L)	Potassium (µg/L)	Sodium (µg/L)	Titanium (µg/L)	Vanadium (µg/L)	Calcium (µg/L)
DMT-1M	DMT01M-052206	05/22/06	2.3 U	5 U	196	78.3	2180	95	NA	NA	NA	8.2	22500
	DMT01M-052206-D	05/22/06	2.3 U	5 U	192	82.1	2410	111	NA	NA	NA	8.4	23600
	DMT-1M-GRW-022807	02/28/07	2.3 U	5 U	80.2	717	20300	3750	NA	NA	NA	2	28500
	DMT-01M-GRW-060809-F	06/08/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-2M	DMT02M-052206	05/22/06	35.5	36	446	109	33.3	0.47	NA	NA	NA	6.1	396000
	DMT-2M-GRW-010807	01/08/07	1.3 B	10 U	23.1 B	42300	104000	2580	NA	NA	NA	50 U	84100
DMT-34M	DMT-34M-GRW-022807	02/28/07	2.3 U	5 U	80.2	72900	133000	2900	NA	NA	NA	1.5	112000
	DMT-34M-GRW-060409-F	06/04/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-35M	DMT-35M-GRW-030207	03/02/07	71.7	80.9	80.2	52.2	6900	106	NA	NA	NA	6.5	17700
	DMT-35M-GRW-061907-L	06/19/07	16.9	18.7	80.2	76.7	7040	122	NA	NA	NA	3.9	14900
	DMT-35M-GRW-061907-LD	06/19/07	42.8	20.3	3270	4090	7070	134	NA	NA	NA	37.8	14400
	DMT-35M-GRW-100107-F	10/01/07	8.6 B	5 UJ	80.2	52.2	6940	130	NA	NA	NA	1.9	15300
DMT-36M	DMT-36M-GRW-022607	02/26/07	2.3 U	5 U	80.2	993	10100	805	NA	NA	NA	1.7	36300
DMT-37M	DMT-37M-GRW-022707	02/27/07	3.9 B	5 U	80.2	1250	24200	3760	NA	NA	NA	1.9	33100
	DMT-37M-GRW-022707-D	02/27/07	2.3 U	5 U	80.2	1260	24100	3710	NA	NA	NA	1.6	32700
DMT-38M	DMT-38M-GRW-030107	03/01/07	3 J	6.3 J	80.2	52.2	385	5.5	NA	NA	NA	16.9	15600
	DMT-38M-GRW-061807-L	06/18/07	2.8 J	5 UJ	80.2	52.2	341	11.6	NA	NA	NA	9.7	10600
DMT-60M	DMT-60M-GRW-112707-F	11/27/07	3.7 J	5 UJ	532	228	12900	305	4850	31900	NA	1.5 U	20800
	DMT-60M-GRW-112707-FD	11/27/07	2.3 U	5 UJ	80.2 U	52.2 U	12600	323	5170	33800	NA	1.5 U	21200
	DMT-60M-GRW-061009-F	06/10/09	3.4 U	5 U	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-77M	DMT-77M-GRW-111808F	11/18/08	9 J	5 UJ	18600	20500	11200	509	8450	109000	42.1	18.4	26800
	DMT-77M-GRW-060809-F	06/08/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-78M	DMT-78M-GRW-111808F	11/18/08	3 U	5 UJ	80.2 U	52000	97200	806	55900	716000	3.8 U	2.5 U	49100
DMT-79M	DMT-79M-GRW-111708F	11/17/08	3 U	5 UJ	80.2 U	5560	5250	540	2790	27000	3.8 U	2.5 U	17800
DMT-80M	DMT-80M-GRW-111708F	11/17/08	3 U	5 UJ	80.2 U	12900	33900	339	8420	131000	3.8 U	2.5 U	51000
EA-5M	EA-5M-GRW-120406-01	12/04/06	3.2 B	10 UL	25 B	4740	20400	834	NA	NA	NA	50 U	66500
	EA-5M-GRW-120406-02	12/04/06	5.8 B	10 U	23.1 B	1660	8290	466	NA	NA	NA	3.6 B	36900
	EA-5M-GRW-120406-02-D	12/04/06	4.7 B	10 U	26.3 B	5500	11100	753	NA	NA	NA	3.3 B	47400
EA-6M	EA-6M-GRW-112906-01	11/29/06	0.89 B	10 UL	200 U	33300	37700	4040	NA	NA	NA	50 U	63700
	EA-6M-GRW-112906-02	11/29/06	1.5 B	10 U	200 U	32800	37300	3990	NA	NA	NA	50 U	62900
	EA-06M-GRW-060409-F	06/04/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA
EA-7M	EA-7M-GRW-030107	03/01/07	2.3 U	5 U	80.2	18300	12800	1420	NA	NA	NA	1.5	32900
	EA-07M-GRW-060909-F	06/09/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA
EA-8M	EA-8M-GRW-022807	02/28/07	2.8 J	5 U	80.2	3930	22600	4580	NA	NA	NA	1.5	30300
	EA-8M-GRW-100107-F	10/01/07	2.3 U	5 UJ	802	5130	22300	4540	NA	NA	NA	15	29400
EA-10M	EA-10M-GRW-030107	03/01/07	2.3 U	5 U	80.2	2470	18100	850	NA	NA	NA	1.5	90100
EA-11M	EA-11M-GRW-120106-01	12/01/06	10 U	10 U	200 U	12500	34900	2550	NA	NA	NA	50 U	55100
	EA-11M-GRW-120106-02	12/01/06	1 J	10 U	200 U	47600	36100	2580	NA	NA	NA	50 U	52500
	EA-11M-GRW-060809-F	06/08/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA

TABLE 4-7A
Groundwater Analytical Results - M-Series Wells - Dissolved Metals
Chromium Transport Study
Dundalk Marine Terminal, Baltimore, Maryland

Location ID	Sample ID	Sample Date	Chromium (µg/L)	Chromium (VI) (µg/L)	Alumium (µg/L)	Iron (µg/L)	Magnesium (µg/L)	Manganese (µg/L)	Potassium (µg/L)	Sodium (µg/L)	Titanium (µg/L)	Vanadium (µg/L)	Calcium (µg/L)
EA-13M	EA-13M-GRW-120506-1	12/05/06	3.4 B	24	200 U	35800	48100	3220	NA	NA	NA	50 U	53100
	EA-13M-GRW-120506-2	12/05/06	5.9 B	6 B	200 U	35400	48900	3240	NA	NA	NA	50 U	49000
EA-15M	EA-15M-GRW-120106-01	12/01/06	3.6 J	10 U	200 U	60200	91600	2710	NA	NA	NA	50 U	63800
	EA-15M-GRW-120106-02	12/01/06	1.9 J	10 U	200 U	60900	91300	2780	NA	NA	NA	50 U	62600
EAC-1M	EAC-1M-GRW-112806-01	11/28/06	0.96 J	10 U	200 U	111	23400	6970	NA	NA	NA	50 U	63800
	EAC-1M-GRW-112806-02	11/28/06	1.1 J	10 U	200 U	108	24900	6740	NA	NA	NA	50 U	67600
EAC-2M	EAC-2M-GRW-030207	03/02/07	2.3 U	5 U	80.2	104	64200	3070	NA	NA	NA	1.5	50400
EAC-3M	EAC-3M-GRW-022707	02/27/07	3.4 J	5 U	80.2	56200	20300	1710	NA	NA	NA	1.5	24800
EAC-4M	EAC-4M-GRW-113006-01	11/30/06	1 J	1.7 J	200 U	245	162000	50.3	NA	NA	NA	50 U	67000
	EAC-4M-GRW-113006-02	11/30/06	2.8 J	2.1 J	200 U	367	225000	65.5	NA	NA	NA	2.8 B	75400
	EAC-4M-GRW-100207-F	10/02/07	2.3 U	5 U	401	261	238000	65.3	NA	NA	NA	7.5	73400

Notes:
Results in µg/L
A "D" appended to a sample ID indicates a duplicate sample
All dissolved samples were field filtered except Chromium (VI), which was lab filtered. The "F" was appended to sample IDs during later investigation phases to indicate that the sample was field filtered
U = Analyte not detected above reported MDL
J = Analyte present. Reported value may or may not be accurate or precise.
UJ = estimated non-detect due to associated inaccurate or imprecise spike recoveries, calibration issues, blank contamination, etc.
UL = Analyte not detected, but flagged as a low bias, usually associated with MS/MSD, LCS, LCSD spike recoveries
UR = Analyte not detected, but was rejected
B = Not detected substantially above the level reported in the laboratory or field blank
L = Analyte is present but flagged as a low bias, usually associated with MS/MSD, LCS, LCSD spike recoveries
R = Analyte was detected, but has been rejected
NA = Not Analyzed

TABLE 4-7B
Groundwater Analytical Results - M-Series Wells - Total Metals
Chromium Transport Study
Dundalk Marine Terminal, Baltimore, Maryland

Location ID	Sample ID	Sample Date	Chromium (µg/L)	Alumium (µg/L)	Iron (µg/L)	Magnesium (µg/L)	Manganese (µg/L)	Potassium (µg/L)	Sodium (µg/L)	Titanium (µg/L)	Vanadium (µg/L)	Calcium (ug/L)
DMT-1M	DMT01M-052206	05/22/06	8.4 B	302	270	2110	82.5	NA	NA	NA	9.8	22700
	DMT01M-052206-D	05/22/06	10.3 B	384	442	2130	78.9	NA	NA	NA	10.5	22400
	DMT-01M-062106	06/21/06	NA	80.2	2510	21600	4070	NA	NA	NA	1.5	25400
	DMT-1M-GRW-022807	02/28/07	3.1 B	80.2	841	21800	3830	NA	NA	NA	2.6	31700
	DMT-01M-GRW-060809	06/08/09	54.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-2M	DMT02M-052206	05/22/06	50	584	403	305	10.3	NA	NA	NA	6.8	413000
	DMT-2M-GRW-010807	01/08/07	6.1 B	75.5 B	41300	103000	2520	NA	NA	NA	50 U	90200
DMT-34M	DMT-34M-GRW-022807	02/28/07	2.3 U	80.2	74000	139000	2870	NA	NA	NA	1.5	116000
	DMT-34M-GRW-060409	06/04/09	10.3 B	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-35M	DMT-35M-GRW-030207	03/02/07	77.8	1450	1430	6850	111	NA	NA	NA	16.4	17500
	DMT-35M-GRW-061907-L	06/19/07	125 B	1160	2400	7750	136	NA	NA	NA	20.1	15700
	DMT-35M-GRW-061907-LD	06/19/07	29.9 B	218	568	7710	127	NA	NA	NA	6.9	15300
	DMT-35M-GRW-100107	10/01/07	64.6 B	1630	7420	7460	173	NA	NA	NA	58.9	16500
DMT-36M	DMT-36M-GRW-022607	02/26/07	2.3 U	80.2	1060	10500	818	NA	NA	NA	2.2	34700
DMT-37M	DMT-37M-GRW-022707	02/27/07	4 B	80.2	1410	24800	4050	NA	NA	NA	2.8	35200
	DMT-37M-GRW-022707-D	02/27/07	2.3 U	80.2	1530	26600	4120	NA	NA	NA	3.2	38400
DMT-38M	DMT-38M-GRW-030107	03/01/07	6.6 B	117	84.4	435	6.2	NA	NA	NA	22.6	18200
	DMT-38M-GRW-061807-L	06/18/07	17.1	1660	480	482	16.3	NA	NA	NA	13	12500
DMT-60M	DMT-60M-GRW-112707	11/27/07	3.2 J	420	236	12400	285	4290	34600	NA	2.5 J	19100
	DMT-60M-GRW-112707-D	11/27/07	2.3 U	80.2 U	52.2 U	12700	304	4390	35000	NA	1.5 U	19600
	DMT-60M-GRW-061009	06/10/09	4 J	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-77M	DMT-77M-GRW-111808	11/18/08	3 U	227	11300	7020	388	5570	116000	5.8 J	2.5 U	20800
	DMT-77M-GRW-060809	06/08/09	62.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-78M	DMT-78M-GRW-111808	11/18/08	7.9 B	2850	54900	96100	806	52400	849000	55.3	7.5	50100
	DMT-79M-GRW-111708	11/17/08	3 U	80.2 U	5820	5300	548	2800	26900	3.8 U	2.5 U	18200
DMT-80M	DMT-80M-GRW-111708	11/17/08	3 U	921	13700	34200	345	8590	134000	11.9	2.5 U	50700
EA-5M	EA-5M-GRW-120406-01	12/04/06	29	1900	4400	3710 B	146	NA	NA	NA	16.3 B	23700
	EA-5M-GRW-120406-02	12/04/06	85.9	3780	9230	7870	466	NA	NA	NA	27.6 B	34700
	EA-5M-GRW-120406-02-D	12/04/06	86.7	3920	9130	7780	458	NA	NA	NA	26.7 B	34300
EA-6M	EA-6M-GRW-112906-01	11/29/06	20.4	1660	33100	34300	3680	NA	NA	NA	5.2 B	58500
	EA-6M-GRW-112906-02	11/29/06	1.5 B	245	32000	36100	3870	NA	NA	NA	50 U	61000
	EA-06M-GRW-060409	06/04/09	3.4 U	NA	NA	NA	NA	NA	NA	NA	NA	NA
EA-7M	EA-7M-GRW-030107	03/01/07	17.6 B	682	24900	13600	1360	NA	NA	NA	2.6	32400
	EA-07M-GRW-060909	06/09/09	11.2 J	NA	NA	NA	NA	NA	NA	NA	NA	NA
EA-8M	EA-8M-GRW-022807	02/28/07	17.7	80.2	4510	24000	4690	NA	NA	NA	1.5	32200
	EA-8M-GRW-100107	10/01/07	2.8 B	80.2	6120	22300	4460	NA	NA	NA	1.5	29700
EA-10M	EA-10M-GRW-030107	03/01/07	55.2	3320	24400	26800	1750	NA	NA	NA	18	130000
EA-11M	EA-11M-GRW-120106-01	12/01/06	8.5 J	1340	16800	35200	2600	NA	NA	NA	2.4 B	54600
	EA-11M-GRW-120106-02	12/01/06	47.3	5750	67900	37700	2750	NA	NA	NA	16.5 B	54800
	EA-11M-GRW-060809	06/08/09	14 J	NA	NA	NA	NA	NA	NA	NA	NA	NA

TABLE 4-7B

Groundwater Analytical Results - M-Series Wells - Total Metals

Chromium Transport Study

Dundalk Marine Terminal, Baltimore, Maryland

Location ID	Sample ID	Sample Date	Chromium (µg/L)	Alumium (µg/L)	Iron (µg/L)	Magnesium (µg/L)	Manganese (µg/L)	Potassium (µg/L)	Sodium (µg/L)	Titanium (µg/L)	Vanadium (µg/L)	Calcium (ug/L)
EA-13M	EA-13M-GRW-120506-1	12/05/06	935	20600	97900	47100	4070	NA	NA	NA	118	109000
	EA-13M-GRW-120506-2	12/05/06	5.8 B	130 B	37400	51100	3380	NA	NA	NA	50 U	52100
EA-15M	EA-15M-GRW-120106-01	12/01/06	6.9 J	619	60600	90300	2690	NA	NA	NA	3.4 B	64500
	EA-15M-GRW-120106-02	12/01/06	3.8 J	44.3 B	59100	89000	2700	NA	NA	NA	50 U	60700
EAC-1M	EAC-1M-GRW-112806-01	11/28/06	2.4 B	299	224	23800	7090	NA	NA	NA	50 U	68500
	EAC-1M-GRW-112806-02	11/28/06	1.2 B	26.6 J	269	24400	6760	NA	NA	NA	50 U	65600
EAC-2M	EAC-2M-GRW-030207	03/02/07	2.3 U	80.2	102	60100	2990	NA	NA	NA	1.5	48100
EAC-3M	EAC-3M-GRW-022707	02/27/07	2.3 UJ	80.2	63900	20600	1950	NA	NA	NA	1.5	26400
EAC-4M	EAC-4M-GRW-113006-01	11/30/06	15.8	758	2080	101000	91.3	NA	NA	NA	4.8 B	59800
	EAC-4M-GRW-113006-02	11/30/06	3.1 B	25.9 B	477	224000	68.9	NA	NA	NA	3 B	76500
	EAC-4M-GRW-100207	10/02/07	7.3 B	270	959	238000	88.6	NA	NA	NA	3.7	81600

Notes:

Results in µg/L

A "D" appended to a sample ID indicates a duplicate sample

U = Analyte not detected above reported MDL

J = Analyte present. Reported value may or may not be accurate or precise.

UJ = estimated non-detect due to associated inaccurate or imprecise spike recoveries, calibration issues, blank contamination, etc.

B = Not detected substantially above the level reported in the laboratory or field blank

L = Analyte is present but flagged as a low bias, usually associated with MS/MSD, LCS, LCSD spike recoveries

NA = Not Analyzed

TABLE 4-8

Groundwater Analytical Results - D-Series Wells - Total and Dissolved Metals

Chromium Transport Study

Dundalk Marine Terminal, Baltimore, Maryland

Total Metals

Location ID	Sample ID	Sample Date	Chromium (µg/L)	Alumium (µg/L)	Iron (µg/L)	Magnesium (µg/L)	Manganese (µg/L)	Potassium (µg/L)	Sodium (µg/L)	Titanium (µg/L)	Vanadium (µg/L)	Calcium (ug/L)
DMT-81D	DMT-81D-GRW-111908	11/19/08	3 U	80.2 U	1520	1670	101	1240	6270	3.8 U	2.5 U	6320
	DMT-81D-061109	06/11/09	4 B	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-82D	DMT-82D-GRW-111908	11/19/08	19.3	9220	12000	4060	732	2670	39500	51.9	21.3	10900
	DMT-82D-GRW-061009	06/10/09	8.3 J	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-83D	DMT-83D-GRW-111808	11/18/08	3 U	80.2 U	12000	2220	304	1430	11700	3.8 U	2.5 U	8120
	DMT-83D-GRW-061009	06/10/09	3.4 U	NA	NA	NA	NA	NA	NA	NA	NA	NA

Dissolved Metals

Location ID	Sample ID	Sample Date	Chromium (µg/L)	Chromium (VI) (µg/L)	Alumium (µg/L)	Iron (µg/L)	Magnesium (µg/L)	Manganese (µg/L)	Potassium (µg/L)	Sodium (µg/L)	Titanium (µg/L)	Vanadium (µg/L)	Calcium (µg/L)
DMT-81D	DMT-81D-GRW-111908F	11/19/08	3 U	5 U	80.2 U	1370	1620	98.1	1210	5900	3.8 U	2.5 U	6160
	DMT-81D-061109-F	06/11/09	3.4 U	5 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-82D	DMT-82D-GRW-111908F	11/19/08	3 U	5 U	703	2650	2170	484	2060	37500	7.9 J	2.9 J	7100
	DMT-82D-GRW-061009-F	06/10/09	3.4 U	5 U	NA	NA	NA	NA	NA	NA	NA	NA	NA
DMT-83D	DMT-83D-GRW-111808F	11/18/08	3 U	5 UJ	80.2 U	11400	2240	305	1400	11800	3.8 U	2.5 U	8090
	DMT-83D-GRW-061009-F	06/10/09	3.4 U	5 U	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

Results in µg/L

A "D" appended to a sample ID indicates a duplicate sample

All dissolved samples were field filtered except Chromium (VI), which was lab filtered. The "F" was appended to sample IDs during later investigation phases to indicate that the sample was field filtered

U = Analyte not detected above reported MDL

J = Analyte present. Reported value may or may not be accurate or precise.

UJ = estimated non-detect due to associated inaccurate or imprecise spike recoveries, calibration issues, blank contamination, etc.

B = Not detected substantially above the level reported in the laboratory or field blank

L = Analyte is present but flagged as a low bias, usually associated with MS/MSD, LCS, LCSD spike recoveries

NA = Not Analyzed

TABLE 4-9
Tidal Study Results
Chromium Transport Study
Dundalk Marine Terminal, Baltimore, Maryland

Shallow Wells			***Upper Sand Wells***			***M-Series Wells***			***D-Series Wells***		
Well ID	**Tidal Efficiency (%)**	**Lag Time (min)**	**Well ID**	**Tidal Efficiency (%)**	**Lag Time (min)**	**Well ID**	**Tidal Efficiency (%)**	**Lag Time (min)**	**Well ID**	**Tidal Efficiency (%)**	**Lag Time (min)**
DMT-1S	*	*	DMT-49US	0	0	DMT-1M	62.7	45	DMT-81D	13.2	116
DMT-3S	*	*	DMT-50US[1]	10.6	-126	DMT-2M	66	139	DMT-82D	4.8	240
DMT-12S	*	*	DMT-50US[1]	9.2	-87	EA-10M	58.1	91	DMT-83D	52.4	9
DMT-13S	*	*	DMT-51US	0	0	DMT-34M	63.4	28			
DMT-14S	4	0	DMT-52US	0	0	DMT-35M	0	0			
DMT-15S	*	*	DMT-54US	0	0	DMT-36M	29.5	63			
DMT-16S	*	*	DMT-64US	45.2	63	DMT-37M	57.76	20			
DMT-17S	*	*	DMT-65US	8.1	52	DMT-38M	0	0			
DMT-18S	*	*	DMT-67US	6	240	DMT-60M	0	0			
EAC-3S	*	*	DMT-70US	39.8	4	DMT-77M	17.4	62			
EAC-4S	*	*	DMT-71US	14.6	88	DMT-78M	73.9	75			
EA-6S	*	*	DMT-72US	21.7	44	DMT-79M	1.6	240			
EA-7S	*	*	DMT-73US	13.9	43	DMT-80M	7.6	193			
EA-10S	6.3	65	DMT-74US	5.5	201	EA-11M	68.28	37			
EA-11S	*	*	DMT-75US	3.7	226	EA-13M	58.23	42			
EA-14S	*	*	TPZ-48	25.1	170	EA-14M	67.04	11			
EA-17S	*	*	TPZ-49	*	*	EA-15M	62.94	43			
P-10	*	*				EA-2M	3.13	194			
DMT-45S	58.4	43				EA-6M	30.85	104			
DMT-46S	18.1	66				EA-7M	39.8	93			
DMT-56S	15.8	89				EA-8M	6.67	201			
DMT-57S	56.1	48				EA-9M	44.74	55			
DMT-58S	69.6	37				EAC-1M	6.73	171			
DMT-2S	*	*				EAC-2M	8.15	149			
DMT-7S	*	*				EAC-3M	58.38	19			
DMT-8S	*	*									
DMT-9S	*	*									
DMT-10S	*	*									
DMT-20S	*	*									
DMT-25S	*	*									
P-3	*	*									
TPZ-B	*	*									
TPZ-24	*	*									
DMT-63S	23.3	62									

Notes:
*Not quantified due to lack of tidal response
1 = Two tidal studies were completed for well DMT-50US in November and December 2007.

TABLE 4-10
Aquifer Test Results
Chromium Transport Study
Dundalk Marine Terminal, Baltimore, Maryland

Test Well	Test Date	Observation Well	Transmissivity (ft^2/day)	Storage Coefficient
Shallow Fill Aquifer				
DMT-21S	January 9, 2007	DMT-20S	64.7	2.40E-02
DMT-21S	January 9, 2007	TPZ-24	107.6	8.57E-03
DMT-23S	November 4-6, 2006	DMT-02S	1052.5	2.70E-02
DMT-24S(1)	June 2, 2006	DMT-08S	520.9	8.50E-03
DMT-24S	June 29, 2006	DMT-08S	393.7	2.70E-03
DMT-24S(2)	January 2-4, 2007	DMT-08S	546.6	4.50E-04
DMT-24S(3)	January 2-4, 2007	DMT-08S	316.0	3.00E-03
DMT-24S(4)	January 2-4, 2007	DMT-08S	296.0	2.30E-03
DMT-25S(5)	Januery 10-11, 2007	DMT-25S	4.8	--
Patapsco Aquifer				
DMT-1M	June 19-21, 2006	EA-09M	2658.8	1.71E-04
DMT-1M	June 19-21, 2006	EA-06M	1540.8	4.20E-04
DMT-1M	June 19-21, 2006	EA-13M	2173.9	9.03E-05
DMT-1M	June 19-21, 2006	EAC-02M	3788.2	1.23E-03
DMT-1M	June 19-21, 2006	EAC-03M	2291.4	4.25E-04
DMT-01M	Oct. 31 - Nov. 2, 2006	EA-09M	2361.7	4.97E-05

(1) Step-drawdown test

(2) First 7 hours of pumping

(3) Entire test and recovery record

(4) Restart portion of test

(5) Papadopulos-Cooper recovery analysis of uncertain accuracy

TABLE 4-11

Laboratory Permeability Results

Chromium Transport Study

Dundalk Marine Terminal, Baltimore, Maryland

Stratum	Boring ID	Start Depth	End Depth	K (cm/s)	K (ft/day)
Upper Silt	INC-16	17	19	1.30E-08	3.69E-05
	DMT-49US	24	29	3.60E-08	1.02E-04
	DMT-53US	10	12	6.70E-07	1.90E-03
	DMT-52US	20	22	1.60E-08	4.54E-05
	DMT-51US	30	32	7.70E-08	2.18E-04
			AVERAGE=	**1.62E-07**	**4.60E-04**
Lower Silt	DMT-32S	35	36	3.09E-08	8.76E-05
	DMT-34M	64	66	1.5E-07	4.25E-04
	DMT-36M	42.5	44.5	1.5E-07	4.25E-04
	DMT-36M	52.5	54.5	6.3E-08	1.79E-04
	DMT-36M	72.5	74.5	2.2E-07	6.24E-04
	DMT-37M	79	81	5.6E-08	1.59E-04
	DMT-37M	59	62	9.7E-08	2.75E-04
	DMT-37M	49	52	9.7E-08	2.75E-04
	INC-12	40	42	3.71E-08	1.05E-04
	TPZ-03	87	88	2.10E-07	5.95E-04
	TPZ-48	39	41	5.23E-08	1.48E-04
	TPZ-48	64	66	6.16E-08	1.75E-04
	TPZ-48	76	78	6.40E-08	1.81E-04
	TPZ-49	48	50	4.59E-08	1.30E-04
	TPZ-49	58	60	1.25E-07	3.54E-04
	TPZ-49	68	78	6.75E-08	1.91E-04
	TPZ-49	78	80	1.34E-07	3.80E-04
			AVERAGE=	**9.77E-08**	**2.77E-04**
Potomac Group Clay Strata	DMT-77M	147	159	3.65E-07	1.03E-03
	DMT-78M	87	99	1.55E-08	4.39E-05
	DMT-79M	110	118.5	1.61E-07	4.56E-04
	DMT-80M	127	138.5	1.09E-07	3.09E-04
	DMT-81D	147	159	3.39E-08	9.61E-05
	DMT-81D	177	189	1.63E-08	4.62E-05
	DMT-82D	207	217	1.27E-07	3.60E-04
	DMT-82D	230	239	4.54E-08	1.29E-04
	DMT-83D	157	169	3.46E-08	9.81E-05
	DMT-83D	257	269	1.23E-08	3.49E-05
			AVERAGE=	**9.20E-08**	**2.61E-04**

TABLE 4-12
Invert Elevations and Tidal Penetration for 9th through 15th Street Outfalls

Outfall	Street Storm Drain	Diameter of Line at Discharge Point (inches)	Elevation of Invert at Discharge Point (ft above MSL)	Average Tidal Penetration (ft)
007	9	91 x 58 in. to a 6.25-ft drop at Structure OS-3; to a 3.5 x 5.5 ft box culvert	–6.5 ft MSL Outfall face always submerged	Approx. 900 ft
008	9.5	18 in. at I-17	+1.67 ft MSL	Little or no tidal intrusion
009	10	68 x 43 in.	–0.14 ft MSL Outfall face 45% submerged at high tide and fully visible at low tide	Approx. 580 ft to M-2
010	10.5	30 in.	Outfall face 0.1 ft submerged at high tide; fully visible at low tide	Minor tidal intrusion
011	11	54 in.	+0.28 ft MSL Outfall face 25% submerged at high tide; fully visible at low tide	Approx. 370 ft
012	11.5	30 in.	+1.4 ft MSL almost fully exposed at high tide	Minimal tidal intrusion
013	12	91 x 58 in.	–1.82 ft MSL 70% submerged at high tide; 45% submerged at low tide	Approx. 900 ft
002	12.5	33 in. at structure E7A	+1.98 ft MSL	—
003	13	54 in.	+0.31 ft MSL Outfall face is 25% submerged at high tide and fully visible at low tide	Approx. 300 ft
004	13.5	33 in. at structure E8A	+1.84 ft MSL	—
005	14	91 x 63 in.	No longer tidally influenced per backflow preventer	None
006 (601)	15 North	96 in.	No longer tidally influenced per backflow preventer	None
006 (602)	15 South	96 in.	No longer tidally influenced per backflow preventer	None
014	H	18 in.	Not tidally influenced, above water level	None

MSL—mean sea level.

TABLE 4-13

Total Particulate Concentrations (mg/m3)

Chromium Transport Study

Dundalk Marine Terminal, Baltimore, Maryland

	Air1	**Air2**	**Air3**	**Air4**	**Air5**	**Air6**	**Air7**	**Air8**	**Air9**
Mean	0.029	0.028	0.030	0.027	0.040	0.034	0.031	0.035	0.035
Std. Dev.	0.012	0.014	0.011	0.012	0.021	0.013	0.012	0.016	0.010
Min.	0.009	0.007	0.008	0.012	0.013	0.015	0.017	0.013	0.020
Max.	0.060	0.059	0.049	0.062	0.090	0.064	0.066	0.075	0.052

TABLE 4-14
Cr(VI) Concentrations (ng/m^3) Based on Nonzero Values and All Wind Directions
Chromium Transport Study
Dundalk Marine Terminal, Baltimore, Maryland

	Air1	**Air2**	**Air3**	**Air4**	**Air5**	**Air6**	**Air7**	**Air8**	**Air9**
Mean	1.53	1.57	1.56	1.50	1.44	1.50	1.39	1.38	1.55
Std. Dev.	0.70	0.77	0.56	0.69	0.66	0.82	0.64	0.56	0.56
Min.	0.69	0.75	0.76	0.69	0.67	0.69	0.76	0.72	0.73
Max.	3.30	3.40	2.90	3.20	3.60	3.70	3.60	2.50	2.80

TABLE 4-15
Hexavalent Chromium Concentrations
Chromium Transport Study
Dundalk Marine Terminal

	Cr(VI) (ng/m^3)	
	Upwind	**Downwind**
Mean	1.10	1.20
Median	0.76	0.93
Std Deviation	0.62	0.66

TABLE 6-1

Calculation of Chrome-VI Discharge to River via Groundwater Transport in the Shallow Aquifer

GW Flux to River			Zone Boundary Wells				Mass Flux		
Flow Zone	**cfd**	**gpm**	**Well**	**Conc (ug/l)**	**Well**	**Conc (ug/l)**	**g/day**	**lbs/day**	**lbs/yr**
1	61.498	0.32	DMT-42S	2.5	DMT-42S	2.5	0.00435	0.00001	0.00351
2	141.21	0.73	DMT-42S	2.5	DMT-17S	2.5	0.01000	0.00002	0.00805
3	877.4	4.56	DMT-17S	2.5	EA-11S	2.5	0.06211	0.00014	0.05002
4	483.6	2.51	EA-11S	2.5	DMT-31S	2.5	0.03424	0.00008	0.02757
5	57.722	0.30	DMT-31S	2.5	DMT-16S	2.5	0.00409	0.00001	0.00329
6	81.833	0.43	DMT-16S	2.5	DMT-32S	2.5	0.00579	0.00001	0.00466
7	146.97	0.76	DMT-32S	2.5	DMT-15S	2.5	0.01040	0.00002	0.00838
8	194.55	1.01	DMT-15S	2.5	DMT-14S	2.5	0.01377	0.00003	0.01109
9	73.246	0.38	DMT-14S	2.5	DMT-12S	2.5	0.00519	0.00001	0.00418
10	20.123	0.10	DMT-12S	2.5	DMT-56S	2.5	0.00142	0.00000	0.00115
11	118.66	0.62	DMT-56S	2.5	DMT-57S	2.5	0.00840	0.00002	0.00676
12	103.17	0.54	DMT-57S	2.5	DMT-58S*	2.5	0.00730	0.00002	0.00588
13	238.8	1.24	DMT-58S*	2.5	DMT-45S	124	0.42770	0.00094	0.34440
14	397.97	2.07	DMT-45S	124	DMT-63S	45	0.95225	0.00210	0.76679
15	573.84	2.98	DMT-63S	45	DMT-39S	9.9	0.44604	0.00098	0.35917
Layer-1 Totals		**18.55**					**1.99**	**0.00439**	**1.60**

Notes:

1. Volumetric flux of groundwater through bulkheads and river bank calculated by the calibrated groundwater flow model for Layer 1 (Shallow Fill Aquifer)
2. Dissolved Cr-Vi concentrations are the most recent available at each river boundary monitoring well.
3. * Concentration at DMT-58S is the analytical result for 9/27/07 (ND) because the well was subsequently damaged.
4. Calculations involving wells having non-detect (ND) results use half of the detection limit.

TABLE 6-2

Calculation of Cr(III) Discharge to River via Groundwater Transport in the Shallow Aquifer*

GW Flux to River			**Zone Boundary Wells**				**Mass Flux**		
Flow Zone	**cfd**	**gpm**	**Well**	**Conc (ug/l)**	**Well**	**Conc (ug/l)**	**g/day**	**lbs/day**	**lbs/yr**
1	61.498	0.32	DMT-42S	1.7	DMT-42S	1.7	0.00296	0.00001	0.00238
2	141.21	0.73	DMT-42S	1.7	DMT-17S	1.7	0.00680	0.00001	0.00547
3	877.4	4.56	DMT-17S	1.7	EA-11S	1.7	0.04224	0.00009	0.03401
4	483.6	2.51	EA-11S	1.7	DMT-31S	1.15	0.01951	0.00004	0.01571
5	57.722	0.30	DMT-31S	1.15	DMT-16S	1.15	0.00188	0.00000	0.00151
6	81.833	0.43	DMT-16S	1.15	DMT-32S	1.15	0.00266	0.00001	0.00215
7	146.97	0.76	DMT-32S	1.15	DMT-15S	1.7	0.00593	0.00001	0.00478
8	194.55	1.01	DMT-15S	1.7	DMT-14S	1.7	0.00937	0.00002	0.00754
9	73.246	0.38	DMT-14S	1.7	DMT-12S	4	0.00591	0.00001	0.00476
10	20.123	0.10	DMT-12S	4	DMT-56S	1.15	0.00147	0.00000	0.00118
11	118.66	0.62	DMT-56S	1.15	DMT-57S	1.7	0.00479	0.00001	0.00386
12	103.17	0.54	DMT-57S	1.7	DMT-58S*	1.7	0.00497	0.00001	0.00400
13	238.8	1.24	DMT-58S**	1.7	DMT-45S	0	0.00575	0.00001	0.00463
14	397.97	2.07	DMT-45S	0	DMT-63S	1145	6.45164	0.01422	5.19511
15	573.84	2.98	DMT-63S	1145	DMT-39S	9.1	9.37667	0.02067	7.55045
Layer-1 Totals		**18.55**					**15.94**	**0.03515**	**12.84**

Notes:

1. *These flux calculations ingnore the fact that Cr(III) has very low solubility and mobility in groundwater.
2. Dissolved Cr(III) concentration calculated as total dissolved chromium concentration minus dissolved Cr(VI) concentration, or zero, whichever is greater.
3. Volumetric flux of groundwater through bulkheads and river bank calculated by the calibrated groundwater flow model for Layer 1 (Shallow Fill Aquifer)
4. ** Concentration at DMT-58S is the analytical result for 9/27/07 (ND) because the well was subsequently damaged.
5. Calculations involving wells having non-detect (ND) results use half of the detection limit.

TABLE 6-3

Calculation of Cr(III) Discharge to River via Groundwater Transport in the Alluvial Sands*

GW Flux to River			Zone Boundary Wells				Mass Flux		
Flow Zone	**cfd**	**gpm**	**Well**	**Conc (ug/l)**	**Well**	**Conc (ug/l)**	**g/day**	**lbs/day**	**lbs/yr**
1	143.66	0.75	DMT-64US	1.7	DMT-64US	1.7	0.00692	0.00002	0.00557
2	139.78	0.73	DMT-64US	1.7	DMT-65US	1.5	0.00633	0.00001	0.00510
3	64.69	0.34	DMT-65US	1.5	DMT-50US	1.7	0.00293	0.00001	0.00236
4	277.68	1.44	DMT-50US	1.7	DMT-67US	1.7	0.01337	0.00003	0.01076
5	887.94	4.61	DMT-67US	1.7	DMT-70US	1.7	0.04274	0.00009	0.03442
6	0.4979	0.00	DMT-70US	1.7	DMT-71US	1.5	0.00002	0.00000	0.00002
7	567.05	2.95	DMT-71US	1.5	DMT-72US	1.7	0.02569	0.00006	0.02069
8	100.87	0.52	DMT-72US	1.7	TPZ-49	1.95	0.00521	0.00001	0.00420
9	114.96	0.60	TPZ-49	1.95	TPZ-48	1.7	0.00594	0.00001	0.00478
10	321.71	1.67	TPZ-48	1.7	DMT-73US	1.7	0.01549	0.00003	0.01247
Layer-2 Totals		**13.60**					**0.12**	**0.00027**	**0.10**

Notes:

1. *These flux calculations ingnore the fact that Cr(III) has very low solubility and mobility in groundwater.
2. Dissolved Cr(III) concentration calculated as total dissolved chromium concentration minus dissolved Cr(VI) concentration, or zero, whichever is greater.
3. Volumetric flux of groundwater through bulkheads and river bank calculated by the calibrated groundwater flow model for Layer 2 (Alluvial Sands)
4. Calculations involving wells having non-detect (ND) results use half of the detection limit.