U.S. Army
Fort Monmouth, New Jersey

Remedial Investigation Report Addendum

M-4 Landfill

Fort Monmouth, New Jersey

December 2010
Revised June 2011

REMEDIAL INVESTIGATION REPORT ADDENDUM FOR THE M-4 LANDFILL FORT MONMOUTH, NEW JERSEY

PREPARED FOR:

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ACRONYMS AND ABBREVIATIONS

µg/L	Micrograms per liter
bgs	Below ground surface
AMC	U.S. Army Material Command
BEE	Baseline Ecological Evaluation
BRAC	Base Realignment and Closure
Brinkerhoff	Brinkerhoff Environmental Services, Inc.
CECOM	U.S. Army Communications and Electronics Command
COC	Contaminant of Concern
DPW	Directorate of Public Works
DRMR	Division of Remediation Management and Response
DSHW	Division of Solid Hazardous Waste
FMETL	Fort Monmouth Environmental Testing Laboratory
ft	Foot or feet
FTMM	Fort Monmouth
GWQS	Ground Water Quality Standards
IGWSCC	Impact to Ground Water Soil Cleanup Criteria
MBC	Maximum Background Concentration
MDL	Method Detection Limit
MODFLOW	Modular finite-difference Flow model
ND	Non-detect
NFA	No Further Action
NJAC	New Jersey Administrative Code
NJDEP	New Jersey Department of Environmental Protection
NRDCSCC	Non-Residential Direct Contact Soil Cleanup Criteria
NSS	Near Surface Soils
PCB	Polychlorinated Biphenyl
PDB	Passive Diffusion Bag
PPE	Personal Protective Equipment
ppm	Parts per million
PQL	Practical Quantitation Limit
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance/Quality Control
RDCSCC	Residential Direct Contact Soil Cleanup Criteria
RI	Remedial Investigation
RIR	Remedial Investigation Report
RIRA	Remedial Investigation Report Addendum
SI	Site Investigation
SIR	Site Investigation Report
SOP	Standard Operating Procedure
SQE	Sediment Quality Evaluation
SRP	Site Remediation Program
SRS	Site Remediation Standards
SVOC	Semivolatile Organic Compound
TAL	Target Analyte List

TCL	Target Compound List
Tetra Tech	Tetra Tech EM, Inc.
TIC	Tentatively Identified Compound
Versar	Versar, Inc.
VOC	Volatile Organic Compound
Weston	Roy F. Weston, Inc.

EXECUTIVE SUMMARY

Tetra Tech, Inc. (Tetra Tech) has been contracted by the United States (U.S.) Army Garrison, Fort Monmouth (FTMM), Directorate of Public Works (DPW), FTMM, New Jersey, to prepare a Remedial Investigation (RI) Report Addendum (RIRA) to document ground water, surface water, and soil conditions at M-4 Landfill located in the Main Post Area of FTMM, New Jersey. This report addresses the RI activities conducted by DPW to investigate ground water and surface water conditions between April 2001 and September 2010; and soil conditions from March 1998 at M-4 Landfill. This work includes a ground water and surface water sampling program to define the areal extent of potential pollutants and evaluate impacts to ground water and surface water in the vicinity of M-4 Landfill, and a landfill delineation study to determine the approximate size and boundary of the former landfill, and evaluate the surficial soil of the landfill cover.

The M-4 Landfill is bordered by North Drive to the north, Wilson Avenue to the east, the Avenue of Memories to the south, and Mill Creek intersects M-4 Landfill in the Main Post area of Fort Monmouth. The M-4 Landfill covers approximately 61,800 square feet (1.4 acres). Aerial photographs dated 1940 depict the M-4 Landfill as a swamp. The M-4 Landfill was historically used as a landfill in 1955 and 1956 for the disposal of demolition debris.

Based on ground water analytical results for M-4 Landfill, there are no contaminants of concern in ground water. Therefore, further RI activities at M-4 Landfill are not required. Continued ground water monitoring, in agreement with the fiscal year 2010 Fort Monmouth Base Realignment and Closure (BRAC) Installation Action Plan (BIAP), is recommended. No Further Action (NFA) is recommended with respect to ground water at the site.

Two VOCs and four metals were detected at concentrations exceeding the NJDEP Surface Water Quality Standards (SWQS). However, these compounds were eliminated as potential contaminants of concerns (COCs) with respect to ground water and are not considered to impact nearby surface water at M-4 Landfill. It is the DPW's contention that VOC and metal concentrations detected in surface water samples exceed the NJDEP surface water criteria are from a source upgradient of the M-4 Landfill and beyond the boundary of Fort Monmouth.

Therefore, based on DPW's assessment regarding surface water, and because no COCs exist in ground water, No Further Action (NFA) is recommended with respect to surface water at the site.

An additional 1.5-feet of certified clean soil cover (a "soil cap") over 13 soil boring locations where SVOCs and metal concentrations exceed the NJDEP NRDCSRS at six-to-12 inches bgs is recommended at M-4 Landfill. Further, additional certified clean soil cover over soil boring locations that do not have the minimum two-feet of cover. Lastly, a deed notice is recommended to be filed to document the presence of the contaminated soil on site.

1.0 INTRODUCTION

Tetra Tech Inc. (Tetra Tech) has been contracted by the U.S. Army Installation Directorate of Public Works (DPW) to prepare a Remedial Investigation Report Addendum (RIRA) for M-4 Landfill located in the Fort Monmouth Main Post area in Fort Monmouth, New Jersey. This report addresses RI activities at the site, including a ground water and surface water sampling program to investigate ground water and surface water conditions from April 2001 to September 2010, subsurface soil investigation in March 1998 and results of a landfill delineation survey.

FTMM DPW conducted these additional investigations described in this RIRA to define the areal extent of potential pollutants and evaluate impacts to ground water and surface water in the vicinity of M-4 Landfill, surficial soil conditions at M-4 Landfill and to determine the approximate size and boundary of the former landfill.

1.1. OBJECTIVES

The objectives of this RIRA are to determine aquifer, chemical, physical characteristics, surficial soil conditions, and to determine whether further remedial investigation or remedial actions are required at M-4 Landfill. The remedial investigation was conducted in accordance with New Jersey Department of Environmental Protection (NJDEP) New Jersey Administrative Code (N.J.A.C) 7:26E - Technical Requirements for Site Remediation (NJDEP 1999).

The RI and subsequent preparation of the RIRA encompassed the following:

- Characterization of ground water quality through quarterly ground water sampling events conducted from April 2001 to July 2010
- Characterization of surface water quality through quarterly surface water sampling events conducted from May 2001 to September 2010
- Comparison of ground water and surface water results with NJDEP Ground Water Quality Standards (GWQS) and Surface Water Quality Standards (SWQS).
- Characterization of the surficial soils that cover the historic fill areas and comparison of soil analytical results to NJDEP Non Residential Direct Contact Soil Remediation Standards (NRDCSRS).
- Determination of the remedial action to address contamination of surficial soils.
- Formulation of a NFA proposal for consideration by the NJDEP based on the results of field and laboratory investigations and the hydrogeologic conditions at M-4 Landfill. The rationale for the NFA proposal is presented in this RIRA.

1.2. REPORT ORGANIZATION

This report is organized to minimize repetition. **Section 2.0** provides background information and a general description of M-4 Landfill located at the Main Post of Fort Monmouth. **Section**

3.0 describes and summarizes the remedial investigation (RI) field activities conducted at M-4 Landfill, including the ground water and surface water sampling programs. **Section 4.0** presents the physical characterization of M-4 Landfill including the lithology and ground water conditions at M-4 Landfill. **Section 5.0** presents site chemical characterization information, which includes ground water, surface water, and soil sampling results and the determination of potential contaminants of concern (COC). Conclusions and recommendations for ground water, surface water, and soil at M-4 Landfill are included in **Section 6.0**. References cited in this RIRA are listed after the text.

2.0 SITE BACKGROUND AND ENVIRONMENTAL SETTING

This section summarizes background information and describes the environmental setting of the area surrounding Fort Monmouth and M-4 Landfill. Specifically, this section describes the site and its location, summarizes site background information, presents current site conditions, and portrays the environmental setting of M-4 Landfill at the Fort Monmouth installation.

2.1. SITE LOCATION AND DESCRIPTION

Fort Monmouth is located in the central-eastern portion of New Jersey in Monmouth County, approximately 45 miles south of New York City and 70 miles northeast of Philadelphia (**Figure 2-1**). In addition to the Main Post, the installation includes the Charles Wood area. The Main Post encompasses approximately 630 acres and bordered to the north by Parkers Creek, to the northeast by New Jersey Transit Railroad, to the east by State Highway 35, to the south/southeast by Oceanport Creek, and to the south by residential areas. The post was established in 1918 during World War I as an Army Signal Corps training center. The Main Post currently provides administrative, training, and housing support functions, as well as providing many of the community facilities for Fort Monmouth. The primary mission of Fort Monmouth is to provide command, administrative, and logistical support for U.S. Army Headquarters' Communications and Electronics Command (CECOM). CECOM is a major subordinate command of the U.S. Army Material Command (AMC) and is the host tenant at Fort Monmouth.

The M-4 Landfill is bordered by North Drive to the north, Wilson Avenue to the east, the Avenue of Memories to the south, and Mill Creek intersects M-4 Landfill in the Main Post area of Fort Monmouth (**Figure 2-2**). The M-4 Landfill covers approximately 61,800 square feet (1.4 acres). Aerial photographs dated 1940 depict the M-4 Landfill as a swamp. The M-4 Landfill was historically used as a landfill in 1955 and 1956 for the disposal of demolition debris.

2.2. SITE CONDITIONS

Tetra Tech conducted a site walk on October 21, 2010, to assess current conditions at the M-4 Landfill. The site consists of two areas separated by Mill Creek and bounded by trees and shrubs. A 360-foot portion of the banks of Mill Creek has been reinforced with concrete plates and covered with grass and shrubs. Vegetation including grasses and large shrubs were present across the site, with trees along the southern side of the site. The entire eastern portion of the site was an open field of grass.

General utilities servicing M-4 Landfill are depicted on **Figure 2-3**. Wetlands present on the Main Post are depicted on **Figure 2-4**.

2.3. SITE BACKGROUND

The U.S. Army Corps of Engineers (USACE), Baltimore District, contracted Roy F. Weston (Weston) to perform a field investigation of two areas at Fort Monmouth: the Main Post and the Charles Wood areas. Suspected hazardous waste sites were initially identified at Fort Monmouth in a report prepared by the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) (USATHAMA 1980). The USATHAMA report identified 37 sites with known or suspected waste materials on the Main Post and the Charles Wood area. Weston conducted a background investigation of the 37 sites and eight additional sites that were identified by Fort Monmouth and NJDEP.

Weston's findings were described in the Investigation of Suspected Hazardous Waste Sites at Fort Monmouth, New Jersey report (Weston 1993). In this background report, additional investigations (including sampling and other field work) were recommended at 22 of the sites on the Main Post and Charles Wood areas, including the M-4 Landfill. NJDEP approved the recommendations on April 20, 1995.

In the Site Investigation, Fort Monmouth, New Jersey, Main Post and Charles Wood Areas, Site Investigation Report (SIR) (Weston 1995), Weston presented the results of field investigation activities performed at 13 sites at the Main Post Area and eight sites at the Charles Wood Area.

The results of the investigation of M-4 Landfill are included in the Weston SIR. Initial field investigation activities including near surface soil sampling, sediment sampling, surface water sampling, monitoring well installation, and ground water sampling were performed. The Weston SI report was used as the basis for the supplemental remedial investigations described in this report (**Appendix A**).

This section summarizes previous site work performed at M-4 Landfill.

2.3.1. 2004 Near Surface Soil Evaluation

To demonstrate that the existing soil cover over M-4 Landfill is in compliance with the Solid Waste Disposal Act of 1965, DPW characterized the near-surface soils by installing 63 borings (B01-B63) at strategic locations throughout the site. DPW performed soil borings and obtained soil samples in March 1998. Samples were collected using a 2-inch Geoprobe® Macrocore sampler. Sampling activities were performed in accordance with the *Fort Monmouth Standard Sampling Operating Procedure* (DPW 1997). A total of 126 soil samples were collected from the 63 borings and were analyzed for the presence of volatile organic compounds (VOC), semivolatile organic compounds (SVOC), pesticides, polychlorinated biphenyls (PCB) and total analyte list (TAL) metals. The soil boring locations in and around M-4 Landfill are identified in the Weston SIR (Weston 1995). The locations of the borings were established in a grid-like pattern within the previously designated boundaries of M-4 Landfill. The Remedial Investigation Report for Near Surface Soils (Versar 2004) provides a detailed explanation of activities performed for M-4 Landfill (**Appendix B**).

In all cases, further analysis of the analytical results did not define a source area or level of contamination that necessitated the identification and evaluation of potential remedial actions. In most cases, either the calculated compliance average was less than the respective RDCSCC or the exceedence was considered marginal. However, to address the exceedences of analytes that did not meet cleanup criteria in near-surface soils at M-4 Landfill, DPW incorporated a document equivalent to a Declaration of Environmental Restriction (DER) into the Fort Monmouth Master Plan for soils at the site. The DER was developed for the entire M-4 Landfill or be restricted to specific areas of the site and specific analytes, as identified in this RIRA.

2.3.2. 2004 Sediment Quality Evaluation

Studies conducted at similar Main Post landfill (M-2 and M-8) indicated PCB-containing materials (e.g., electrical ballasts) disposed in each landfill. In addition, PCBs were detected in soil and/or ground water at both the M-2 and M-8 Landfill. Therefore, assuming that the landfills on the Main Post had received similar waste materials, DPW initiated a sediment sampling investigation in the second quarter of 2000 to evaluate potential impacts to stream sediments in creeks and/or brooks running adjacent to the Main Post and Charles Wood (CW-3A only) landfills. The M-4 Landfill was included in the sediment sampling program to supplement Weston's findings related to soil and ground water.

To determine potential PCB-related impacts to sediments in Mill Creek, DPW collected 13 sediment samples from the surface and near-surface sediments of Mill Creek on April 13, 2000. The samples were obtained along the 360-foot portion of Mill Creek that flows adjacent to the western perimeter of M-4 Landfill. Sample depths ranged from surface (0-6 inches) to near-surface (6-12 inches bgs) at each boring location (Boring B-1 through B-13), with the exception of Boring B-5, which was also sampled at a depth of 18-24 inches bgs. All 13 sediment samples were analyzed for PCBs and compared to sediment sampling guidance concentrations defined in the NJDEP *Guidance for Sediment Quality Evaluations* (NJDEP 1998).

Only one of the 13 samples (B-5, collected from 6-12 inches bgs) contained a total PCB concentration (0.051 milligrams per kilogram [mg/kg]) exceeding the laboratory Method Detection Limit (MDL). This sample result also exceeded the NJDEP Effects Range – Low (ER-L) guidance concentration of 0.023 parts per million (ppm) for total PCBs, but did not exceed the ER-M (0.180 mg/kg) or the LEL for Arochlor 1254 (0.060 mg/kg). Arochlor 1254 is the only Arochlor previously detected at the site. The SSEL for Arochlor 1254 (0.34 mg/kg) was not exceeded. The NJDEP ER-L guidance concentration for total PCB represents the concentration at which adverse benthic effects are found in approximately 10 percent of studies. No other guidance criteria were exceeded. Analysis of the remaining 12 samples, including upgradient samples, did not indicate PCBs exceeding laboratory MDLs. Because the result at Boring B-5 exceeds only the ER-L guidance concentration, and the results of samples collected upgradient of Boring B-5 were non-detect (ND) for total PCBs, no long-term adverse benthic effects are expected in Mill Creek.

Because PCB concentrations exceeded NJDEP the ER-L guidance concentration at Boring B-5, another sample was collected from 18-24 inches bgs at this location. The deeper sample did not contain PCBs at concentrations exceeding the MDL. Because the upgradient samples collected

from locations near Boring B-5 contain PCBs exceeding the laboratory MDL, the shallow sample result at B-5 is likely isolated. Therefore, PCBs are not expected to have long-term adverse benthic effects in Mill Creek. The sediment quality evaluation is addressed in the Remedial Investigation Report and Sediment Quality Evaluation for the M-4 Landfill, Versar, February 2004. The report is presented in **Appendix C**.

2.3.3. DPW Reduction of Ground Water Analysis

In November 2004, DPW requested a reduction in ground water analysis for samples collected from the M-4 Landfill based on the results of the long-term ground water monitoring. The results indicated that no volatile organic compounds (VOC) or semivolatile organic compounds (SVOC) had been detected in concentrations exceeding the NJDEP GWQS in any on-site monitoring well since 2000. Subsequently, NJDEP approved the reduction of ground water analysis to target analyte list (TAL) metals only, via electronic correspondence dated November 16, 2004 (NJDEP Correspondence November 12, 2004) **(Appendix D)**.

2.3.4. Landfill Delineation Project

On August 1, 2008, DPW presented to the NJDEP Site Remediation Program (SRP) for approval a landfill delineation study involving advancement of test pits and soil borings to confirm the boundaries of nine solid waste landfills at FTMM, including M-4 Landfill. The NJDEP SRP reviewed and approved the DPW's study according to a letter dated August 19, 2008 (NJDEP 2008) (**Appendix E**).

2.3.5. 2009 Regulatory Approach to Fort Monmouth Landfill Letter

According to this letter from the NJDEP SRP, the Army and NJDEP have been involved in discussions pertaining to soil cover requirements for the FTMM landfills since at least 1996 (NJDEP 2009a). A well-vegetated soil cover approximately 1 foot thick exists on the surface of the great majority of the nine landfills, including M-4 Landfill, but areas of exposed waste deposits are present on some of the landfills. NJDEP stated that surface soils on all the landfills contain contaminants at concentrations exceeding New Jersey Soil Remediation Standards (SRS), and some of these levels of contaminants appear to be associated with specific waste materials such as PCBs. However, in many locations, the soil contaminants are indicative of historical fill. NJDEP stated that in locations where SRSs are exceeded, the SRP would accept placement of an additional 1-foot-thick clean soil cover to eliminate direct contact threat. Existing areas of exposed waste deposits must either be removed or properly re-graded and covered with 1 to 2 feet of clean soil cover. The SRP also stated that it would verify that the NJDEP Division of Solid and Hazardous Waste (DSHW) would accept 1 additional foot of soil cover as a proper final cover for the landfills.

The NJDEP DSHW requires evaluation of the landfills for methane gas generation and installation of passive or active gas venting systems as necessary. NJDEP stated that FTMM must perform a methane gas evaluation for each landfill or present existing documentation and data that conclusively show absence of subsurface methane gas at each landfill. In addition, deed notices would be required for all landfills due to the documented presence of waste

deposits, even if NFA status would be achieved. The NJDEP letter of February 24, 2009, appears in **Appendix F**.

2.3.6. 2010 Sanitary Landfill Minor Disruption Approval

In September 2010, NJDEP granted FTMM Sanitary Landfill Minor Disruption approval (permit no. LCB100002) for the performance of on-going remedial investigation and remedial activities pertaining to the nine inactive landfill sites located throughout the FTMM army base **(Appendix G).** The minor disruption activities approved include soil borings, soil sampling, test pits, piezomerter and monitoring well installation, injection of chemical and biological oxidation stimulants for ground water remediation and methane gas surveys. The approval was granted with a five-year expiration.

2.3.7. 2010 NJDEP Regulatory Requirements for Landfills

In a letter dated November 2010, NJDEP SRS provided Appendix 1 *NJDEP Regulatory Approach – Fort Monmouth Landfills* (**Appendix H**). The letter indicates the NJDEP Solid and Hazardous Waste Program (SHWP) has determined that NJDEP SRP will assume the lead regulatory role for NJDEP. Appendix 1 provides a summary and discussion of all NJDEP regulatory requirements for the Fort Monmouth Landfills including: 1) Surface water and sediment; 2) Landfill cover/ surface soils; 3) Methane Gas; 4) Deed Notices and 5) Operation and Maintenance (NJDEP, 2010).

2.3.8. Public Notification

In accordance with the Notification and Public Outreach Rule of the NJDEP Technical Requirements for Site Remediation (TRSR) (N.J.A.C. 7:26E-1.4), Fort Monmouth established a Restoration Advisory Board (RAB) in 2006 with representatives from the local municipalities who represent a variety of interests and viewpoints. The RAB acts as a focal point to exchange information between Fort Monmouth and the local communities regarding environmental and restoration activities and meets on a quarterly basis to review and comment on on-going environmental work. The meetings are open to the public and are advertised in local newspapers. All environmental projects subject to the NJDEP TRSR are presented at the RAB.

Although the Public Notification requirements were amended in 2009 with the implementation of signs or periodic letters to inform the public of on-going environmental work, on June 17, 2010, Fort Monmouth requested that the NJDEP grant approval of an alternate notification and public outreach plan utilizing the existing RAB and document repository of Fort Monmouth environmental reports, which is accessible to the public. The NJDEP response indicated that the alternative plan provided adequate public notice and complied with the intent of 7:26E-1.4; NJDEP approved the request on June 24, 2010.

Public notification documentation is presented in **Appendix I**.

2.3.9. Aerial Photograph Site Analysis

An Aerial Photograph Site Analysis of the Main Post was performed by DPW in 2010. This section presents the results of this analysis with regard to the M-4 Landfill. These results are also presented in **Appendix J**.

Figure 4: May 2, 1957: An aerial photograph dated 1957 reveals additional buildings constructed on the eastern side of the Main Post near the main gate, as well as an oval running track towards the center of the southern portion of the post. An incinerator is depicted in the southeast corner of the post boundary off of Main Street in Oceanport. The M-3, M-4, M-5, and M-8 landfills are now clearly visible on the northeastern portion of the post; in addition, M-12 and M-14 are clearly visible towards the center of the post. A small probable magazine area is noted and located slightly north of the current M-2 Landfill area on the southwestern section of the post. The surrounding area appears to be more developed, with less open space and additional residential housing.

Figure 6: May 13, 1963 – M3, M5 and M8 Landfills**:** Changes in this aerial photograph are primarily in the M3, M4, M5 and M8 landfills which consolidate all of the landfills into one area labeled "Site 1." There is an L-shaped dividing wall on what looks to be the border of the M8 and M5 landfills. Possible debris/rubble and light-toned surface are both noted in the northwest portion of the M5 landfill. The M2 landfill is labeled as "Site 2 Poss Landfill," and seems to be fully delineated. A small fill area is depicted behind the Gosselin housing area within the vicinity that the current M14 landfill.

Figure 7: December 6, 1969: An aerial photograph dated 1969 shows several new buildings that still remain today: the theater (building 1215); bowling alley (building 689); and buildings 361, 362, and 363. The "Site 1" area that comprises the M-3, M-4, M-5, and M-8 landfills shows a defined boundary for M-8 and is now labeled as a landfill. Numerous new fill areas have been noted, including a small area of the current M-18 landfill, an additional fill area in the western portion of the M-12 landfill, and a small fill area located south of the 750 area. On the Oceanport Avenue section of the Main Post, a tank cluster is identified behind the building 116 warehouse.

2.4. CURRENT CONDITIONS

On October 21, 2010, Tetra Tech conducted a drive by to assess current conditions at M-4 Landfill. The site consisted of an open field, which is maintained through landscaping.

2.5. ENVIRONMENTAL SETTING

This section summarizes the description of the geological and hydrogeological setting of the area surrounding Fort Monmouth and the Main Post area as presented in Versar, Inc.'s (Versar), 2005 Remedial Investigation Report (RIR) (**Appendix K**) (Versar 2005).

2.5.1. Geology

Monmouth County lies within the New Jersey Section of the Atlantic Coastal Plain physiographic province. The M-4 Landfill is located in what may be referred to as the Outer Coastal Plain subprovince, or the Outer Lowlands.

In general, New Jersey Coastal Plain formations consist of a seaward-dipping wedge of unconsolidated deposits of clay, silt, sand, and gravel. These formations typically strike northeast-southwest with a dip ranging from 10 to 60 feet per mile and were deposited on Precambrian and lower Paleozoic rocks. These sediments, predominantly derived from deltaic, shallow marine, and continental shelf environments, date from Cretaceous through the Quaternary periods. The mineralogy ranges from quartz to glauconite.

As presented in the Site Investigation Report - Main Post and Charles Wood Areas, Fort Monmouth, New Jersey, prepared by Weston (Weston 1995), several natural and anthropogenic factors contribute to the wide range in concentrations of metals found in soils, which further impact the concentration of metals in ground water. Soils derived from the glauconitic sands contain abundant aluminum, calcium, potassium, iron, magnesium, and manganese (among others), which are likely to be present at elevated concentrations in the ground water, particularly when sediments are entrained in the collected ground water samples.

2.5.2. Hydrogeology

A description of the hydrology of the site is provided in Section 2.4.2 of **Appendix J** (Versar 2005).

Brinkerhoff prepared the *MODFLOW Ground Water Modeling Report*, dated June 10, 2010, which is included as **Appendix L**. In this report, Brinkerhoff developed and refined site-wide ground water models for both the Main Post and the Charles Wood areas of Fort Monmouth (Brinkerhoff 2010).

As part of the ground water modeling project, Brinkerhoff performed a Preliminary Tidal Evaluation of select monitoring wells throughout the Main Post of Fort Monmouth. The study locations were mutually selected by Brinkerhoff and representatives of Fort Monmouth. These locations were chosen to represent an overall profile for the Main Post area. On September 29, 2009, wireless downhole data loggers were placed into each of the 25 predetermined ground water monitoring wells targeted for the study. Data was collected for approximately 30 days.

Monitoring wells M4-MW05, MW-4MW07, and M4-MW10 were included in this evaluation of M-4 Landfill. The area of M-4 Landfill is along the east side of Mill Creek to the south of the confluence of Mill Creek and Parkers Creek. M4-MW10, which is directly adjacent to Mill Creek, exhibited a rhythmic cycle of ground water fluctuations indicative of tidal influence. Additionally, ground water data collected for M4-MW07, approximately 160 feet east of Mill Creek, did not appear to indicate tidal influence; however, subtle fluctuations corresponding with large rainfall events were apparent. Although it is not tidally influenced, the location of M4MW7 indicates that it is susceptible to irregular ground water elevation changes caused by

surface water permeation. Areas with ground water elevations less than 5 feet above mean sea level (amsl) are considered within the Primary Zone of potential tidal influence. Ground water elevations for M-4 Landfill ranged from 2.5 to 7.1 feet amsl; therefore, M-4 Landfill is not considered to be within the Primary Zone of potential tidal influence (Brinkerhoff 2010).

According to the modeling report, the suggested flow directions indicated by the ground water flow model are generally consistent with that seen in previous ground water investigations when compared to ground water contour maps prepared using depth-to-water measurements collected in the field on January 28, 2010. The ground water contour maps illustrating the January 2010 measurements at M-4 Landfill created as part of the ground water modeling report is presented in **Appendix L and as Figure 4-1** with ground water at the site flowing toward the west (Brinkerhoff 2010).

In general, ground water flows from areas of relatively high topographic elevations toward lower topographic elevations where site surface water features are present. The MODFLOW simulation shows that the central portion of the Main Post is a relatively high ground water divide because this portion of Fort Monmouth is almost completely surrounded by low-elevation surface water. The Main Post area can be characterized as having a small hydraulic gradient. When combined with the low hydraulic conductivity of the aquifer materials, this translates into very slow ground water migration. Particle markers, which represent typical travel paths and speeds for water molecules in the system, indicate extremely long travel times. In several areas of the Main Post, representative markers did not reach the nearest surface water sink within the 200-year travel time shown. As a result of the slow ground water velocity, recharge to the aquifer from rainfall, although very limited, has the effect of adding a downward component to the ground water flow (Brinkerhoff, 2010).

The physical conditions of the site would likely contribute to ground water contaminant plumes with a dominant elongation in a downgradient direction. Vertical contaminant migration would typically be heavily impeded by the fine-grained aquifer materials present at depth (Brinkerhoff 2010).

3.0 SITE ACTIVITIES

Fort Monmouth DPW conducted RI activities at the M-4 Landfill, including quarterly surface water and ground water sampling based on the findings of Versar's September 2003 RIR, RIR NSS and RIR SQE, and previous work conducted at the site by Weston in 1995. In addition, DPW has conducted additional site work including landfill delineation activities, stream bank stabilization activities, monitoring well installation, a BEE, and a sensitive receptor survey to address the NJDEP's comments dated July 25, 2007. This section summarizes work performed from 2001 to the present.

3.1. LANDFILL DELINEATION ACTIVITIES

In October 2008, a Landfill Boundary Delineation was conducted to determine the exact aerial extent of the M-4 Landfill. Trench excavations were performed at a total of 16 locations along the M-4 Landfill boundary (**Figure 3-1**). Trench logs and a photographic documentation log depicting trenching activities are included in **Appendix M**. According to the results of the trench excavation, the landfill boundaries expanded to include areas where landfilled materials were not previously encountered.

3.2. STREAM STABILIZATION

DPW contracted Princeton Hydro, LLC (Princeton Hydro), to provide streambank stabilization and erosion control design services for five areas located on the Fort Monmouth property, including M-4 Landfill. In a report for NJDEP dated December 5, 2008, Princeton presented the design for the proposed streambank stabilization and erosion control as well as the necessary historic background information and documentation to describe the existing conditions of the site. The report is presented in **Appendix N**.

The objective of the report was to describe the type of streambank stabilization and erosion control measures proposed for the project and how the proposed designs addresses issues with erosion, water quality, and stability on the subject site. The stabilization of the streambank and landfill areas is the first phase to be performed in preparation of complete landfill capping, which will be reported in a separate document and is not part of this RIRA.

For the M-4 Landfill, stream bank stabilization is being proposed on both the left and right banks of Wampum Brook along the M-4 Landfill (**Figure 3-2**). The full engineering design is presented in the Princeton Hydro report included as **Appendix N**. The proposed stabilization is not anticipated to have any negative hydraulic impacts on the areas upstream or downstream of M-4 Landfill. The proposed stabilization will prevent additional scour and erosion of the streambanks on the site and thereby reduce the stream's pollutant load, and increase sediment removal functions associated with the establishment of integrated vegetative cover (Princeton Hydro 2008).

3.3. MONITORING WELL INSTALLATION

A total of five ground water monitoring wells (M4-MW06, M4-MW07, M4-MW08, M4-MW09 and M4-MW10) comprises the quarterly ground water monitoring program conducted by the DPW at M-4 Landfill. Two monitoring wells (M4-MW08 and M4-MW10) were installed in the southwestern corner of M-4 Landfill, one monitoring well (M4-MW07) was installed in the southeast corner, one monitoring well (M4-MW06) was installed in the northwestern corner, and one monitoring well (M4-MW10) was installed in the northern area of M-4 Landfill. Wells M4-MW07, M4-MW08 and M4-MW09 were installed by J.C. Anderson in December 1994, well M4-MW10 was installed by Lutz Environmental, Inc. in November 1999, and M4-MW06 was installed by Tabasco Drilling Corporation in July 2010. The wells were constructed with 4-inch diameter 10 Slot Poly Vinyl Chloride pipe ranging to depths of 15.5 to 22 feet below ground surface (bgs). Well boring logs and monitoring well records are provided in **Appendix O.** The locations of the five monitoring wells at M-4 Landfill are presented in **Figure 3-3**.

3.4. GROUND WATER DEPTH MEASUREMENTS

During each round of the ground water sampling, measurements of the depth to water in each of the monitoring wells were recorded with an accuracy of 0.01 foot. Depth-to-ground water measurements and water quality parameters for the latest eight quarters of ground water sampling are presented in **Table 3-1 and Table 3-2,** respectively. The ground water elevation at each well was calculated by subtracting the elevation of the top of the well casing with the depth to water at the well.

3.5. GROUND WATER SAMPLING ACTIVITIES

As a part of the remedial investigation, quarterly ground water sampling was conducted by the DPW from April 2001 to July 2010 at M-4 Landfill. Sampling activities were performed in accordance with the Fort Monmouth Standard Sampling Operating Procedure (DPW 1997).

Ground water samples were collected during 38 quarterly sampling events. On November 16, 2004, NJDEP approved DPW's request to reduce the ground water sampling analytical parameters at M-4 Landfill. Starting the first quarter of 2005, ground water sampling analysis for site was reduced to TAL metals only. From April 2001 to October 2004, the ground water samples were analyzed for VOCs, SVOCs, pesticides, PCBs and TAL metals. From January 2004 to July 2010, ground water samples were analyzed for TAL metals only. Two additional low-flow sampling rounds were conducted and samples were analyzed for TAL metals. A total of 190 samples were collected throughout the ground water sampling program.

Because of the potential benefits of low-flow sampling, two rounds of low-flow sampling (Low-flow #3 and Low-flow #4) were conducted on April 6, 2010 and July 21, 2010, respectively. Of the 190 total ground water samples, 20 samples were collected and analyzed for TAL metals to determine whether elevated metal concentrations observed in the ground water samples were caused by sediments rather than ground water. The samples were analyzed by the Fort Monmouth Environmental Testing Laboratory (FMETL) for TAL metals utilizing U.S.

Environmental Protection Agency (EPA) Methods 3120B and 3112B. These analytical results are discussed in Section 5.1.

Sampling equipment was thoroughly decontaminated before and after each use, in accordance with Fort Monmouth Standard Operating Procedures (DPW 1997). The ground water samples were collected and immediately placed in laboratory-supplied bottleware. The sample containers were labeled, sealed, packed in ice, and transported to FMETL in accordance with proper chain-of-custody procedures.

3.6. SURFACE WATER SAMPLING ACTIVITIES

To determine whether ground water contamination at M-4 Landfill has impacted nearby surface water, DPW conducted quarterly surface water sampling at M-4 Landfill from May 2001 to September 2010. Of the three surface water (stream) sampling locations associated with the site (SS-5, SS-15, and SS-16), SS-5 and SS-15 were sampled from May 2001 to September 2010; SS-16 was sampled from May 2001 to August 2004 only. A total of 90 surface water samples was collected during 38 quarterly sampling events and analyzed for VOCs. Beginning the fourth quarter of 2004 t0 September 2010, SS-15 was also analyzed for TAL Metals. A total of 38 surface water samples were collected from SS-5 and SS-15; 14 surface water samples were collected from location SS-16. **Figure 3-4** depicts the locations of the three surface water stream sampling locations at M-4 Landfill.

Sampling equipment was thoroughly decontaminated before and after each use in accordance with the Fort Monmouth Standard Operating Procedures (DPW 1997). The surface water samples were collected and immediately placed in laboratory-supplied bottleware. The sample containers were labeled, sealed, packed in ice and transported to the FMETL under proper chain-of-custody procedures. Copies of the chain-of-custody for the laboratory analyses, sample IDs, stream sampling locations, collection/analysis date, analytical parameters and analysis method can be found in **Appendix R**. The results of the surface water sampling program are discussed in Section 5.0.

3.7. SOIL BORING AND SOIL SAMPLING ACTIVITIES

To demonstrate that the existing soil cover over the M-4 Landfill is in compliance with the Solid Waste Disposal Act of 1965, DPW characterized the near-surface soils by installing 63 borings (B01-B63) at strategic locations throughout the site. DPW performed soil borings and obtained soil samples in March 1998. Samples were collected using a 2-inch Geoprobe® Macrocore sampler. Sampling activities were performed in accordance with the *Fort Monmouth Standard Sampling Operating Procedure* (DPW 1997). A total of 126 soil samples were collected from the 63 borings and were analyzed for the presence of volatile organic compounds (VOC), semivolatile organic compounds (SVOC), pesticides, polychlorinated biphenyls (PCB) and total analyte list (TAL) metals (**Table 3-3**). The soil boring locations in and around the M-4 Landfill are identified in the Weston SIR (Weston 1995). The locations of the borings were established in a grid-like pattern within the previously designated boundaries of the M-4 Landfill. **Figures 5-2 through 5-4** depict the locations of the soil sampling locations at M-4 Landfill. The

Remedial Investigation Report for Near Surface Soils (Versar 2004) provides a detailed explanation of activities performed for the M-4 Landfill (**Appendix B**).

3.8. SENSITIVE RECEPTOR SURVEY

A visual and documentary search of sensitive populations was performed by the U.S. Army Fort Monmouth (FTMM), Directorate of Public Works (DPW) and their subcontractor to identify any potentially sensitive populations within 200 feet of the FTMM boundary. The identification of said populations is in accordance with New Jersey Department of Environmental Protection (NJDEP) statutory requirement. An Offsite Receptor Report (dated October 13, 2010) was prepared for the Main Post of Fort Monmouth by Environmental Data Resources, Inc. (EDR) of Southport, Connecticut. A copy of the Offsite Receptor Report, identifying sensitive receptors in the area, is provided in **Appendix P**. In the following written summary, the sensitive populations and their locations have been identified. Their locations are plotted on the Offsite Receptor Survey map, **Figure 3-5**.

Although sensitive populations were identified within 200 feet of the Fort Monmouth boundary, all of the environmentally impacted locations are a distance from the fence line and in all cases exceed the 200-foot buffer established by NJDEP.

In addition to the sensitive receptors, DPW identified off-site wells within 2,000 feet of the Fort Monmouth perimeter. No production wells were identified within 2,000 feet of the Fort Monmouth boundary. The majority of off-site wells are monitoring wells associated with various remedial activities. In their ground water model developed for Fort Monmouth, Brinkerhoff Environmental Services, Inc. (Brinkerhoff), determined that the overall ground water flow pattern for the Main Post is easterly with a localized northeasterly component. Fort Monmouth is bounded by surface water bodies to the east and northeast. Any domestic and/or irrigation wells to the east or northeast of the Main Post would not be impacted by the base (Brinkerhoff, 2010).

Surface water bodies interact with ground water at Fort Monmouth. The interaction takes place in three basic ways: (1) streams gain water from inflow of ground water through the streambed, (2) streams lose water to ground water by outflow through the streambed, or streams do both--gaining in some reaches and losing in other reaches. When ground water discharges into a surface water body, the altitude of the ground water table in the vicinity of the creek must be higher than the altitude of the stream water surface. Conversely, for surface water to seep to ground water, the altitude of the water table in the vicinity of the stream must be lower than the altitude of the stream water surface. The surface water bodies at Fort Monmouth (Oceanport and Parkers Creeks) may be gaining or losing depending upon the tidal cycle. Throughout the entire tidal cycle, however, the net result is that ground water flows into the creeks, albeit at low flow rates.

3.9. BASELIE ECOLOGICAL EVALUATION (BEE)

Shaw Environmental, Inc. was contracted by the Army to conduct a BEE for Fort Monmouth's Main Post and Charles Wood Areas. Sampling of multiple media was conducted in 2010, the

results of which are not available for discussion herein. The final BEE will be submitted to the NJDEP under separate cover in June 2011.

4.0 SITE PHYSICAL CHARACTERISTICS

The following sections represent the findings of the site geologic and hydrogeologic characterization program for M-4 Landfill. DPW collected the ground water elevation data from April 2001 to 2010. Specifically, this section summarizes lithology and ground water flow direction data collected for the area surrounding M-4 Landfill.

4.1. LITHOLOGY

The lithology encountered at M-4 Landfill consists primarily of fill material (sand, silt, broken concrete, gravel, and plant fragments), fine sand, and clay. Geologic cross-section A-A' was prepared for two monitoring wells. Cross-section A-A' depicts the profiles for monitoring wells M4-MW07 and M4-MW10. Wells M4-MW07 and M4-MW10 encountered fill consisting of crushed concrete, sand with silty clay laminae, organics (grass roots), greenish gray to black silty clay, and coarse sand with iron oxide laminae ranging from 0.5 to 18 feet bgs.

As discussed in the 1995 SIR, the wide range of concentrations of metals in soils further impact the concentration of metals detected in ground water (Weston 1995). Soils derived from glauconitic sands contain abundant aluminum, calcium, potassium, iron, magnesium, and manganese (among others), which are likely to be present at elevated concentrations in the ground water, particularly when sediments are entrant during the collection of ground water samples.

4.2. GROUND WATER FLOW DIRECTION

Ground water contour maps were generated for the latest three quarterly ground water sampling rounds (**Figures 4-1 through 4-3**). Ground water was encountered at M-4 Landfill at depths ranging from 2.5 feet to 7.1 feet bgs, grading toward Mill Creek. The ground water underlying the site appears to be flowing consistently west towards Mill Creek.

4.3. GLAUCONITIC SOIL AND METALS EVALUATION

A Basewide Glauconitic Investigation Report was completed by DPW in March 2011 and a Background Metals Evaluation was prepared by Brinkerhoff for DPW in May 2011. Both documents indicate the potential for soil particles present in ground water samples which are potentially affecting the metals analysis results in ground water samples collected from the overall FTMM site. Additional ground water sampling including the comparison of filtered and unfiltered samples results has been proposed to determine the potential affect of soil particles on metals analysis results. Results and conclusions from these future sampling events will be provided to NJDEP under separate cover.

The Basewide Glauconitic Investigation Report and the Background Metals Evaluation Report are provided in **Appendix Q**.

5.0 SITE CHEMICAL CHARACTERIZATION

This section includes a discussion of the chemical characterization of M-4 Landfill based on various samples collected and analyzed from the site, including 36 rounds of ground water monitoring well samples, two rounds of low-flow ground water samples, 38 rounds of surface water samples and surficial soil samples. DPW personnel were responsible for the collection of samples during this remedial investigation. Sample analyses were performed by FMETL, a New Jersey certified laboratory (Certification No. 13461).

Ground water analytical data was compared against NJDEP criteria and COCs were identified based on those results. Ground water data was compared to NJDEP GWQS Practical Quantitation Limits (PQL), whichever was higher. Surface water was compared to NJDEP SWQS and surficial soil samples was compared to the NJDEP NRDCSRS.

According to the 2008 SIR Report prepared by Shaw Environmental (Shaw), several factors, both natural and anthropogenic, can influence chemical concentrations, specifically metals, found in environmental samples collected at Fort Monmouth. The primary natural influence at Fort Monmouth is parent material: glauconitic quartzose sands of the Tinton and Red Bank sands and their fluvially- and tidally-reworked equivalents. The mineral glauconite found in these sands is a potassium-, sodium-, calcium-, iron-, aluminum-, magnesium-rich hydrosilicate. These glauconitic soils therefore contain abundant iron, aluminum, calcium, magnesium, manganese, sodium, and potassium (Shaw 2008).

Ground water quality is often affected by the composition of the aquifer; in this case, the Tinton and Red Bank sands. Coastal Plain aquifers are susceptible to saltwater encroachment. Aquifers under Fort Monmouth can also be identified by saltwater intrusion, affecting ground water chemistry. High concentrations of sodium are likely a result of saltwater intrusion (Shaw 2008).

As a result of these natural influences, aluminum, calcium, iron, manganese, magnesium, potassium, and sodium are likely to be present in elevated concentrations and are not considered COCs in soil and ground water at Fort Monmouth. Therefore, these metals were not included in ground water results presented in **Table 5-1**. All other analytical results for environmental samples collected at Fort Monmouth as part of the remedial investigation were compared with applicable NJDEP criteria and the MBCs, if applicable. If they exceeded the NJDEP regulations, sample concentrations were compared to the MBC. Those compounds that exceeded the regulatory standard and established background levels were classified as COCs.

All analytical data for this site were validated for any laboratory issues and the data validation packages for the last quarterly sampling events are provided in **Appendix S**.

This section summarizes ground water sampling results, surface water sampling results, COCs, and quality assurance and quality control (QA/QC) sampling results for M-4 Landfill.

5.1. GROUND WATER SAMPLING RESULTS

This section presents the results of laboratory analyses performed for the 36 rounds of ground water sampling and 2 additional low-flow sampling conducted from 2001 to July 2010 from the five monitoring wells (M4-MW06, M4-MW07, M4-MW08, M4-MW09, and M4-MW10) at M-4 Landfill. From April 2001 to October 2004 (rounds 1 through 15) ground water samples were collected and analyzed for VOCs plus 15 tentatively identified compounds (TIC), SVOCs plus 15 TICs, pesticides, PCBs, and TAL metals.

On November 16, 2004, NJDEP approved DPW's request to reduce the analyses performed on ground water samples collected at M-4 Landfill. Starting the first quarter of 2005, ground water sampling analysis for M-4 Landfill was reduced to only TAL metals. From January 2004 to July 2010 (rounds 16 through 38), ground water samples were analyzed for TAL metals only.

As discussed in Section 2.2.1, low-flow sampling methodology was proposed by the DPW to assess the impact of suspended sediments on the dissolved-phase metals concentrations at the site. Two rounds of low-flow sampling (Low-flow #3 and Low-flow #4) were conducted on April 6, 2010 and July 21, 2010 (respectively), using a low-flow ground water sampling technique for TAL metals.

Fort Monmouth is underlain by a Class III-A aquifer. The ground water quality criteria for Class III-A is considered to be the criteria for the most stringent classification for vertically or horizontally adjacent ground waters that are not Class III-A (N.J.A.C. 7:9-6.7E). The NJDEP criteria used for comparison of ground water analytical results were the higher of the PQLs and the NJDEP GWQS for Class II-A aquifers (N.J.A.C. 7:9-6, Table 1) (NJDEP 1999b).

During the 15 quarterly sampling events conducted prior to the NJDEP approval letter for the reduction of ground water sampling analyses, no VOCs or PCBs were detected in site ground water. Six SVOCs were detected in site ground water at concentrations less than their respective NJDEP GWQS. Three pesticides were detected in site ground water at concentrations less than their respective NJDEP GWQS. A total of 11 metals was detected in site ground water with two metals detected at concentrations exceeding their respective NJDEP GWQS.

Following the reduction of sampling analyses approval from the NJDEP, 12 metals were detected in site ground water during the last 18 sampling quarters, with seven metals detected at concentrations exceeding their respective NJDEP GWQS.

This section discusses analytical results of ground water samples collected from the M-4 Landfill according to the four analytical categories: VOCs, SVOCs, pesticides and PCBs, and TAL metals. These four sections will concentrate on the most recent eight quarters of sampling conducted from October 2008 to July 2010. These eight quarters define the most current conditions of ground water at M-4 Landfill. The ground water sampling results are summarized in **Table 5-1**.

5.1.1. Volatile Organic Compounds (VOCs)

No VOCs were detected at concentrations exceeding their respective NJDEP GWQS at the site.

5.1.2. Tentatively Identified Compounds (TICs)

No TICs were detected at concentrations greater than the appropriate NJDEP GWQS at the site (500 µg/L for VOCs and 100 µg/L for an individual compound).

5.1.3. Semivolatile Organic Compounds

No SVOCs were detected at concentrations exceeding their respective NJDEP GWQS at the site.

No Tentatively Identified Compounds (TICs) were detected greater than the appropriate NJDEP GWQS at the site (500 µg/L for SVOCs and an individual compound can exceed 100 µg/L)

5.1.4. Pesticides and PCBs

No pesticides or PCBs were detected at concentrations exceeding their respective NJDEP GWQS at the site.

5.1.4 TAL Metals

During the most recent eight sampling events, including two rounds of low-flow sampling, seven TAL metals were detected at concentrations exceeding the NJDEP GWQS in at least one sample at M-4 Landfill.

Antimony was detected at concentrations exceeding the GWQS of 6 micrograms per liter (µg/L) during five separate rounds of sampling conducted at four separate monitoring well locations. Concentrations ranged from 6.51 µg/L in M4-MW08 to 18.7 µg/L in M4-MW08.

Arsenic was detected at concentrations exceeding the GWQS of 3 µg/L during five separate rounds of sampling conducted at four separate monitoring well locations. Concentrations ranged from 3.61 µg/L in M4-MW09 to 109 µg/L in M4-MW08.

Beryllium was detected at concentrations exceeding the GWQS of 1 µg/L during one round of sampling conducted at one monitoring well location (M4-MW07) at a concentration of 1.28 µg/L.

Cadmium was detected at concentrations exceeding the GWQS of 4 µg/L during one round of sampling conducted at one monitoring location (M4-MW08) at a concentration of 9.23 µg/L.

Lead was detected at concentrations exceeding the GWQS of 5 µg/L during three separate round of sampling conducted at three separate monitoring well location. Concentrations ranged from 5.0 µg/L in M4-MW09 to 31.1 µg/L in M4-MW08.

Selenium was detected at concentrations exceeding the GWQS of 40 µg/L during one round of sampling conducted at three separate monitoring well location at a concentration ranging from of 52.7 µg/L to 87.0 µg/L.

Thallium was detected at a concentration exceeding the GWQS of 2 µg/L during one round of sampling conducted at one monitoring well location (M4-MW09) with a concentrations of 2.02 µg/L.

5.2. SURFACE WATER SAMPLING RESULTS

To determine whether ground water contamination at the M-4 Landfill has impacted nearby surface water, DPW conducted quarterly surface water sampling at M-4 Landfill from May 2001 to September 2010. Of the three surface water (stream) sampling locations, SS-5 and SS-15 were sampled from May 2001 to September 2010; SS-16 was sampled from May 2001 to August 2004 only. A total of 90 surface water samples was collected during 38 quarterly sampling events and analyzed for VOCs. However, beginning the fourth quarter of 2004 to September 2010, SS-15 was also analyzed for TAL metals. A total of 38 surface water samples were collected from each of the two stream locations (SS-5 and SS-15). Fourteen surface water samples were collected from the stream location SS-16. **Figure 3-4** depicts the locations of the surface water stream sampling locations associated with Fort Monmouth and M-4 Landfill. The samples were collected by the DPW and analyzed by the FMETL for VOCs and TAL metals.

This section discusses analytical results of surface water samples collected from M-4 Landfill according to the two analytical categories: VOCs and TAL metals. These four sections will concentrate on the most recent eight quarters of sampling conducted from December 2008 to September 2010, which define the most current conditions of surface water at M-4 Landfill. SS-16 is not included in this discussion because sampling at that location was discontinued in August 2004 and would not represent the most current condition of surface water at M-4 Landfill. SS-16 is located between SS-15 and SS-05 and is downstream of SS-15. Because of its location, the results from SS-15 and SS-05 are representative of that particular stretch of the stream. All the laboratory analytical results for surface water samples (including results for SS-16) are summarized in **Table 5-2**.

5.2.1. Volatile Organic Compounds

Five VOCs were detected in site surface water: two VOCs were detected exceeding the health-based NJDEP fresh water criteria and the remaining three VOCs were detected did not exceed the health-based NJDEP fresh water criteria.

Tetrachloroethene (PCE) was detected at concentrations exceeding the NJDEP criteria of 0.34 µg/L during the last eight quarterly rounds of sampling conducted at two separate surface water stream sampling locations. Concentrations ranged from 0.42 µg/L at SS-5 to 3.03 µg/L at SS-15.

Trichloroethene (TCE) was detected at a concentration exceeding the NJDEP criteria of 1.00 µg/L during one of the last eight rounds of quarterly sampling conducted at one surface water stream sampling location at a concentration of 1.26 µg/L at SS-15.

5.2.2. Tentatively Identified Compounds (TICs)

No TICs were detected greater than the appropriate NJDEP SWQW at the site (500 µg/L for SVOCs and an individual compound can exceed 100 µg/L)

5.2.3. TAL Metals

Eleven metals were detected in site surface water with, four metals detected exceeding the health-based NJDEP fresh water criteria and the remaining seven metals detected did not exceed the health-based NJDEP fresh water criteria.

Antimony was detected at concentrations exceeding the NJDEP criteria of 5.6 µg/L during five of the last eight rounds of quarterly sampling conducted at one surface water stream location. Concentrations ranged from 6.06 µg/L to 17.8 µg/L.

Arsenic was detected at concentrations exceeding the NJDEP criteria of 0.017 µg/L during five of the last eight rounds of quarterly sampling conducted at one surface water stream location. Concentrations ranged from1.13 µg/L to 66.6 µg/L.

Lead was detected at a concentration exceeding the NJDEP criteria of 5.00 µg/L during one round in the last eight rounds of quarterly sampling conducted at one surface water stream location at a concentration of 5.74 µg/L

Mercury was detected at a concentraion exceeding the NJDEP criteria of 0.05 µg/L during one round in the last eight rounds of quarterly sampling conducted at one surface water stream location at a concentration of 0.18 µg/L.

5.3. SOIL SAMPLE RESULTS

The analytical results from the 126 soil samples collected from 63 borings at the M-4 Landfill are discussed below, and are included in **Table 5-3**. The soil analytical data is provided in **Appendix R**.

5.3.1. VOCs

VOC analyses were conducted on soil samples collected from the 63 soil borings at the M-4 Landfill. Each of these soil samples was collected at approximately the same depth range, 24 inches bgs. There were no exceedances of the NJDEP NRDCSRS for any VOCs identified in any of the 63 soil borings.

5.3.2. SVOCs

SVOC analyses were conducted on soil samples collected from the 63 soil borings at the M-4 Landfill (see **Figure 5-2**). Each of these soil samples was collected at approximately the same depth range, 6-12 inches bgs.

Soil cleanup criteria for SVOCs were exceeded in 24 of the 63 soil boring locations. Five SVOCs were detected in site soils at concentrations greater than the NRDCSRS See comment above. The five SVOCs that exceeded the NRDCSRS are, with number of exceedances in parentheses, Benzo(a)anthracene (1), Benzo(a)pyrene (18), Benzo(b)fluoranthene (1), Bis(2-ethylhexyl)phthalate (6), and Dibenz(a,h)anthracene (4). A discussion of these exceedances is presented below.

- Benzo(a)anthracene was detected in one of the site soil samples greater than the NRDCSRS of 0.2 mg/kg at a concentration of 3.7 mg/kg (B-9).
- Benzo(a)pyrene was detected in 18 site soil samples greater than the NRDCSRS of 0.2 mg/kg. The exceedance concentrations ranged between 0.21 mg/kg (B-13) and 3.5 mg/kg (B-9).
- Benzo(b)fluoranthene was detected in one of the site soil samples greater than the NRDCSRS of 2.0 mg/kg at a concentration of 4.0 mg/kg (B-9).
- Bis(2-ethylhexyl)phthalate was detected in six site soil samples greater than the NRDCSRS of 140 mg/kg. The exceedance concentrations ranged between 1,500 mg/kg (B31) and 10,538 mg/kg (B20).
- Dibenz(a,h)anthracene was detected in four site soil samples greater than the NRDCSRS of 0.2 mg/kg. The exceedance concentrations ranged between 0.41 mg/kg (B-47) and 0.69 mg/kg (B-9).

5.3.3. Pesticides and PCBs

Pesticide and PCB analyses were conducted on soil samples collected from the 63 borings at the M-4 Landfill. Each of these soil samples was collected at approximately the same depth range, 6-12 inches bgs. Each of the 63 borings was analyzed for 19 pesticides and 7 PCB compounds. There were no exceedances of the NJDEP NRDCSRS for any Pesticides and PCBs identified in any of the 63 soil borings.

5.3.4. Metals

The soil samples from the 63 borings were analyzed for 24 TAL metals (**Figure 5-3**). The samples were collected from depths of 6-12 inches. Two metals were detected at concentrations greater than their respective NRDCSRS at ten of 63 boring locations. The two metals that exceeded the NRDCSRS in the borings are, with the number of exceedances in parentheses, Arsenic (10) and Thallium (1). A discussion of these exceedances is presented below.

- Arsenic was detected in ten of the site soil samples greater than the NRDCSRS of 19.0 mg/kg. The exceedance concentrations ranged between 19.16 mg/kg (B-41) and 266 mg/kg (B-34).
- Thallium was detected greater than the NRDCSRS of 79.0 mg/kg in one site soil sample at a concentration of 242 mg/kg (B-34).

5.4. CONTAMINANTS OF CONCERN – GROUND WATER

No VOCs, SVOCs, pesticides, or PCBs were detected in the ground water samples collected from the M-4 Landfill at concentrations exceeding the NJDEP GWQS criteria. A total of seven metals (antimony, arsenic, beryllium, cadmium, lead, selenium, and thallium) were detected in ground water samples at concentrations exceeding the NJDEP GWQS. **Figure 5-1** shows the specific exceedances from the last 8 sampling quarters. The specific exceedences and each constituent considered to be a potential COC are discussed below and are presented in **Table 5-4.**

A low-flow sampling methodology was used to reduce the presence of suspended sediments within the ground water samples collected from M-4 Landfill. Decreases in non-native metals (arsenic, antimony, beryllium, cadmium, lead, selenium, and thallium) and in naturally occurring metals (aluminum, barium, calcium, copper, iron, magnesium, manganese, nickel, potassium, sodium, and zinc) were seen in the sample results after the low-flow sampling events. However, the native metal constituents (those indigenous to the soils at Fort Monmouth) were consistently present in the ground water samples collected from M-4 Landfill.

The two separate rounds of low-flow ground water sampling conducted in April and July 2010, respectively, were performed during the quarterly ground water sampling program at M-4 Landfill. This technique was used to determine whether the detected metal concentrations observed in the ground water samples were caused by contaminated sediments suspended in the ground water during the course of well purging and sampling activities, or whether sampling results were an accurate representation of aquifer/ground water conditions. This low-flow sampling approach resulted in the reduction of concentrations or the non-detections of six uncharacteristic metals (arsenic, beryllium, cadmium, lead, selenium, and thallium) during the two rounds of low-flow ground water sampling conducted at M-4 Landfill. Concentrations of antimony detected during the low-flow sampling events continued to exceed the GWQS criteria.

The ground water analytical results were compared with the low-flow sampling results and the NJDEP GWQS. As a result of this comparison, six metals were eliminated as COCs in ground water at M-4 Landfill. Antimony concentrations exceeded the NJDEP criteria even after comparison to the low-flow sampling results. However, because concentrations of antimony were below the MBC for Fort Monmouth, antimony is not considered a COC in ground water at M-4 Landfill.

5.5. CONTAMINATS OF CONCERN – SURFACE WATER

Two VOCs (PCE and TCE) and four metals (antimony, arsenic, lead, and mercury) were detected at concentrations exceeding the NJDEP SWQS. PCE was detected in surface water exceeding the NJDEP criteria from two stream sampling locations (SS-5 and SS-15) sampled during five of the last eight rounds of sampling. TCE was detected in surface water collected from one stream sampling location (SS-15) exceeding the NJDEP criteria only once in the last eight sampling events. However, because these compounds were not detected in ground water and are not considered to impact nearby surface water at M-4 Landfill, PCE and TCE are not considered to be COCs. Mercury was detected in one surface water sampling location exceeding

the NJDEP criteria only once in the last eight quarters. Because of the infrequency and magnitude of exceedances in surface water, mercury is not considered a COC. Lead, antimony, and arsenic were detected in one surface water sampling location (SS-15) exceeding the NJDEP criteria. However, lead, antimony, and arsenic were eliminated as COCs in ground water at the site and therefore are not considered to impact nearby surface water at M-4 Landfill.

The highest concentrations of the VOCs and metals were detected in surface water samples collected from SS-15, which is located at the boundary of Fort Monmouth and is upgradient of M-4 Landfill. It is the DPW's contention that the concentrations of the two VOCs and four metals detected exceeding the NJDEP SWQS in the surface water samples are from a source beyond the boundary of Fort Monmouth. Therefore, no VOCs and metals are identified as COCs in surface water at M-4 Landfill. A summary of the COC for surface water are presented in **Table 5-5.**

5.6. CONTAMINANTS OF CONCERN - SOIL

In order to determine the potential COCs in the surface soils at M-4, the first step was to identify exceedances of the NJDEP NRDCSRS for samples collected at M-4. If concentrations were greater than the NRDCSRS, the sample concentrations were then compared to site specific MBC established for specific analytes, where appropriate. An analyte that exceeded both the regulatory standard and the MBC was classified as a COC. These exceedances are summarized in **Tables 5-3, 5-5 and 5-6**, and illustrated on **Figure 5-2 through 5-4**.

Soil cleanup criteria for SVOCs were exceeded in 24 of the 63 soil boring locations. After comparison to the site specific MBC's, only 13 of the 63 soil boring locations contained SVOCs concentrations greater than both the NRDCSRS and site specific MBC's. The following five SVOCs were detected in site soils at concentrations greater than both the NRDCSRS and MBC; with number of exceedances in parentheses, benzo(a)anthracene (1), benzo(a)pyrene (7), benzo(b)fluoranthene (1), bis(2-ethylhexyl)phthalate (6), and dibenz(a,h)anthracene (4). The five SVOCs are therefore considered potential COCs in soils at M-4.

Soil cleanup criteria for TAL metals were exceeded in 10 the 63 soil boring locations. After comparison to the site specific MBC's, only 4 of the 63 soil boring locations contained metals concentrations greater than both the NRDCSRS and site specific MBC's. Arsenic and Thallium were detected in site soils at concentrations greater than both the NRDCSRS and MBC. Therefore, arsenic and Thallium are considered potential COCs in soils at M-4.

5.7. QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance and quality control (QA/QC) samples were collected in accordance with the current version of the NJDEP Field Sampling Procedures Manual in effect at the time sampling was conducted. No evidence of any QA/QC issues were identified based on the results of the QA/QC sample results.

6.0 CONCLUSIONS

Geologic publications indicate that M-4 Landfill is located within an aquitard (the Navesink-Hornerstown Confining Unit). The low hydraulic conductivity of the aquitard and the thickness of the aquitard at the site conform to the requirements of a Class III-A aquifer, as specified in the NJDEP Ground Water Quality Standards (N.J.A.C. 7:9-6, January 7, 1993).

The analytical results for the ground water samples collected at M-4 Landfill from April 2001 to July 2010 indicate that no COCs exist within M-4 Landfill ground water. The Class II-A criteria were used for comparison with site-specific data obtained from the various ground water sampling rounds because the Ground Water Quality Standards (N.J.A.C. 7:9-6.7E) state that the ground water quality criteria to be used for Class III-A aquifers are the most stringent criteria associated with vertically or horizontally adjacent ground waters that are not Class III-A (NJDEP 1999b).

Based on the results of the ground water quality evaluation, no VOCs, SVOCs, pesticides or PCBs were detected in ground water samples collected at M-4 Landfill in concentrations in excess of the NJDEP GWQS. The seven non-native metals that exceeded the NJDEP cleanup criteria were eliminated as COCs in ground water at M-4 Landfill as a result of a comparison between the ground water sampling results, the low-flow sampling results, and the MBCs.

The two VOCs and four metals detected in surface water exceeding the NJDEP SWQS were eliminated as potential COCs in surface water because they are not considered potential COCs in ground water and are therefore not impacting nearby surface water at M-4 Landfill. It is the DPW's contention that the concentrations of the two VOCs and four metals detected exceeding the NJDEP SWQS in the surface water samples are from a source beyond the boundary of Fort Monmouth. Therefore, no VOCs or metals are identified as COCs in surface water at M-4 Landfill.

Based on ground water and surface water analytical results for M-4 Landfill, further remedial investigation activities at the site are not required. Tetra Tech recommends continued ground water and surface water monitoring, in agreement with the fiscal year 2010 Fort Monmouth Base Realignment and Closure (BRAC) Installation Action Plan (BIAP). No Further Action (NFA) is recommended with respect to surface water and ground water at the site.

The surficial soil analytical results indicate concentrations of SVOC and metals detected greater than the NJDEP NRDCSRS and MBCs for the Main Post. To address the exceedances of analytes that did not meet cleanup requirements in the near surface soils, it is recommended that DPW apply an engineering control and/or removal to these areas. Tetra Tech recommends an additional 1 to 1.5 feet of certified clean soil cover (a "soil cap") over the 13 soil boring locations where SVOC and metal concentrations exceed the NRDCSRS at six-to-12 inches bgs. This will provide a total of two-feet of clean soil as a remedial action and engineering control to address the contamination of surficial soils and prevent exposure. This action will be properly designed and constructed to allow proper drainage, to facilitate the growth of vegetation and to ensure that the soil cover is durable. Additionally, it is recommended that hot-spot removals prior to placement of soil cover where surface contamination is found to be one order of magnitude

greater than the NRDCSRS. This remedial action is in agreement with NJDEP's 2010 Regulatory Requirements for Fort Monmouth Landfills (NJDEP, 2010).

In addition, Tetra Tech recommends additional certified clean soil cover over soil boring locations that do not have the minimum two-feet of cover per DEP recommendations. Given the inactive and undisturbed status of the landfill, the performance of long-term surface water and ground water monitoring proximate to the M-4 Landfill, the negligible impacts reported to-date, the lack of ground water use at or downgradient of the M-4 Landfill and the low levels of COCs in the shallow surface soils across the site, Tetra Tech recommends that a deed notice be filed to document the presence of the contaminated soil at M-4.

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