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# FINAL REMEDIAL INVESTIGATION/PUBLIC HEALTH AND ENVIRONMENTAL ASSESSMENT REPORT FORT STORY VA

12/1/1992

JAMES M. MONTGOMERY CONSULTING ENGINEERS

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U.S. Army Corps
of Engineers

Omaha District

# Fort Story, Virginia

*Final Remedial Investigation/Public Health and Environmental Assessment Report for the*

***Remedial Investigation/Feasibility Study***

December 199[illegible]

JMM James M. Montgomery

# ARCHITECT ENGINEER
# FINAL REMEDIAL INVESTIGATION/
# PUBLIC HEALTH AND ENVIRONMENTAL ASSESSMENT

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## LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| A-E | Architect-Engineer |
| APHA | American Public Health Association |
| AR | Army Regulation |
| ARAR | applicable or relevant and appropriate regulations |
| ASTM | American Society for Testing and Materials |
| ATSDR | Agency for Toxic Substances and Disease Registry |
| AWWA | American Water Works Association |
| bls | below land surface |
| BNA | base-neutral and acid extractable compound |
| BTEX | Benzene, Toluene, Ethylbenzene and Xylene |
| BTU | British Thermal Unit |
| CFR | Code of Federal Regulations |
| CGI | combustible gas indicator |
| cm/sec | centimeters per second |
| COC | Chain Of Custody Record |
| DEH | Directorate of Engineering and Housing |
| DO | Delivery Order |
| DOT | Department of Transportation |
| DQCR | Daily Quality Control Report |
| DQO | data quality objectives |
| DSIR | Draft Site Investigation Report |
| EPA | Environmental Protection Agency |
| FID | flame ionization detector |
| ft./day | feet per day |
| FTEGID | Fort Eustis Geotechnical Information Document |
| FTEFARD | Fort Eustis Final Analytical Results Document |
| GC/MS | gas chromatography/mass spectrophotometry |
| gpm | gallons per minute |
| HMA | Helicopter Maintenance Area |
| ID | inside diameter |
| IEC | Installation Environmental Coordinator |
| JMM | James M. Montgomery Consulting Engineers, Inc. |
| MCL | maximum contaminant level |
| MCLG | maximum containment level goal |
| mg/kg | milligram per kilogram |
| mg/l | milligrams per liter |
| MRD | USACE Missouri River Division Laboratory |
| MRL | Method Reporting Level |
| MS/MSD | matrix spike/ matrix spike duplicate |
| NAPL | non-aqueous phase liquid |
| ND | Non-Detect |
| NGVD | National Geodetic Vertical Datum of 1929 |
| NIOSH | National Institute for Occupational Safety and Health |
| NTU | Nephlometric Turbidity Units |
| OD | outside diameter |
| OSHA | Occupational Safety and Health Administration |
| OSO | On-Site Safety Officer |
| OVM | Organic Vapor Meter |
| PA/SI | preliminary assessment/site investigation |
| PCB | polychlorinated biphenyls |
| PID | photoionization device |

| | |
|---|---|
| PM | Project Manager |
| ppm | parts per million |
| PVC | polyvinyl chloride |
| QA/QC | quality assurance/quality control |
| QCSP/FIP | Final Quality Control and Sampling Plan/ Field Investigation Plan, Fort Story and Fort Eustis, Virginia. |
| QCSR | Quality Control Summary Report |
| RCRA | Resource Conservation and Recovery Act of 1976 |
| RI/FS | Remedial Investigation/ Feasibility Study |
| SHERP | Final Safety, Health and Emergency Response Plan, Fort Story and Fort Eustis, Virginia |
| SPT | standard penetration test |
| TFH-H | total fuel hydrocarbons-heavy fraction |
| TFH-L | total fuel hydrocarbons- light fraction |
| TOC | top of casing |
| TOX | total organic halogens |
| USACE | U.S. Army Corps of Engineers |
| USAEHA | U.S. Army Environmental Hygiene Agency |
| USATHAMA | U.S. Army Toxic and Hazardous Materials Agency |
| USCS | Unified Soil Classification System |
| USGS | U.S. Geological Survey |
| USPHS | U.S. Public Health Service |
| UST | underground storage tank |
| UV | ultraviolet |
| VOC | volatile organic compound |
| VWCB | Commonwealth of Virginia, State Water Control Board |
| WPCF | Water Pollution Control Federation |

# Executive Summary

# EXECUTIVE SUMMARY

James M. Montgomery, Consulting Engineers, Inc. (JMM) has completed a Remedial Investigation/Public Health and Environmental Assessment (RI/PHEA) for two project sites at Fort Story, Virginia: Landfill 3 and the Pond Adjacent to Landfill 3. This work was performed under contract to the U.S. Army Corps of Engineers (USACE) for the Directorate of Engineering and Housing (DEH).

This RI/PHEA was intended to characterize surface and subsurface site features; assess contamination in site soils, sediments, surface waters and groundwater; identify probable sources of site contamination; evaluate potential risks to humans and ecological receptors at or near each site; and identify potential site clean-up goals based on available regulations and standards. The major pathways of concern by which people could be potentially exposed to contaminated media for these project sites have been identified to be recreational uses of creeks and lakes and consumption of contaminated fish. Ecological receptors identified in the area include plants, animals and aquatic organisms. Based on risk assessment findings, appropriate recommendations for further action were developed, and are summarized below.

*Landfill 3*

Low concentrations of metals were identified in site groundwater and surface water. In addition, low concentrations of phenol were detected in the surface water. These contaminants were determined to be insignificant and pose no significant human health risks. Environmental impacts to wildlife and aquatic organisms is also insignificant. Therefore, no further investigation or remedial action is recommended for this site.

*Pond Adjacent to Landfill 3*

Contaminants detected in the pond surface water include metals, acetone, chlorides, sulfates and nitrates. The sediment contains low concentrations of metals and cyanide. These contaminants have viable exposure pathways but the hazard indices for the site are considered insignificant. It has been determined that no significant human health or environmental risks exist at this site and no further action is recommended.

# Section 1

## 1.0 INTRODUCTION

James M. Montgomery, Consulting Engineers, Inc. (JMM) is the prime Architect-Engineer (A-E) contracted by the U.S. Army Corps of Engineers (USACE) to perform Remedial Investigation/Public Health and Environmental Assessment (RI/PHEA) evaluations of two project sites at Fort Story, Virginia. Fort Story is located within the Hampton Roads region of southeastern Virginia (see Figure 1-1). The two project sites are Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3.

## 1.1 STUDY OBJECTIVES

The RI/PHEA addresses the components of the U.S. Environmental Protection Agency's (EPA) requirements as stipulated in EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA, 1988b) and is the subject of this report. The objectives of this RI/PHEA evaluation performed for Fort Story project sites are:

- characterize site physical characteristics
- assess contamination in site media
- select potential applicable or relevant and appropriate requirements (ARARs) for use as remedial action goals
- assess risks to human health and the environment

Figure 1-2 presents the major components of the RI/PHEA process, resulting in preparation of the RI/PHEA report.

## 1.2 REPORT ORGANIZATION

Section 2.0 summarizes the field investigation techniques implemented at the two Fort Story project sites. This discussion addresses procedures for monitoring well construction and groundwater sampling, surface water sampling, sediment sampling and in situ permeability testing.

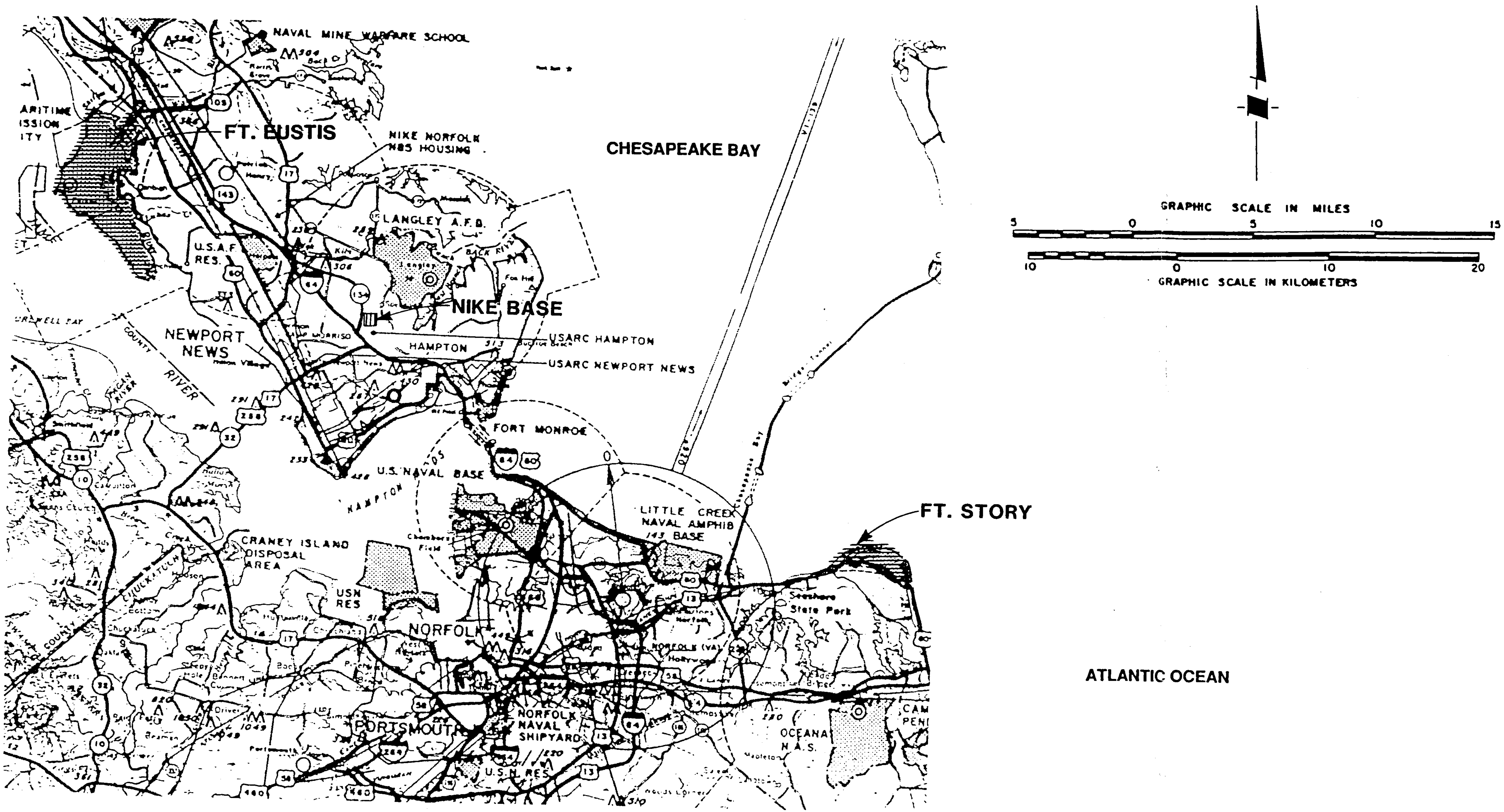
Section 3.0 describes the physical characteristics of the Fort Story Installation and, specifically, of the two project sites. This discussion focuses on climatological, geological, topographical and hydrogeological features.

Section 4.0 discusses applicable or relevant and appropriate requirements (ARARs) available from all pertinent regulations, standards and criteria for contaminated soil, sediment, groundwater and surface water. Based on site features, exposure potentials of compounds of concern, and knowledge of these regulations and criteria, JMM has selected potential ARARs and has identified To-Be-Considered (TBC) material, wherever appropriate.

Section 5.0 discusses the nature and extent of environmental contamination detected at each project site. This includes consideration of historical environmental data as well as data from JMM's RI/PHEA evaluations.

Section 6.0 describes potential transport pathways associated with site contaminants. This discussion focuses on consideration of site sources, site physical features, and physical and chemical properties of the compounds of concern.

Section 7.0 presents the results of a baseline risk assessment performed for Site 3, Landfill 3 (Landfill 3), and Site 3A, Pond Adjacent to Landfill 3 (Pond 3A). This evaluation includes

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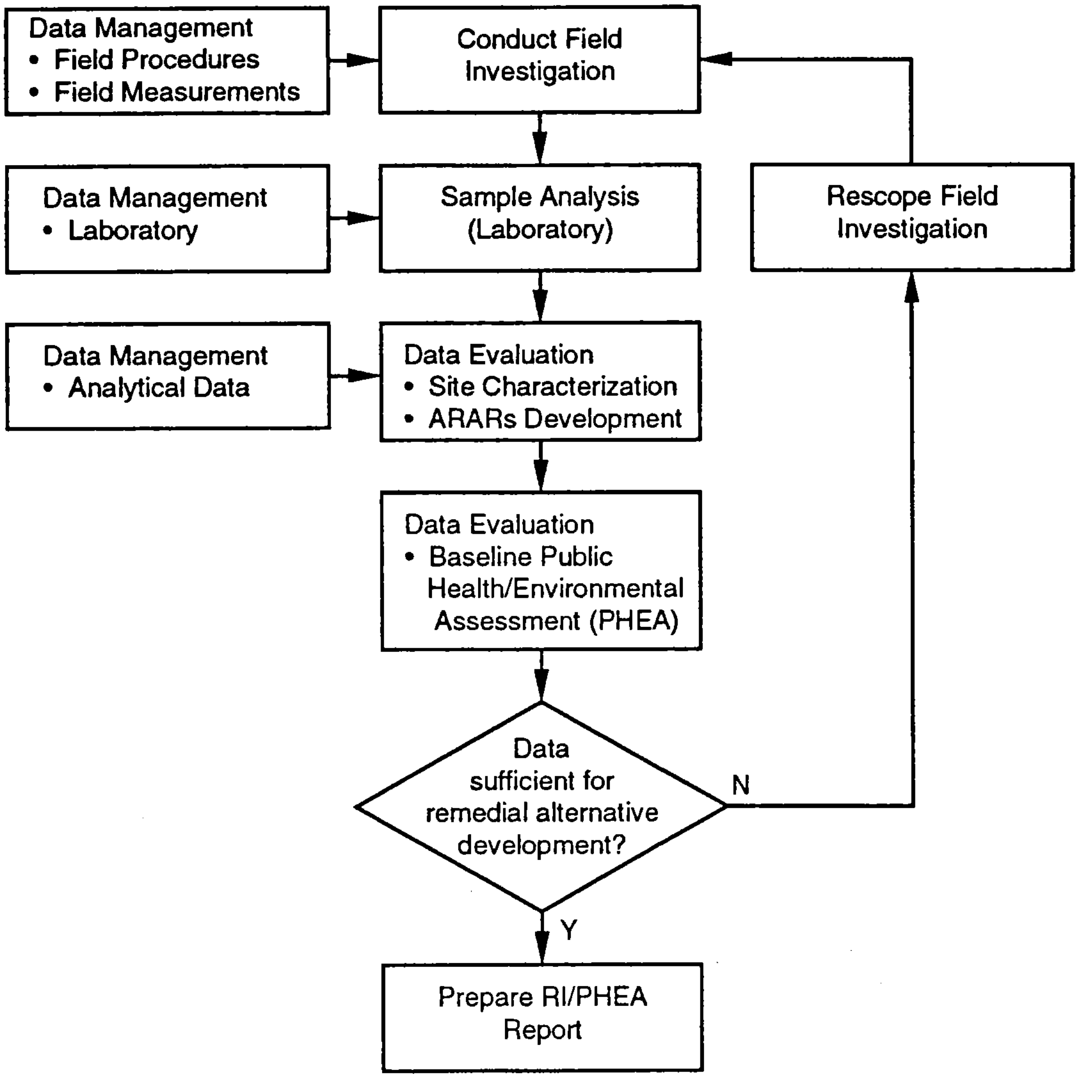
Vicinity Map
Location of USACE Project Installations
Ft. Eustis/Ft. Story

Figure 1-1

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Major Components of the Remedial Investigation (RI)/Public Health and Environmental Assessment (PHEA) Process

Figure 1-2

identification of compounds of concern, exposure pathways and potential receptors, exposure characteristics, health effects data for compounds of concern, and risk computations.

Section 8.0 presents the results of the baseline environmental assessment. This evaluation addresses risk to environmental receptors posed by site contaminants detected at each project site.

Section 9.0 presents conclusions regarding the nature and extent of site contamination and the nature of human health and environmental risks posed by compounds of concern. Then, recommendations for further study necessary for each project site are outlined.

In addition, appendices included with this report present supplemental information:

Appendix A - Geotechnical Information
Appendix B - Results of Previous Site Investigations
Appendix C - Toxicological Profiles of Contaminants of Concern
Appendix D - Exposure Assessment Models
Appendix E - References

## 1.3 SITE BACKGROUND

This report addresses two RI/PHEA project sites at Fort Story, Virginia. The location of these two sites at the Fort Story Installation is presented in Figure 1-3. The following sections present background information for the two sites. Appendix B includes sample locations and analytical results from the previous investigations.

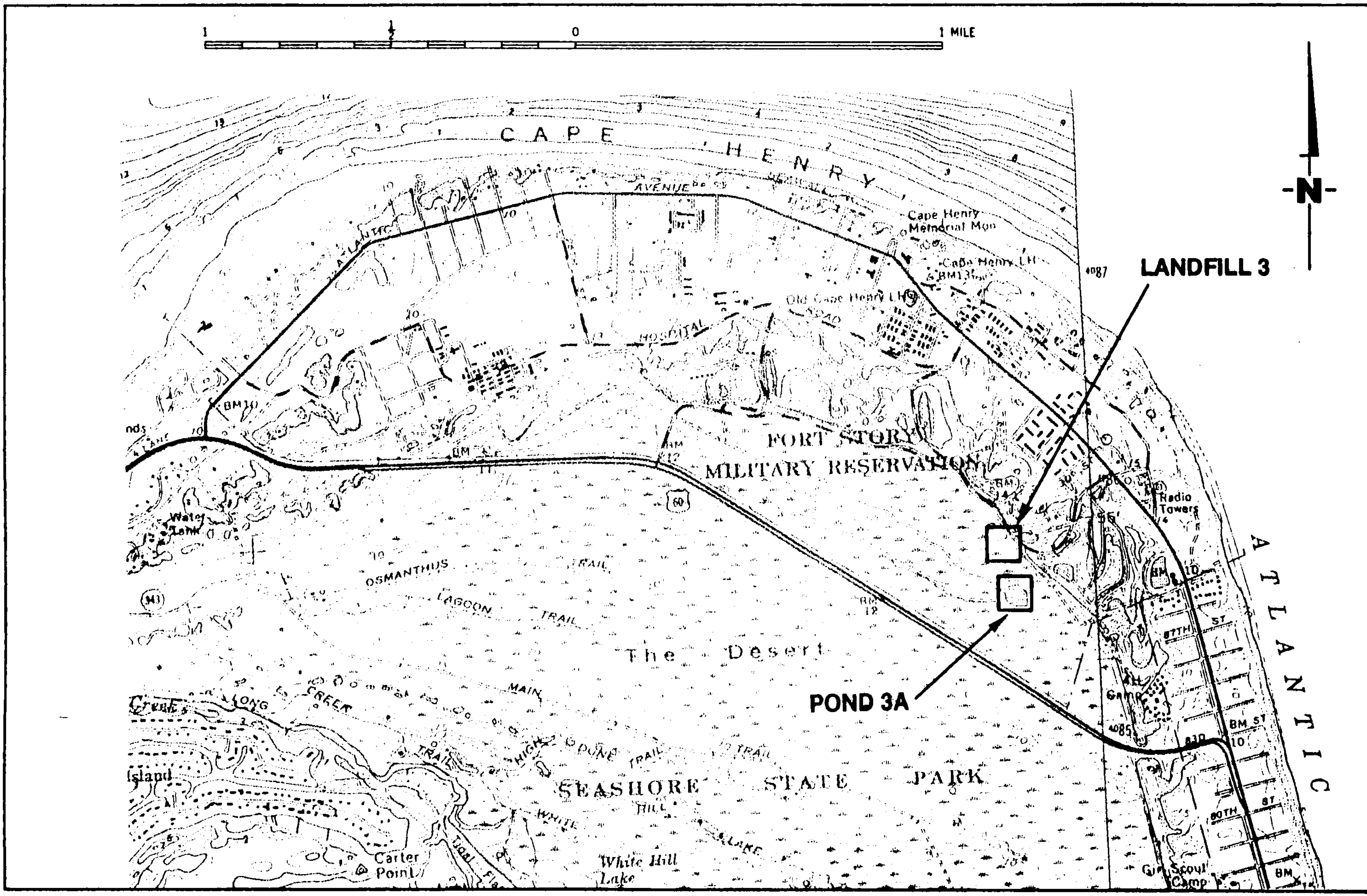
Landfill 3 is a former sanitary landfill operated from 1962 through 1974. The site is located on the southeastern corner of Fort Story along Coast Artillery Road near Building 401. Previous studies, including the installation and sampling of monitoring wells, have been performed at this site.

Landfill 3 is approximately five acres in size, with slight grass cover over the landfill area. Residentail and construction debris were the primary types of wastes buried in the landfill. Empty pesticide containers were reportedly disposed at the landfill which could lead to possible organic contamination of the groundwater. Following the period of landfill operation, a cover was placed over the landfill, but there is no documentation concerning the physical characteristics of the cover. The source of the construction debris was the demolition of barracks formerly located at the Fort Story Block 600 area. Originally this area was abandoned as a flat-land landfill. All existing mounds are debris from Block 600 and small amounts of sand provide additional cover to the area.

In 1977, the U.S. Army Environmental Hygiene Agency (USAEHA) conducted a study that included the installation of three wells: Monitoring Wells (MW) 7, 8 and 9. Analytical data gathered from these wells during this study indicated the presence of zinc, lead, chromium and total organic carbon (TOC). Since the concentrations of these metals were only slightly above the National Interim Primary Drinking Water Regulations (NIPDWR), the USAEHA concluded that their presence did not constitute a health risk.

Pond 3A, is located south of Landfill 3 in the southeastern section of Fort Story along Route 60. This is a man-made pond used initially for recreational fishing.

In 1988, the pond water in Pond 3A was sampled and found to have a pH of 6.7, with a measured total dissolved solids (TDS) content of 140 to 147 milligrams per liter (mg/L) and a turbidity of 8 to 9 nephelometric turbidity units (NTU). Concentrations of iron, lead and zinc were greater than the NIPDWR water quality criteria for fresh water. Also, small traces of DDD and DDE (pesticide constituents) were found in the bank sediments with their presence traced back to past control of mosquitoes in the area (ESE, 1988).

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Project Site Locations
Ft. Story, VA

Figure 1-3

# Section 2

## 2.0 SUMMARY OF INVESTIGATIVE TECHNIQUES

The remedial investigation activities at the Fort Story Remedial Investigation/Public Health and Environmental Assessment (RI/PHEA) project sites involved the assessment of groundwater and surface water contamination at Site 3, Landfill 3, and surface water and sediment contamination at Site 3A, Pond Adjacent to Landfill 3. Five groundwater and three surface water samples were collected from Site 3, and three surface water and five sediment samples were collected from Site 3A. Sampling locations are indicated on Figure 2-1. This section describes the field investigation techniques, including monitoring well (MW) construction procedures and methods used to collect groundwater, surface water and sediment samples. All quality control (QC) related issues, such as field QC procedures and types of QC samples collected, are documented in JMM's *Quality Control Summary Report* (JMM, 1991a).

## 2.1 MONITORING WELL INSTALLATION PROCEDURES

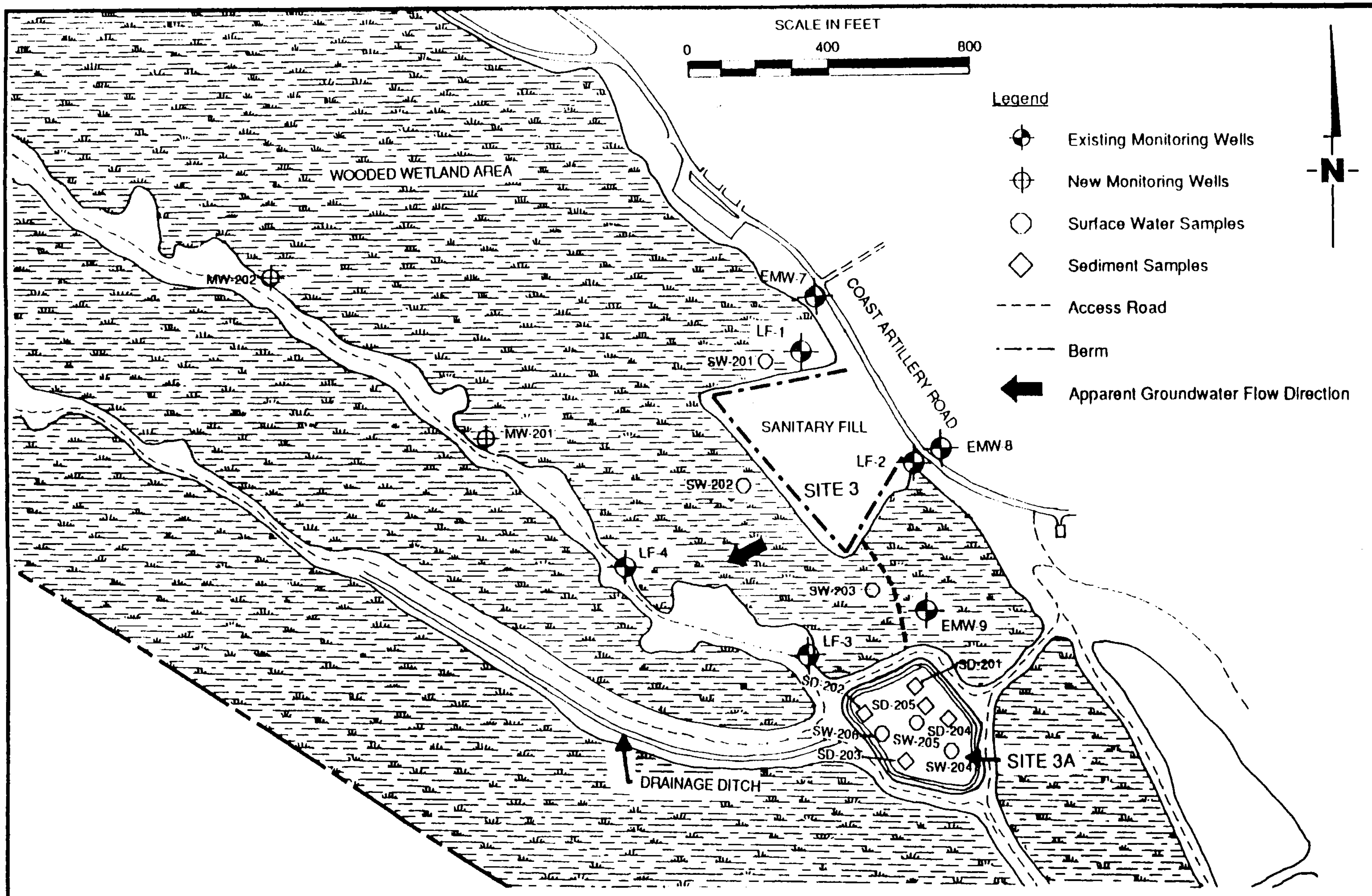
JMM constructed two new MWs, designated as MW-201 and MW-202, at Site 3, Landfill 3. The locations of these MWs are indicated on Figure 2-1. Also indicated on Figure 2-1 are the locations of four MWs, designated as LF-1 through LF-4, constructed by the U.S. Army Environmental Hygiene Agency (USAEHA) during a 1987 investigation (USAEHA, 1987); and three MWs, designated as EMW-7 through EMW-9, constructed by the USAEHA during a 1977 study (USAEHA, 1977). In 1987, USAEHA attempted to sample EMW-7, EMW-8 and EMW-9 for a second round of sampling. During sampling, it was determined that EMW-7 and EMW-8 could not provide sufficient quantites of groundwater for sampling (USAEHA, 1987). Consequently, USAEHA installed four additional groundwater monitoring wells (i.e., LF-1, LF-2, LF-3, and LF-4).

As required by the project Scope of Services, JMM's 1990 field effort included the construction and sampling of two new groundwater monitoring wells (i.e., MW-201 and MW-202) and the sampling of three MWs previously installed by USAEHA. To meet these requirements, the following groundwater monitoring wells that could be identified in the field, were sampled: MW-201, MW-202, LF-1, LF-2 and LF-3. At the time that sampling activities occurred, JMM was not informed of the existence of monitoring well LF-4. Table 2-1 presents the water level and construction data for the MWs installed by JMM (i.e., MW-201 and MW-202) and USAEHA (i.e., LF-1 through LF-4).

### 2.1.1 Monitoring Well Boring Construction Procedures

MW borings were constructed using the hollow-stem auger drilling technique. Hollow-stem augering involves construction of the borehole by simultaneously rotating and axially advancing the auger column into unconsolidated or poorly consolidated formations. The auger flights convey the cuttings produced by the lead auger upward to the surface. Augers with an inside diameter (ID) and an outside diameter (OD) of 4.25 and 8.25 inches, respectively, were used for drilling. Due to the shallow depth of the water table aquifer, MWs installed in low-lying areas were susceptible to problems with heaving sand. During drilling of MW-201, some sandy formation material was observed moving into the auger column. To control this condition, small quanitites of chlorinated water were added to the auger column. The chlorinated water was supplied from the potable water distribution system at Fort Story.

During the construction of MW borings, the auger was advanced to the desired sampling depth, and sampling tools were inserted through the axis of the hollow stem column. At various depths formation samples were obtained to characterize the lithology of the borehole by driving a two-inch diameter split-spoon sampler into the formation materials with a 140-pound hammer. In addition, a geotechnical sample was obtained using the split-spoon sampler from each MW boring, within the zone where water was encountered. Analyses conducted on the geotechnical samples, presented in Appendix A, includes soil particle gradation, moisture content and soil classification.




JMM

Site 3, Landfill 3 and Site3A, Pond Adjacent to Landfill 3
Ft. Story, VA

Sources: USAEHA, 1977 and 1987.

Figure 2-1

## TABLE 2-1

## MONITORING WELL CONSTRUCTION SUMMARY
## RI/FS
## FORT STORY, VIRGINIA

| Well Number | TOC[a] Elevation (ft., NGVD)[b] | Ground Elevation (ft., NGVD) | Total Boring Depth (ft., BLS)[c] | Top of Screen (ft., BLS) | Bottom of Screen (ft., BLS) |
|---|---|---|---|---|---|
| MW-201 | 12.03 | 10.07 | 11.5 | 1.5 | 11.5 |
| MW-202 | 10.77 | 11.01 | 11.0 | 1.0 | 11.0 |
| LF-1 | 20.04 | 16.54 | 15 | 3.2 | — |
| LF-2 | 19.65 | 17.02 | 15 | 2.4 | — |
| LF-3 | 14.04 | 12.04 | 14.5 | 3 | — |
| LF-4 | 16.97 | 13.64 | 15 | 2.4 | — |

(a) TOC- Top of Casing
(b) NGVD- National Geodetic Vertical Datum of 1929
(c) BLS - Below Land Surface

Note: Information above on monitoring wells LF-1 through LF-4 was obtained from data supplied in the USAEHA 1987 report. All four USAEHA monitoring wells were installed using 0.010-inch slot size PVC well screen.

Each soil sample was field screened for detection of volatile organic compounds (VOCs) with a photoionization detector (PID) and classified utilizing the Unified Soil Classification System (USCS). The field geologist recorded lithologic data, PID screening data, standard penetration test (SPT) blow counts, and depths to distinct strata on the appropriate Drilling Logs. Comments describing sampling irregularities and difficulties encountered during drilling also were indicated on the Drilling Logs. Appendix A presents Drilling Logs for MWs installed by JMM as well as USAEHA's 1987 MWs.

The drill rig, drill pipes and sampling equipment were steam cleaned prior to use at each site. All drilling and sampling tools were steam cleaned between individual holes, and the rig was routinely examined for hydraulic fluid leaks. Equipment decontamination procedures are described in Section 2.6. During all drilling operations, air quality in and near the open borehole was monitored using a PID for personnel health and safety purposes.

### 2.1.2 Monitoring Well Construction Procedures

MWs were completed by introducing the well assembly and well gravel pack material through the axis of the auger string. The well assembly consisted of nominal two-inch ID, schedule 40, potable water grade PVC pipe and well screen with flush-joint, threaded couplings. Factory-slotted 0.020-inch screens were utilized in the construction of MW-201 and MW-202. The well screen was placed two feet higher than the depth at which the groundwater was first encountered during drilling to intercept any potential floating product. A closed shoe fitted to the bottom of the well screen prevented the entry of foreign material into the well. PVC glues were not used during well construction.

Gravel pack material No. 2 Morie sand was emplaced around the wells to a depth of 2 feet above the top of the well screen. A two-foot layer of bentonite pellets was installed in the borehole annular space above the gravel pack material. Cement grout with a maximum of three percent bentonite was installed to seal the well to ground level. At locations where the water table was shallow enough to prohibit the specified thicknesses of gravel pack and bentonite pellets, the well design was altered to maximize the thickness of the cement grout seal. An alignment test also was performed on each well. The test consisted of verifying that a 10-foot section of PVC pipe, with an OD one-quarter inch less than the ID of the well casing, could freely pass through the total length of the well. MW-201 was completed above ground, and MW-202 was completed flush with the ground surface. Monitoring Well Summary Sheets that describe the drilling method used, personnel involved, elevations, well design and well materials were prepared for each MW constructed and are presented in Appendix A.

During construction of the MWs, precautions were taken to prevent the entrance of foreign material into the wells. If work on the well was interrupted (e.g., an overnight shutdown), well openings were covered with PVC pipe end caps. After completion of each well, a permanent locking, vented cap was installed. All wells were tagged with a metal identification plate indicating the well number, elevation, total depth and screened interval.

### 2.1.3 Monitoring Well Development Procedures

MWs were developed by air surging and hand bailing to remove fine-grained materials adjacent to the screened interval of the wells. Water generated by well development activities was collected in properly labeled, DOT-approved, 55-gallon drums. Decisions regarding disposal of development water will be based on the presence or absence of contamination as determined by analysis of the groundwater samples collected from the wells.

MW development was performed as a two-phase process consisting of the initial development phase and the final development phase. Initial development of the wells was performed by the drilling subcontractor, under supervision by JMM field geologists, after a minimum of 48 hours had elapsed from the placement of the grout seal. The purpose of the initial development procedure was to ensure that the contractor had provided a viable well capable of producing water in sufficient volume for sampling purposes. Whether a MW was an acceptable water producer was judged by the JMM field geologist, in conjunction with the JMM Field Team Leader, based on professional experience. Initial development for MW-201 and MW-202 was performed by hand bailing instead of air surging to prevent possible damage to grout seals. Development by hand bailing involved plunging a bailer, two-feet in length and one-inch in diameter, up and down within the screened interval.

Final development of wells involved pumping, bailing, or pumping in combination with bailing. At least a 24-hour waiting period ensued between completion of initial well development and initiation of final well development. JMM personnel performed final development, including the periodic monitoring of development water temperature, pH and conductivity. Temperature and pH were determined using an Orion SA 250 temperature/pH meter. A Yellow Springs Instruments Model 33 conductivity/temperature meter was utilized for conductivity measurements. Turbidity measurements were obtained when final development was completed using a LaMotte Model 2008 turbidity meter. All measurements were documented on Monitoring Well Development Sheets; completed sheets are presented in Appendix A. Pumping was performed using a low capacity [0.5-2 gallons per minute (gpm)], gasoline-powered centrifugal pump. Intermittent bailing during final development pumping removed any sediment that passed through the well screen during pumping.

At least as much water that was introduced into the well during construction was removed from the well during development, including initial and final development. A minimum of five well volumes (including filter pack volume) were withdrawn. Section 2.2 discusses the calculation of well volumes. The well was considered developed if the measured parameters had stabilized after withdrawal of the necessary well volumes and the water was clear (i.e., visibly free of sand or sediment). The development process took a minimum of 4 hours per well. Development continued after the minimum quantity of water was withdrawn if the measured parameters did not stabilize to within 10 percent or the water was cloudy. If the water was still cloudy at the end of 8 hours but the water temperature, pH and specific conductance had stabilized to within 10 percent, the well was considered developed.

### 2.1.4 Groundwater Level Measurement Procedures

A Marine Moisture Flexidip product/water level indicator was used to obtain static water level measurements from each MW installed for this project. Measurement of the static water levels was performed prior to purging for groundwater sample collection. Two additional static water level measurements were performed, each within a 24-hour period. The first set of measurements were taken on June 11, 1990 and included measurements of water levels in MW-201 and MW-202. The second set of measurements occurred on August 31, 1991 and included measurements of water levels in MW-201 and MW-202, as well as LF-2 through LF-4. Well LF-1 could not be located during the second round of measurements. Table 2-2 presents the results of both rounds of static water level measurements.

## 2.2 GROUNDWATER SAMPLING PROCEDURES

JMM sampled wells MW-201, MW-202 and USAEHA-installed wells LF-1, LF-2 and LF-3. MWs were sampled by determining the volume of water contained in the well, purging the required number of well volumes, measuring the variation of field parameters during purging, and collecting the groundwater samples. The well volume for each MW is the volume of water contained in the well screen, casing and gravel pack material as constrained by the measured static water level and total depth of the well. The purge volume is the number of well volumes required to be pumped from a well prior to collecting the groundwater samples. The *Final QCSP/FIP*

## TABLE 2-2

## MONITORING WELL WATER ELEVATION SUMMARY
## RI/FS
## FORT STORY, VIRGINIA

| Location Number | TOC Elevation (ft., NGVD) | 6/11/90 Depth to Water (ft., BTOC) | 6/11/90 Water Elevation (ft., NGVD) | 8/31/91 Depth to Water (ft., BTOC) | 8/31/91 Water Elevation (ft., NGVD) |
|---|---|---|---|---|---|
| MW-201 | 12.03 | 4.1 | 7.9 | 4.64 | 7.39 |
| MW-202 | 10.77 | 2.8 | 8.0 | 3.30 | 7.47 |
| LF-1 | 20.04 | — | — | — | — |
| LF-2 | 19.65 | — | — | 9.40 | 10.25 |
| LF-3 | 14.04 | — | — | 3.97 | 10.07 |
| LF-4 | 16.97 | — | — | 6.99 | 9.98 |

NGVD - National Geodetic Vertical Datum of 1929
TOC - Top of Casing
BTOC - Below Top of Casing
BLS - Below Land Surface

(JMM, 1990a) specifies that the purge volume from all MWs sampled for the project be equivalent to three well volumes.

Well volumes were calculated as the product of a well volume factor and the length of submerged well footage. The well volume factor represents the quantity of water contained per linear foot of submerged well (including well screen, casing and gravel pack). Calculations based on an 8.25-inch diameter borehole, two-inch casing diameter, and an assumed porosity of 30 percent for the gravel pack material produce a value of 0.95 gallons per foot for the well volume factor used in well volume calculations for Fort Story MWs installed by JMM. Because of uncertainty regarding the borehole diameters for MWs constructed by USAEHA, the borehole diameter was conservatively estimated at 12 inches. The well volume factor calculated using a 12-inch diameter borehole, two-inch casing diameter, and an assumed gravel pack porosity of 30 percent is 1.88 gallons per foot. Therefore, a well volume factor of 1.88 gallons per foot was utilized for calculating the well volumes of the USAEHA-installed wells.

Measurements of the static water level and total depth of each MW were required for the calculation of the respective well volumes. Water level and total depth measurements were obtained using a Marine Moisture Flexidip product/water level indicator. This device was decontaminated between MWs according to the procedures described in Section 2.6. Through visual displays and audible signals, the Flexidip has the capability to indicate the air/non-aqueous phase interface and the non-aqueous/aqueous phase interface. Depth to floating product (if present), depth to water and total well depth, and respective purge volume were recorded on the Groundwater Sampling Logs. Appendix A contains Groundwater Sampling Logs completed for MW-201, MW-202, LF-1, LF-2 and LF-3. The Groundwater Sampling Logs for LF-1, LF-2 and LF-3 were incorrectly labeled as EMW-7, EMW-8 and EMW-9 in Appendix A. The labels were corrected by JMM and initialized.

Purging of the MWs was performed using a Teflon bailer, measuring 1 inch in diameter and 3 feet in length. Sterile nylon cord was used to lower and withdraw the bailer from the wells. The nylon cord was discarded following the sampling of each well. Bailing obtained a discharge rate of approximately 2.0 gpm. Purge water was contained in appropriately labeled, DOT-approved 55-gallon drums. Upon completion of sampling activities at each site, the purge water drums were transported to a temporary containment area on the Installation. Based on the analytical results from the groundwater samples obtained from each well, the contents of the respective drums will be either disposed of at the Installation or stored at the Installation for eventual off-site disposal.

During purging operations, periodic field measurements of purge water temperature, pH and conductivity were obtained. Temperature and pH were determined using an Orion SA 250 pH meter. A Yellow Springs Instruments Model 33 conductivity meter measured purge water conductivity. The measurements were obtained at each well with the initiation of purging and periodically thereafter as each well volume was withdrawn. Each measurement obtained was recorded on the Groundwater Sampling Log for the given well and sampling event. Appendix A presents these logs. Purging of the Fort Story MWs required between three and five rounds of measurements, including a round at the end of purging activities. Additionally, a PID scan of the final purge water sample assessed the presence of volatile organic compounds (VOCs).

Following the withdrawal of the specified purge volumes, groundwater samples were obtained from the wells. The Teflon bailer was used to collect groundwater samples. Groundwater samples were collected for the analysis of VOCs, base/neutral/acid extractable compounds (BNAs), pesticides/polychlorinated biphenyls (pesticides/PCBs), total metals, dissolved metals, cyanide and inorganics. Samples collected for dissolved metals analysis were filtered in the field using a 0.45-micron filter. A sufficient sample volume was collected in a decontaminated two-liter amber glass bottle. The sample was transferred through the filter and into the appropriate sample containers using a peristaltic pump and polyethylene tubing. The pump and Teflon bailer were decontaminated following the collection of each groundwater sample. However, the polyethylene tubing and filter were discarded after each sample was collected.

## 2.3 IN SITU PERMEABILITY TESTING PROCEDURES

In situ permeability (slug) tests were performed in each of the wells installed for this project (i.e., MW-201 and MW-202) to provide information regarding the general magnitude of the hydraulic conductivity of the aquifer materials at the site investigated. The slug testing procedure included the use of enclosed one-inch diameter, stainless-steel bars of three-foot and six-foot lengths to displace a known volume of water in the wells. Water level changes in the well were measured using a 5 pounds per square inch gage (psig) pressure transducer and data logger. The bars, with all measuring tapes, water level indicators, pressure transducer and data logger used in the testing, were decontaminated between wells according to the procedures described in Section 2.6.

At the beginning of each slug test, the static depth to water and the total depth of the well were determined. The pressure transducer was inserted into the well, and the data logger was configured for direct reading of the transducer. Based on the water column thickness in the well, either the three-foot or six-foot slug bar was submerged in the well water column. After placement of the bar, the transducer water level was observed continually to monitor the return of the well water level to the measured static level. After the attainment of static conditions in the well with the slug bar in place, the bar was rapidly withdrawn and at that instant the data logger began recording water level data. Data collection continued until groundwater levels in the well had stabilized to the observed static water level. Slug test data collected using this procedure were compiled and analyzed using the Bouwer and Rice method (Bouwer and Rice, 1976 and Bouwer, 1989). The method is valid for use in wells that partially penetrate an unconfined aquifer and are screened through the water table, characteristics of the wells installed for this project. Compiled and analyzed slug test data is discussed further in Section 3.

## 2.4 SURFACE WATER SAMPLING PROCEDURES

Three surface water samples were collected from areas outside the boundaries of Landfill 3, where standing water was present. Figure 2-1 shows the locations of these samples, designated as SW-201 through SW-203. In addition, three surface water samples were collected from Site 3A, Pond Adjacent to Landfill 3. Figure 2-1 shows the locations of these samples, designated as SW-204 through SW-206..

Surface water samples were collected and analyzed for VOCs, BNAs, pesticides/PCBs, total metals, cyanide and inorganics. Surface water samples at Site 3 were collected by directly filling sample containers. At each designated sampling point, the first sample collected was submitted for VOC analysis. This sample was obtained as a grab sample by immersing the VOC sample vial directly into the surface water and allowing the vial to fill. This process was done carefully to minimize disturbance of the surface water. The remaining sample containers (i.e., for the analysis of BNAs, pesticides/PCBs, total metals, cyanide and inorganics) were filled from a composite sample. The composite sample was collected by lowering a decontaminated two-liter amber glass bottle into the surface water and allowing the bottle to fill by immersing the bottle's lip and slowly tilting the bottle upright. After the composite sample was transferred to the appropriate sample containers submitted for analysis, the two-liter amber glass bottle was decontaminated according to procedures described in Section 2.6.

A point source Teflon bailer was lowered from a 16-foot Jon boat to collect surface water samples at Site 3A. At each of the three locations, JMM collected grab samples of surface water at one-third and two-thirds the total depth of the pond. Following collection, the two grab samples from each sampling location were composited for analysis. VOC sample vials were filled from the first grab sample prior to compositing. The point source bailer was then decontaminated prior to the next location.

## 2.5 SEDIMENT SAMPLING PROCEDURES

Five sediment samples, designated as SD-201 through SD-205, were collected from Site 3A using a Vibracore sampling rig. Figure 2-1 shows the locations of these samples. A barge was fabricated on-site to provide a means of accessing sampling points with the Vibracore sampling rig. Vibracore sampling was performed by driving a 16-foot long, two-inch diameter aluminum sampling tube into unconsolidated sediments. Using the equipment to create a vibrating motion, the sampling tube was driven to a depth of 10 feet below the pond bottom. The sample tube was retrieved and placed on plastic sheets.

With minimal disturbance to the sediment sample, the core was carefully sheared open using a metal cutting tool. One-foot increments were delineated on the recovered sample. Using a stainless-steel spatula, the recovered sediment core was parted at one-foot intervals. Immediately after parting the sample, a PID was used to scan the intervening air space. The core interval exhibiting the highest PID reading was selected as the location for collecting a VOC grab sample.

After sampling for VOCs, the remainder of the core was composited in a stainless-steel mixing bowl for the collection of samples for the remaining analytes. Samples of the composited sediments were collected for analysis of BNAs, pesticides/PCBs, total fuel hydrocarbons - heavy fraction (TFH-H), metals, EP Toxicity metals, cyanide and inorganics. Between sampling points, the spatula and mixing bowl were decontaminated according to procedures described in Section 2.6. In addition, new sampling tubes, which were free of contamination, were utilized at each sampling point. After the collection of each sample, used sampling tubes were discarded.

## 2.6 EQUIPMENT DECONTAMINATION PROCEDURES

Strict decontamination procedures were followed during drilling and sampling activities to prevent cross-contamination. Before use, all drilling and sampling equipment was decontaminated by steam cleaning or by an Alconox wash, a tap water rinse, a methanol rinse and a double distilled water rinse. The drill pipe and drill tools were steam cleaned prior to drilling each boring. Sampling equipment, including split-spoon samplers, hand augers, stainless-steel mixing bowls and stainless-steel mixing utensils, was cleaned using the Alconox wash procedures. Decontamination activities were conducted at each site. Decontamination water from the sampling equipment was containerized at each site and handled as discussed in Section 2.1.3.

Samples of the source water used for decontamination activities were not collected during the RI/FS field investigation. This source water consisted of distilled water obtained from Water and Health, Inc., and potable water that was available at the Installation. The results of source water analyses are generally used to determine whether contamination was introduced through the sample collection procedures as a result of poor source water quality. The same source water, however, was used during the PA/SI activities at the LACV-30 Wetlands Maintenance Facility (i.e., the distilled water was obtained from the same vendor and the potable water from the same location as for this project). Samples of potable water and distilled water were collected for this project and analyzed for VOCs, BNAs, pesticides/PCBs, total metals and dissolved metals. Therefore, the results presented in the *Analytical Results Report for the Preliminary Assessment/Site Investigation LACV-30 Maintenance Facility Wetlands Area* and the *Site Investigation/Decision Plans and Specifications for Underground Storage Tank Removal Atlantic Street Gas Station, Fort Story, Virginia* (JMM, 1991b) for Installation water and distilled water samples should provide a general indication of the quality of the source water used for the earlier projects.

Table 2-3 contains a summary of the results from the source water samples. Chloroform and dichlorobromomethane were detected in the distilled and Installation tap water samples. These compounds are known chlorinated byproducts from the water treatment process. Zinc was detected in the total metals and dissolved metals analyses of tap water available from the Installation.

## TABLE 2-3

## SOURCE WATER ANALYTICAL RESULTS

| Type of Source Water | Analysis | Compound | Concentration |
|---|---|---|---|
| Distilled | VOC | Chloroform | 68 µg/l |
| Distilled | VOC | Dichlorobromomethane | 14 µg/l |
| Tap Water[(a)] | VOC | Chloroform | 74 µg/l |
| Tap Water | VOC | Dichlorobromomethane | 13 µg/l |
| Tap Water | Total Metals | Zinc | 0.66 mg/l |
| Tap Water | Dissolved Metals | Zinc | 1.0 mg/l |

(a) Tap water samples were collected from the Fort Story Installation.

## 2.7 HEALTH AND SAFETY ACTIVITIES

JMM developed a *Final Safety, Health and Emergency Response Plan (SHERP)* (JMM, 1990b) to provide guidelines and stipulate procedures for protecting site personnel and the environment during the investigation. The requirements outlined in the *SHERP* were followed by all personnel on the site during the field program.

An exclusion zone was established around all work areas. Traffic cones and construction ribbon delineated the exclusion zone. All personnel working on site had fulfilled the training requirements specified in *Hazardous Waste Operations and Emergency Response*, 29 CFR 1910.120 (OSHA, 1989).

A PID meter monitored the presence of organic vapors potentially emanating from the soil samples, the borehole, and in the breathing zone of the workers. Hearing protection was always available. All personnel wore hardhats, steel-toed boots and nitrile gloves when handling any drill cuttings, soil samples or groundwater.

All intrusive activities at Fort Story were conducted in Level D personal protective equipment (PPE). Although JMM was prepared to do work in Level C PPE, PID readings taken during the work effort did not exceed the permissible levels for Level D conditions as delineated in the *SHERP*.

## 2.8 SURVEYING ACTIVITIES

The two newly installed MWs at Site 3 (i.e., MW-201 and MW-202) were surveyed to establish horizontal and vertical locations. The horizontal coordinates were surveyed from permanent site features using the Commonwealth of Virginia State Plane Coordinate System. The horizontal control was established to the nearest 0.5 foot. Vertical control was established using differential and trigonometric leveling to the nearest 0.1 foot and referenced to the National Geodetic Vertical Datum of 1929 (NGVD). Top of pipe elevations were also surveyed, with vertical control within 0.01 foot. Differential leveling for elevation measurements was conducted using a surveying quality level and rod. Trigonometric elevations were obtained with an electronic theodolite total station. Table 2-4 contains the surveying results.

## TABLE 2-4

## SURVEYING RESULTS - SITE 3, LANDFILL 3, MONITORING WELLS FORT STORY, VIRGINIA

| Location | Ground Elevation (ft., NGVD)(c) | TOC(b) (ft., NGVD) | VSPCS(a) | |
|---|---|---|---|---|
| | | | Northing | Easting |
| MW-201 | 10.07 | 12.03 | 221719.9210 | 2728432.1030 |
| MW-202 | 11.01 | 10.77 | 222165.9820 | 2727831.2500 |

(a) VSPCS- Commonwealth of Virginia State Plane Coordinate System
(b) TOC- top of casing
(c) NGVD- National Geodetic Vertical Datum of 1929

# Section 3

## 3.0 INSTALLATION-WIDE CHARACTERISTICS

Fort Story is located in the City of Virginia Beach in southeastern Virginia. JMM's Remedial Investigation/Public Health and Environmental Assessment (RI/PHEA) project sites, Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3, are located in the southeast portion of the Fort Story Installation. Virginia Beach is located in the Hampton Roads region of southeastern Virginia, which is included in the coastal tidewater portion of the Atlantic Coastal Plain physiographic province. Occupying an area of approximately 1,450 acres, Fort Story is situated on Cape Henry, which roughly divides the waters of the Chesapeake Bay to the north from those of the Atlantic Ocean to the east. Section 3.3 contains a site-specific description of the Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3, characteristics.

### 3.1 CLIMATE

The climate of the Fort Story area is a maritime-type climate characterized by an average annual temperature of 60 degrees Fahrenheit (60° F). Winters are typically mild, with temperatures averaging 42° F. During the summer months, temperatures average 77° F and the maximum daily temperatures average 85° F. Average annual precipitation is 45 inches; 25 inches of which is received from April through September. Annual snowfall averages 7.3 inches. Convective thunderstorm activity in the summer is a significant component of precipitation. Though the region lies north of the typical hurricane and tropical storm track, annual precipitation is occasionally augmented by the local passage of these storm events [Environmental Science and Engineering (ESE), 1988].

### 3.2 HYDROGEOLOGY

The Virginia Coastal Plain sediments consist of an eastward thickening wedge of generally unconsolidated, interbedded sands and clays with minor occurrences of gravel and shell fragments. Within the Fort Story area, the sediments exceed 3,500 feet thick and are underlain by crystalline basement rocks (Lloyd, et al., 1985). Utilizing well data from the region, Meng and Harsh (1988) determined the distribution of the principal aquifer units within these sediments. Their analyses indicated that the hydrogeologic framework of the coastal plain sediments within the Fort Story vicinity consists of a system of six aquifer units separated by intervening semi-confining units. In order of increasing depth from ground surface, these aquifers include (Meng and Harsh, 1988):

- The Columbia Aquifer, which is the water table aquifer, comprised of undifferentiated Holocene age sediments;
- The Yorktown-Eastover Aquifer, which occurs within the Yorktown and Eastover formations of Pliocene and Miocene Age, respectively;
- The Chickahominy - Piney Point Aquifer, which occurs within the Chickahominy and Piney Point formations of Eocene Age and the Old Church Formation of Oligocene Age, where present ; and
- The Upper, Middle, and Lower Potomac Aquifers, which occur within the Potomac Group of Cretaceous age.

The Columbia, Yorktown - Eastover, and Chickahominy - Piney Point Aquifers and intervening semi-confining units comprise roughly the upper one-quarter of the total thickness of the coastal plain sediments in the Fort Story area. The remaining sediment thickness consists of the Upper, Middle and Lower Aquifers and intervening semi-confining units that comprise the Potomac Group. Groundwater chloride concentrations exceed 5,000 milligrams per liter (mg/l) at a depth of approximately 900 feet below land surface (bls) in the Fort Story vicinity (Lloyd et al., 1985). The shallower aquifers, including the Columbia, Yorktown - Eastover, Chickahominy - Piney Point, and Upper Potomac Aquifers, are characterized by transmissivities of less than 50,000 gallons per day per foot (gpd/ft). Transmissivities in the range of 50,000 to 100,000 gpd/ft are estimated for the Middle and Lower Potomac Aquifers (Lloyd et al, 1985).

Meng and Harsh (1988) indicate that the thickness of the Columbia Aquifer in the Fort Story area is approximately 120 feet. The Columbia Aquifer is separated from the underlying Yorktown - Eastover Aquifer by the Yorktown semi-confining layer, which has an approximate thickness of 40 feet. The lithology of the Columbia Aquifer is characterized primarily as Holocene beach sand and nearshore marine sand, which commonly contains pebbles, shell fragments and blocks of coquinite (Johnson, 1972). The underlying Yorktown semi-confining unit is comprised of the upper portion of the Yorktown formation and described as marine silt with occasional interbeds of fine sand and coquina (Johnson, 1972).

The Yorktown - Eastover Aquifer underlies the Yorktown confining unit and is encountered between depths of approximately 160 and 440 feet (bls). The depths to the tops of the Chickahominy - Piney Point Aquifer and the Upper Potomac Aquifer are approximately 810 and 1,130 feet bls, respectively. The respective thicknesses of these aquifers in the Fort Story area are 140 and 220 feet. Meng and Harsh (1988) indicate that insufficient data are available in the Fort Story vicinity for direct characterization of the thicknesses of the Middle and Lower Potomac Aquifers from well data.

## 3.3 SITE SPECIFIC CHARACTERISTICS

This section discusses specific site descriptions of the topography, stratigraphy and hydrogeology. Appendix A presents further relevant geologic data.

### 3.3.1 Topography

Land features encountered at Fort Story consist of linear sand ridges, sand flats and wetland areas. A series of prominent linear, well-drained sand ridges that roughly bisect the Fort Story area dominates the topography. The central ridges trend parallel to the coastline and are characterized by maximum elevations exceeding 85 feet, National Geodetic Vertical Datum of 1929 (NGVD). A second series of sand ridges located on Fort Story are comprised of an active dune complex located adjacent to the coastline. The coastal sand ridges attain maximum elevations over 25 feet NGVD. Broad, poorly drained sand flats are located adjacent to the sand ridge areas. Land surface elevations in the sand flat areas typically range between 5 and 10 feet, NGVD. South of the central sand ridges, the Fort Story topography consists of an extensive wooded wetland area, formerly a back-bay lagoonal feature which is the northeastern section of the wetlands ecosystem that comprises Seashore State Park. Most of the Installation's facilities and operations are confined to the sand ridge and sand flat areas.

**3.3.1.1 Site 3, Landfill 3.** Site 3, Landfill 3, is located adjacent and south, southwest of the central sand ridge in the southeast portion of the Fort Story Installation. The landfill is topographically lower than the central sand ridge but topographically higher than the surrounding wooded wetland area. This wetland area is a small segment of the wetland ecosystem that extends into Seashore State Park. Its surface is relatively level with some grassy vegetation and bermed on the perimeter. The bermed area contains some debris piles. Access to the landfill can be gained from the Coast Artillery Road on the northern side or on the southern side by a road between the landfill and pond cutting through the wetland area. Figure 2-1 shows the locations and features of Sites 3 and 3A.

**3.3.1.2 Site 3A, Pond Adjacent to Landfill 3.** Site 3A, Pond Adjacent to Landfill 3, is a five-acre man-made freshwater pond located south of the closed landfill and initially intended for recreational fishing (USAEHA, 1977). The sandy roads leading up to and surrounding the pond, except the road between the landfill and pond, represent topographic highs in relation to the surrounding wooded wetlands area. Access to the pond can be gained by these roads.

### 3.3.2 Site Stratigraphy

The landfill and pond sites are underlain by Holocene Age sand deposits. Based on soil and monitoring well (MW) borings from work performed by JMM in 1990 and work by the USAEHA in 1987 (USAEHA, 1987), the sand deposits are medium to fine grained, subangular to subrounded and mostly well sorted with some poorly sorted silty lenses. Further, the USAEHA's boring log for MW-LF-3, near the man-made five-acre pond, indicates the presence of organic material 8 feet below land surface. This is typical for a former back bay, lagoonal environment (USAEHA, 1977; USAEHA, 1987). Appendix A provides lithologic boring logs and grain-size distribution graphs from analyses performed on geotechnical soil samples from the screened interval of the two monitoring wells installed by JMM.

### 3.3.3 Site Hydrogeology

The hydrogeology of the Landfill 3 and Pond 3A sites was evaluated based on the review of lithological boring logs, groundwater elevation obtained from site monitoring wells, review of background literature, and in situ permeability tests. During this evaluation, JMM determined that site location maps for Landfill 3 previous project deliverables (JMM, 1990a and JMM, 1990c) did not adequately present the spatial distribution of monitoring well locations. Site maps for previous JMM reports were completed prior to receipt of project survey data. The survey data for monitoring wells MW-201 and MW-202 provide horizontal and vertical control with respect to the Virginia State Planar Coordinate System (VSPCS) and elevations of the monitoring well's top of casing were reported using the National Geodetic Vertical Datum of 1929 (NGVD). The survey data for monitoring wells installed by USAEHA only provide the elevations with respect to NGVD. Using the relevant portion of the General Site Map, Fort Story, Virginia (March 1986), and available survey data, a revised site location map (presented in Figure 2-1) was prepared. Because the exact locations of monitoring wells installed by USAEHA with respect to VSPCS were approximated based on field observations, the delineation of the hydraulic gradient across the sites may contain marginal error. Nevertheless, a reasonably accurate determination of general groundwater flow trends across Landfill 3 and Pond 3A can be obtained using the groundwater elevation data (which are presented in Table 2-2).

Topographic relief in this area plays a major role in defining shallow groundwater flow direction. The water table in the vicinity of Sites 3 and 3A appears to roughly mimic local ground surface gradient changes, which is typical for shallow, unconfined aquifer systems. Groundwater elevations obtained in August 1991 (Table 2-2) indicate that groundwater is flowing from the central sand ridge area in a west-southwest direction toward the low-lying wetlands area. The groundwater flow direction arrow on Figure 2-1 shows that groundwater flow is from the landfill in a direction away from the pond, which suggests no landfill leachate - pond interaction.

Groundwater discharge to the wetlands area is most likely occurring, based on the fact that the wetlands lie in a topographically low region with an elevation estimated to be below or equal to the nearby groundwater elevations. Typically, for conditions such as these, there is a location where the water table intersects the ground surface to form a groundwater discharge. It is important to note that the occurrence of groundwater discharge to the wetlands is dependent on the position of the water table relative to the ground surface elevation. Periods of low precipitation could cause the water table to drop below the surface of the wetlands, and thus cause the hydraulic gradient to stagnate or be reversed as surface water recharges the underlying aquifer system. These changes in hydraulic gradient are also impacted by tidal influences on groundwater elevations. Due to the uncertainty associated with the impact of rain-related infiltration or tidal influences, any variations in the localized groundwater gradient can not be determined. The short duration of any changes, however, is not expected to impact upgradient receptors or wells designated as upgradient locations.

In situ permeability tests were performed on groundwater MW-201 and MW-202, installed west of Landfill 3 and screened in the upper portion of the Columbia Aquifer. Hydraulic conductivity (K) was calculated using the Bouwer and Rice method, which is valid for slug tests performed in wells partially penetrating an unconfined aquifer (Bouwer and Rice, 1976; Bouwer, 1989). A summary of these values is presented in Table 3-1. The software used to derive K employed an additional three methods: the Hvorslev method (1951), the Cooper, Bredehoeft and Papadopolous method (1967), and the Ferris and Knowles method. However, the Bouwer and Rice method was considered the most appropriate for the aquifer conditions at this site. However, due to the very limited amount of drawdown produced by slug test procedures and the very fast recovery, the calculated K values are only qualitative indicators of the aquifer characteristics in the immediate vicinity of the wells. Therefore, each individual value for a well does not necessarily reflect area-wide aquifer properties. The estimated K values determined for these wells are consistent with ranges estimated for typical unconsolidated sand deposits (Kruseman and de Ridder, 1983; Fetter, 1980). Appendix A provides a summary of the information used to develop these K values, including raw data, graphs and calculation results.

## TABLE 3-1

## IN SITU PERMEABILITY TEST RESULTS SUMMARY
## RI/FS
## FORT STORY, VIRGINIA

| Well Number | Hydraulic Conductivity (ft./min.) | (ft./day) | (m/day) |
|---|---|---|---|
| MW-201 | $4.61 \times 10^{-3}$ | 6.64 | 2.02 |
| MW-202 | $1.46 \times 10^{-2}$ | 21.02 | 6.41 |
| Average Value | $9.60 \times 10^{-3}$ | 13.83 | 4.22 |

# Section 4

## 4.0 POTENTIALLY APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Section 121(d) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the 1986 Superfund Amendments and Reauthorization Act (SARA), requires that on-site remedial actions must attain (or waive) federal and more stringent state applicable or relevant and appropriate requirements (ARARs) of environmental laws upon completion of the remedial action. The revised National Contingency Plan of 1990 (NCP) requires compliance with ARARs during remedial actions as well as at completion, and compels attainment of ARARs during removal actions to the extent practicable (EPA, 1991a).

Applicable requirements are standards or criteria promulgated under federal or state law that specifically address a hazardous substance pollutant contaminant, remedial action, location or other circumstance at a project site. Applicable requirements are directly translatable to environmental concerns at a project site (EPA, 1988b).

Relevant and appropriate requirements are standards or criteria promulgated under federal or state laws that are suited to the particular site because they address site problems sufficiently similar to those on which the regulations are based. For example, maximum contaminant levels (MCLs) promulgated under the Safe Drinking Water Act (SDWA) would not be considered applicable to a project site where the site groundwater has no potential as drinking water. However, MCLs might be considered relevant or appropriate requirements if the groundwater could be used for drinking water or if the site groundwater discharges to surface waters that could be used to supply drinking water. (EPA, 1988b).

Identification of ARARs first requires determination whether a given requirement is applicable; then, if it is not applicable, a determination whether it is both relevant and appropriate. This evaluation compares a number of site-specific factors, including the hazardous substances present at a site, physical site features, or the type of remedial action; with those addressed in the statutory or regulatory requirements. A given requirement might be relevant, but not appropriate, for the project site; such a requirement would not be ARAR for the site. When a requirement is deemed both relevant and appropriate in a given case, this requirement must be complied with to the same degree as if it were applicable.

To-be-Considered Material (TBCs) are non-promulgated advisories or guidance issued by federal or state government that are not legally binding and do not have the status of potential ARARs. In many circumstances, TBCs will be considered along with ARARs in determining a site cleanup level that is sufficiently protective of human health and the environment.

There are several different types of ARARs, including chemical-specific, action-specific, and location-specific ARARs. Chemical-specific ARARs are usually health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numerical values. These values establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the ambient environment.

Action-specific ARARs are technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes.

Location-specific ARARs are restrictions placed on the concentration of hazardous substances or the conduct of activities solely because they occur in special locations.

In this evaluation, JMM identifies chemical-specific ARARs based on site characterization information. Location-specific and action-specific ARARs will be identified at a later stage during the Pre-Feasibility Study.

## 4.1 CHEMICAL-SPECIFIC ARARS

Chemical-specific ARARs are used to set concentration limits or discharge limitations in various media for specific hazardous substances. Sections 4.1.1, 4.1.2, and 4.1.3 present JMM's potential chemical-specific ARARs and TBC standards for sediment, surface water, and groundwater at Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3, at Fort Story.

### 4.1.1 Sediment

Chromium, copper, lead, zinc and cyanide were detected in sediment samples collected at Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3, at Fort Story. To date, regulatory standards have not been promulgated by federal or state authorities for most of these compounds in sediments. For the purposes of ARARs analysis for sediments, JMM consulted available regulatory standards or criteria for chemical compounds in soil.

On July 27, 1990, the U.S. Environmental Protection Agency (EPA) published Corrective Action for Solid Waste Management Units at Hazardous Waste Management Facilities (55 *Fed. Reg.* 30798). These proposed regulations pertain to corrective action for releases of hazardous waste or hazardous waste constituents from any solid waste management unit located at a hazardous waste treatment, storage or disposal facility (TSDFs). Standards of 400 mg/kg and 2,000 milligrams per kilogram (mg/kg) were proposed for hexavalent chromium (chromium VI) and cyanide, respectively, in soil (40 CFR Part 264).

JMM considers the RCRA Corrective Action standards for chromium VI and cyanide as TBC material because they are proposed, not promulgated, standards. If these standards were promulgated, they could be relevant and appropriate requirements.

Table 4-1 presents JMM's TBC material for compounds detected in sediment at Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3, Fort Story, Virginia. Regulations or standards are not available for these compounds in sediment or soil; therefore, no potential ARARs have been identified.

### 4.1.2 Surface Water

Contaminants detected in surface water sampled collected at Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3, primarily consisted of VOCs, BNAs, and metals. Predominant compounds detected include acetone, toluene, 4-methylphenol, phenol, and total copper, lead, mercury and zinc. The pesticide DDT was detected in a single surface water sample (SW-201) collected in the area between the fill and pond. In addition, chlorides, fluorides, nitrates as nitrogen, and total sulfates were detected in specific surface water samples.

JMM's major considerations in the identification of ARARs for surface water at Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3, are the interaction of site groundwater with nearby surface water bodies (e.g., adjacent wetlands area Broad Bay, Chesapeake Bay, Atlantic Ocean) and the predominant human exposure pathways associated with these sites.

Based on evaluation of site topographic features and water level data as discussed in Section 3.0, JMM has determined that surface water in Pond 3A is essentially an expression of the groundwater and generally has a similar water elevation as the groundwater.

In addition, as is discussed in detail in Section 5.0, the groundwater beneath the sites could eventually discharge into the Chesapeake Bay, located north of the sites; or Broad Bay, located southwest of the sites. These possible groundwater flow patterns could be caused by the presence of a groundwater divide present across the Fort Story Installation. Also, tidal influences could

**TABLE 4-1**
**TO-BE-CONSIDERED MATERIAL FOR SEDIMENT**
**REMEDIAL INVESTIGATION**
**SITE 3 AND SITE 3A**
**FORT STORY, VIRGINIA**

| Compound of Concern | To-be-Considered Material[a] (mg/kg) | Selected Potential ARARs |
|---|---|---|
| Chromium | 400[b] | — |
| Copper | — | — |
| Lead | — | — |
| Zinc | — | — |
| Cyanide | 2,000 | — |

(a) These values are EPA's proposed RCRA Corrective Action Standards for Solid Waste Management Units at Hazardous Waste Management Facilities (55 Fed. Reg. 30798).

(b) This proposed standard is conservative because it assumes that all chromium is present as hexavalent chromium (chromium VI and compounds).

create greater mixing and dispersion of chemical compounds in the groundwater. Since the regional aquifers are not currently used to supply drinking water, JMM considers consumption of contaminated fish as a possible primary human exposure pathway to be considered during development of ARARs for surface water.

Available regulations or standards pertinent to surface water quality include EPA Ambient Water Quality Criteria for Protection of Human Health, EPA Ambient Water Quality Criteria for Protection of Aquatic Life (freshwater, chronic), Commonwealth of Virginia Water Quality Criteria, and EPA MCLs. EPA Water Quality Criteria are intended to be protective of human health from exposures associated with fish consumption or drinking water ingestion, or both (EPA, 1986b). EPA's Ambient Water Quality Criteria are intended to be protective of aquatic life. JMM chose those standards that are sufficiently protective of possible chronic effects in freshwater species. The Virginia Water Quality Criteria are enforceable standards promulgated by the State Water Control Board as part of an anti-degradation program for protection of surface waters (Commonwealth of Virginia, 1990).

Finally, EPA MCLs are enforceable standards promulgated under the Safe Drinking Water Act of 1986 (EPA, 1991, 40 CFR Parts 141, 142 and 143). In addition, MCLs address the use of the best available water treatment technology, treatment costs and other considerations. MCLs are set at levels which are as close as possible to Maximum Contaminant Level Goals (MCLGs). MCLGs are EPA's non-enforceable health goals for public water systems. MCLGs for substances considered to be probable human carcinogens are set at the zero level and MCLGs for substances that are not probable human carcinogens are set based upon chronic toxicity or other data. MCLGs may be potentially relevant and appropriate requirements for the cleanup of groundwater that is or may be used for drinking.

The Commonwealth of Virginia's MCLs are equivalent to the EPA MCLs for those chemical compounds detected in environmental media at Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3.

JMM considers EPA's (Clean Water Act) Water Quality Criteria for Protection of Human Health to possibly be relevant and appropriate for surface water remediation at Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3. These criteria are intended to be protective of human exposures via fish consumption or drinking water ingestion, or both. EPA asserts that these criteria may be relevant and appropriate at sites where such exposure routes are a concern and the surface water is not designated as a drinking water supply (EPA, 1991c).

EPA's Ambient Water Quality Criteria for Protection of Aquatic Life (freshwater, chronic) are not legally-enforceable standards. Therefore, these criteria are not applicable. However, these criteria are potentially relevant and appropriate to site remediation (EPA, 1988b).

The Virginia Ambient Water Quality Criteria for Protection of Aquatic Life (freshwater, chronic) are available as potential ARARs. These criteria are enforceable standards emphasizing the protection of freshwater aquatic species.

EPA's MCLs, when available for a constituent of concern, are potential ARARs for the cleanup of groundwater that is or may be used for drinking. Due to the interaction likely to be occurring between groundwater and surface waters at the Fort Story Installation, JMM considers EPA MCLs to be possibly relevant and appropriate requirements for surface water.

JMM considers that EPA's Secondary MCLs (SMCLs) and EPA's MCLGs are TBC material. The Secondary MCLs were proposed to address taste and odor detection levels for a variety of contaminants. These standards are not enforceable requirements, and therefore are not potentially applicable (but might be relevant and appropriate) requirements. EPA SMCLs are available for chlorides, fluorides, copper, zinc and total sulfate. EPA has not promulgated MCLGs for any of the compounds detected in site surface waters.

JMM selected potential ARARs for compounds detected in surface waters at Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3, using the following regulations or standards in descending order of preference whenever available:

- EPA Water Quality Criteria for Protection of Human Health, adjusted for fish consumption only (or, if fish consumption values are not available, adjusted for water and fish ingestion);

- EPA Ambient Water Quality Criteria for Protection of Aquatic Life (freshwater, chronic);

- Virginia Ambient Water Quality Criteria for Protection of Aquatic Life (freshwater, chronic), only if stricter than EPA's Ambient Water Quality Criteria above; or

- EPA MCLs.

This ARARs selection process is based only on site characterization data and exposure pathway evaluation completed during the RI. JMM recognizes that ARARs may have to be refined later during this RI/FS evaluation to reflect constraints of viable remedial technologies. For example, technologies available for use in treating surface water may not be capable of attaining clean-up levels dictated by EPA's Water Quality Criteria.

Table 4-2 presents the available regulations or standards, TBCs, and JMM's selected potential ARARs for site surface waters associated with Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3, at Fort Story. Potential ARARs were not selected for acetone, 4-methylphenol, chlorides and total sulfates due to the unavailability of pertinent regulations or standards.

### 4.1.3 Groundwater

JMM detected primarily metals (total and dissolved) in groundwater samples collected from existing and JMM-installed monitoring wells (MWs) located at Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3, at Fort Story. In addition, common anions (e.g., chlorides, fluorides, sulfates) and carbon disulfide were detected in the groundwater.

Available regulations or standards pertinent to groundwater quality include EPA MCLs, Virginia Groundwater Protection Levels (VGPLs), Virginia Water Quality Criteria for Groundwater, and EPA Water Quality Criteria.

The VGPLs are health-based standards derived from Federal Resource Conservation and Recovery Act (RCRA) groundwater protection standards (EPA, 1990) and Commonwealth of Virginia State Water Control Board Regulations (Commonwealth of Virginia, 1990), the Virginia Water Quality Criteria for Groundwater are enforceable standards promulgated by the State Water Control Board as part of an anti-degradation program for protection of groundwater (Commonwealth of Virginia, 1990).

EPA Water Quality Criteria and EPA MCLs were discussed earlier in Section 4.1.2 (Surface Water). These regulations might be pertinent to site groundwater cleanup because of the interaction likely to be occurring between the groundwater and surface waters at the Fort Story Installation.

TABLE 4-2

CHEMICAL-SPECIFIC ARARS AND TBCS FOR SURFACE WATER
REMEDIAL INVESTIGATION
SITE 3 AND SITE 3A, FORT STORY, VIRGINIA

| Compound of Concern | Available Regulations or Standards | | | | | To-be-Considered Material (f) | | Selected Potential ARARs |
|---|---|---|---|---|---|---|---|---|
| | EPA Water Quality Criteria for Protection of Human Health | | EPA Ambient Water Quality Criteria for Protection of Aquatic Life (Freshwater, Chronic) | Virginia Water Quality Criteria for Protection of Aquatic Life (Freshwater, Chronic) | EPA Maximum Contaminant Levels (MCLs) | Secondary MCLs | MCL Goals | |
| | Fish Consumption Only | Water and Fish Ingestion | | | | | | |
| Acetone | — | — | — | — | — | — | — | — |
| Toluene | 424 mg/l | 14.3 mg/l | 17 mg/l | — | 1,000 µg/l | — | — | 424 mg/l[a] |
| 4-Methylphenol | — | — | — | — | — | — | — | — |
| Phenol | — | 3.5 mg/l | 2.5 mg/l | 1.0 µg/l | — | — | — | 1.0 µg/l[b] |
| DDT | 0.024 ng/l | 0.025 ng/l | $1.0 \times 10^{-6}$ mg/l | 0.001 µg/l | — | — | — | 0.024 ng/l[a] |
| Chlorides | — | — | — | — | — | 250 mg/l | — | — |
| Fluorides | — | — | — | — | 4 mg/l | 2.0 mg/l | — | 4 mg/l[e] |
| Nitrates as Nitrogen | — | 10 mg/l | — | — | — | — | — | 10 mg/l[b] |
| Sulfates, total | — | — | — | — | — | 250 mg/l | — | — |
| Copper, total | — | — | 0.012 mg/l | 0.012 mg/l | — | 1.0 mg/l | — | 0.012 mg/l[d] |
| Lead, total | — | 50 µg/l | 0.0032 mg/l | 0.0032 mg/l | — | — | — | 50 µg/l[c] |
| Mercury, total | 146 ng/l | 144 ng/l | $1.2 \times 10^{-5}$ mg/l | — | — | — | — | 146 ng/l[a] |
| Zinc, total | — | — | 0.11 mg/l | 47 µg/l | — | 5.0 mg/l | — | 47 µg/l[d] |

(a) These selected potential ARARs are EPA Water Quality Criteria for fish consumption only. Units are in milligrams per liter (mg/l) or nanograms per liter (ng/l).
(b) These selected potential ARARs are Virginia Water Quality Criteria for Protection of Aquatic Life. Units are in mg/l or micrograms per liter (µg/l).
(c) These selected potential ARARs are EPA Water Quality Criteria for water and fish ingestion. Units are in mg/l or micrograms per liter (µg/l).
(d) These selected potential ARARs are either EPA Ambient Water Quality Criteria for Protection of Aquatic Life or Virginia Water Quality Criteria for Protection of Aquatic Life, whichever value is stricter when both are available.
(e) This designated potential ARAR is an EPA MCL.
(f) TBC Material consists of EPA Secondary MCLs and MCL Goals, all of which are not enforceable requirements.

JMM considers EPA MCLs to possibly be ARARs for the cleanup of groundwater at Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3, due to the fact that this groundwater could be used for drinking (EPA, 1991a).

The VGPLs, which were developed by the Commonwealth of Virginia in the 1970s, are most pertinent for use as guidelines for groundwater protection associated with solid waste management units such as landfills, surface impoundments, or waste piles that are permitted or seeking permit acceptance. JMM considers the VGPLs as potential ARARs for groundwater cleanup (Krishnan, 1991).

The EPA (Clean Water Act) Water Quality Criteria are potentially relevant and appropriate requirements for groundwater cleanup at Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3, due to the interaction likely to be occurring between groundwater and surface waters at the Fort Story Installation.

The Virginia Water Quality Criteria for Groundwater are considered potential ARARs because they are enforceable standards for groundwater protection, despite that the State Water Control Board intended for these standards to be primarily used in permitting applications (Barron, 1991).

JMM selected potential ARARs for compounds detected in groundwater at Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3, using the following regulations or standards in descending order of preference, whenever available:

- EPA MCLs;
- VGPLs;
- EPA Water Quality Criteria; or
- Virginia Water Quality Criteria for Groundwater.

The VGPL standard was selected as a potential ARAR only if this standard is more stringent than a corresponding value for a given compound, or if a given compound has a VGPL standard but not an MCL standard. If a compound of concern has neither an MCL nor a VGPL standard, then the stricter standard among EPA's (Clean Water Act) Water Quality Criteria and the Virginia Water Quality Criteria for Groundwater was selected as a potential ARAR, if available.

Table 4-3 presents the available regulations or standards and JMM's selected potential ARARs for site groundwater associated with Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3, at Fort Story.

## TABLE 4-3

## CHEMICAL-SPECIFIC ARARS AND TBCS FOR GROUNDWATER REMEDIAL INVESTIGATION SITE 3 AND SITE 3A, FORT STORY, VIRGINIA

| Compound of Concern | Available Regulations or Standards | | | | | | | Selected Potential ARARs |
|---|---|---|---|---|---|---|---|---|
| | | | EPA Water Quality Criteria | | | To-be-Considered Material | | |
| | EPA Maximum Contaminant Levels (MCLs) | Virginia Groundwater Protection Levels (VGPLs) | Fish Consumption Only | Water and Fish Ingestion | Virginia Water Quality Criteria for Groundwater | Secondary MCLs | MCL Goals | |
| Ethylbenzene | 7000 mg/l | — | 3.28 mg/l | 1.4 mg/l | — | — | — | 7,000 mg/l[c] |
| Carbon disulfide | — | 1,000 µg/l | — | — | — | — | — | 1,000 µg/l[a] |
| Chlorides | — | — | — | — | 50 mg/l | 250 mg/l | — | 50 mg/l[b] |
| Fluorides | 5 mg/l | — | — | — | 1.4 mg/l | — | — | 5 mg/l[c] |
| Nitrates as Nitrogen | 10 mg/l | — | — | 10 mg/l | — | — | — | 10 mg/l[c] |
| Sulfates, total | — | — | — | — | 50 mg/l | 250 mg/l | — | 50 mg/l[b] |
| Arsenic, total | — | 50 µg/l | 17.5 ng/l | — | — | — | — | 50 µg/l[a] |
| Chromium, total | 0.1 mg/l | 50 µg/l | 3,433 mg/l | — | — | — | — | 50 µg/l[a] |
| Copper, total | — | 1,000 µg/l | — | — | — | 1.0 mg/l | — | 1,000 µg/l[a] |
| Lead, total | — | 50 µg/l | — | 50 µg/l | — | — | — | 50 µg/l[a] |
| Lead, dissolved | 0.05 mg/l | — | — | — | 0.05 mg/l | — | — | 0.05 mg/l[c] |
| Zinc, total | — | 50 µg/l | — | — | — | — | — | 50 µg/l[a] |
| Zinc, dissolved | — | — | — | — | 0.05 mg/l | 5.0 mg/l | — | 0.05 mg/l[b] |

(a) These selected potential ARARs are Virginia Groundwater Protection Levels.
(b) These selected potential ARARs are Virginia Water Quality Criteria for Groundwater.
(c) These selected potential ARARs are either EPA MCLs. For dissolved lead, the EPA MCL and the Virginia Water Quality Criterion for Groundwater are equivalent values.

# Section 5

# 5.0 NATURE AND EXTENT OF CONTAMINATION

The objective of this section is to characterize the types of contaminants detected in the groundwater, sediment or surface waters at Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3. The selected potentially applicable or relevant and appropriate requirements (ARARs) will be used to evaluate the significance of these analytical results. This section provides a comparison of analytical results from site media with respect to those regulatory standards selected as potential ARARs. Figure 5-1 identifies sampling locations which were used to evaluate the nature and extent of contamination. Results from the groundwater, sediments and surface water samples collected during the remedial investigation (RI) are included in this section and Appendix B contains the results from previous investigations.

## 5.1 SITE 3, LANDFILL 3

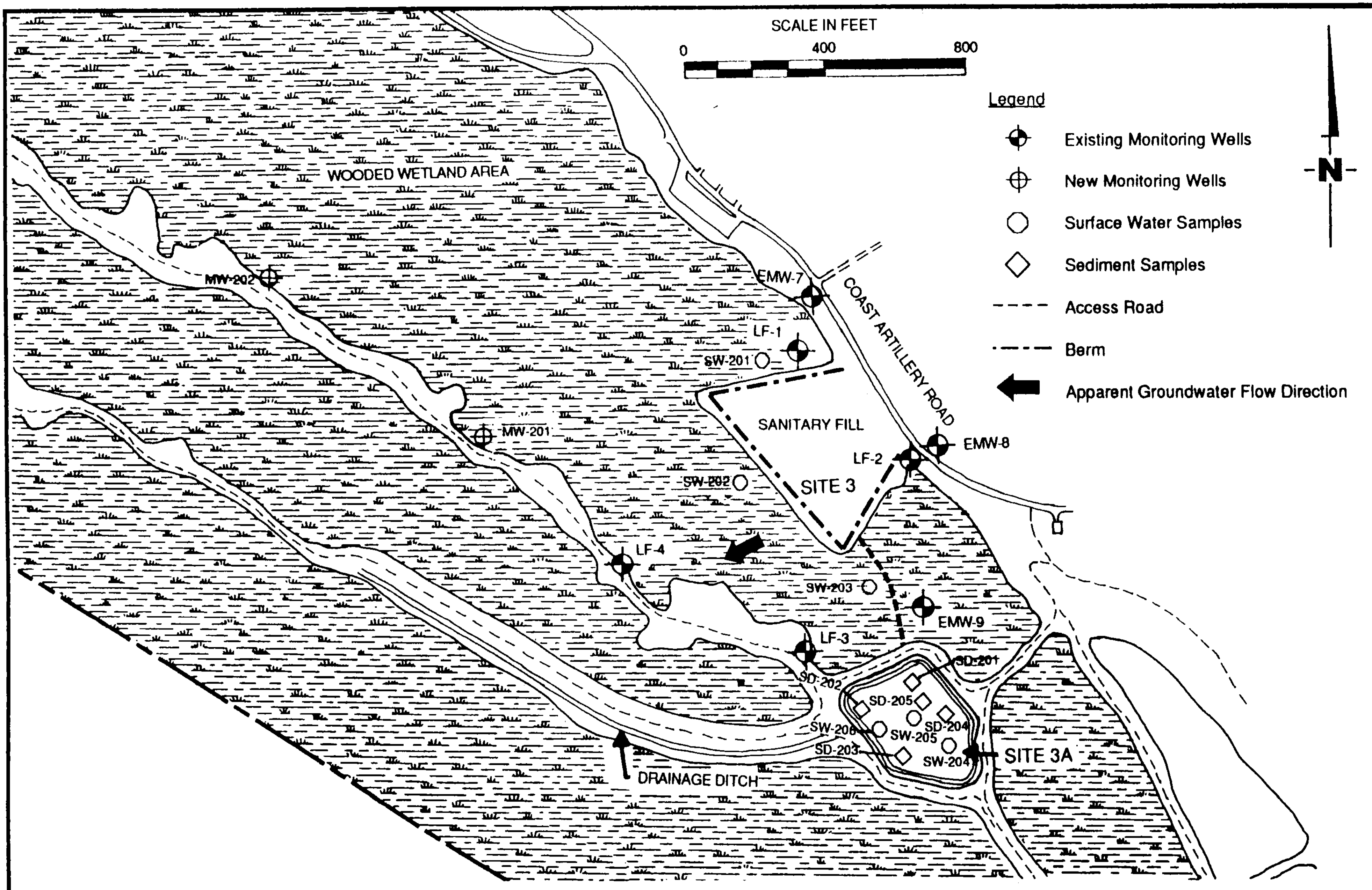
Landfill 3, which reportedly operated from 1962 to 1974, is located on the southeastern corner of Fort Story along Coast Artillery Road. Residential and construction wastes were primarily disposed in the landfill. However, empty pesticide containers were also reportedly disposed at the landfill, which could lead to possible organic contamination of the groundwater. Although a cover was placed on the landfill, a formal closure plan for the landfill was not prepared because the landfill was never permitted. The information required to characterize the extent of contamination at the site is available from groundwater and surface water data collected during the RI; as well as from previous investigations conducted by the United States Army Environmental Hygiene Agency (USAEHA) in 1977 and 1987, and the United States Army Toxic and Hazardous Materials Agency (USATHAMA) in 1988.

### 5.1.1 Previous Investigations at Site 3

In 1977, USAEHA conducted a landfill study at Site 3, Landfill 3, to evaluate the leachate generated at the site due to the landfill's close proximity to a freshwater pond (Site 3A, Pond Adjacent to Landfill 3) and the ocean. Three monitoring wells, MW-7, MW-8 and MW-9, were installed by USAEHA during this study. For clarification purposes, JMM redesignated these existing monitoring wells as EMW-7, EMW-8 and EMW-9, but they were not sampled as part of the RI. The monitoring wells EMW-7 and EMW-8 were installed upgradient of the site whereas monitoring well EMW-9 was installed downgradient. During the 1977 study, USAEHA collected groundwater samples from each well. The analytical results are presented in Appendix Table B-1. After reviewing the analytical results, USAEHA determined that the upgradient wells (i.e., EMW-7 and EMW-8) could not be considered representative of site-background water quality. In addition, the groundwater flow direction could not be determined. However, USAEHA assumed the direction to be toward the ocean (USAEHA, 1977).

USAEHA (1977) compared compounds detected in the groundwater samples to EPA's Maximum Contaminant Levels (MCLs), which are enforceable standards promulgated under the Safe Drinking Water Act of 1986. MCLs for the compounds of concern are also presented in Table B-1. USAEHA determined that arsenic, chromium and lead concentrations in groundwater samples collected from the downgradient well, EMW-9, slightly exceeded respective MCL concentrations; however, they considered the exceedance to be slight and no significant health or environmental hazard resulted. High levels of total organic carbon (TOC) and chemical oxygen demand (COD) were present in all wells, indicating organic material from the landfill or the surrounding swamp may be migrating through the site. USAEHA concluded that the leachate probably flows out to sea due to the high permeability of the sand on which the landfill is located. This investigation concluded that the landfill is not causing any local problems (USAEHA, 1977).

USAEHA conducted an Environmental Operations Review (EOR) in 1987 and recommended that monitoring wells EMW-7, 8 and 9 be sampled and analyzed for trace organic priority pollutants. It




Site 3, Landfill 3 and Site3A, Pond Adjacent to Landfill 3
Ft. Story, VA

Figure 5-1

Sources: USAEHA, 1977 and 1987.

was determined that monitoring wells 7 and 8 were non-functional, and new monitoring wells needed to be installed (ESE, 1988). Prior to installing the new monitoring wells, EMW-9 was sampled and no volatile organics or pesticides/PCBs were detected (USAEHA, 1987).

USAEHA installed four new MWs, designated as LF-1 through LF-4, in 1987 at locations depicted in Figure 5-1. Well LF-1 best represents background conditions whereas LF-4 represents downgradient conditions. Water level elevations in the wells indicated that locally, groundwater flows away from the ocean in a southwesterly direction. However, it is suspected that the construction of the landfill disturbed the groundwater flow, thereby resulting in a flow that moves in a radial direction from the landfill. USAEHA recommended additional water level measurements to determine whether the flow may be influenced by seasonal or tidal factors (USAEHA, 1987).

The USAEHA collected groundwater samples from the four monitoring wells and analyzed these samples for VOCs, BNAs, pesticides/PCBs, metals and inorganics. All metals samples were filtered (i.e., dissolved) with the exception of samples collected from LF-3. VOCs were not detected in any of the samples, except for ethylbenzene which was detected at a concentration of 0.006 mg/l in the LF-1 sample. This concentration was below the MCL goal of 0.70 mg/l. No BNAs or pesticide/PCBs were detected in any of the samples. Results of the metals analyses are present in Appendix B, Table B-2. As expected, concentrations of several metals in LF-3 were higher than the associated samples because the LF-3 sample could not be filtered and thus represent total metals. USAEHA compared these results to Commonwealth of Virginia Water Quality Criteria and EPA MCLs. Manganese exceeded state and federal criteria/standards in all samples. USAEHA considered iron to be naturally occurring at the site and attributed the presence of ferrous concentrations to organic decomposition of debris. Zinc, as well as manganese and iron, concentrations were lower in the downgradient well (i.e., LF-4) than in the upgradient wells, indicating zinc, manganese and iron were probably naturally occurring metals. Inorganic results are presented in Appendix B, Table B-3. Chlorides and sulfates exceeded state but not federal criteria/standards. The pH parameter, however, was not within acceptable state and federal guidelines for three of the four samples. USAEHA considered an acidic pH to be expected in this area due to the formation of organic acids in a reducing environment that was present at this landfill. USAEHA concluded that there was no organic or metals contamination problem at the site. In addition, although the groundwater was slightly acidic, inorganic results did not indicate that leachate infiltration was present. USAEHA recommended that additional chemical monitoring at Site 3, Landfill 3, was not required (USAEHA, 1987).

JMM was retained by the U.S. Army Corps of Engineers to perform a Remedial Investigation/Feasibility Study (RI/FS) evaluation at this site. This evaluation involves several phases of activity, such as collecting additional environmental data to characterize site conditions, determining the nature and extent of contamination at the site, and assessing human health and environmental risks posed by site contaminated media and associated exposure pathways. These phases are discussed further in Section 1.1, Study Objectives.

### 5.1.2 Current Investigation at Site 3, Landfill 3

The Site 3, Landfill 3 investigation for this project involved the assessment of groundwater and surface water contamination. Five groundwater samples were collected. Two of the groundwater samples were collected from MWs installed as part of the RI, and the three remaining groundwater samples were collected from MWs installed as part of a 1987 USAEHA investigation.

The investigation of Site 3, Landfill 3 also included an assessment of surface water contamination. Surface water samples were collected where water was present in areas outside the perimeter of Site 3, Landfill 3. Three surface water samples were collected for the RI, and the source of contaminants in these samples was Landfill 3.

**5.1.2.1 Groundwater Results.** Groundwater quality in the vicinity of Landfill 3 was assessed by collecting groundwater samples from five MWs and submitting the samples to the laboratory for chemical analysis. Groundwater samples were analyzed for PCBs, VOCs, BNAs, pesticides, total metals, dissolved metals, cyanide, and inorganic anions such as chloride, nitrate as nitrogen, sulfate, and fluoride. In addition to the samples submitted for chemical analyses, four field parameters were measured after purging the MW and prior to collecting the groundwater sample. Table 5-1 presents the measured field parameters and the analytical results for groundwater samples at Site 3, Landfill 3.

No pesticides, PCBs, cyanide or BNAs were detected in the samples collected during the groundwater sampling activities at Landfill 3. The only VOC detected during the sampling was carbon disulfide, which was detected in groundwater samples from all five MWs at concentrations ranging from 3.2 micrograms per liter (µg/l) to 33 µg/l. The source of carbon disulfide is uncertain, but it is often found in natural carbon-rich environments. The levels of carbon disulfide detected in groundwater at Landfill 3 are also comparable to levels found at other Fort Story Installation Restoration Program sites (JMM, 1992). The concentrations of carbon disulfide in all five groundwater samples were below the 1,000 µg/l concentration, which was designated as a potential ARAR.

The groundwater samples were analyzed for total and dissolved forms of arsenic, barium, cadmium, chromium, lead mercury, nickel, selenium and zinc. The potential ARARs for the metals concentrations in groundwater apply to the following compounds: total arsenic, total chromium, total copper, total lead, dissolved lead, total zinc and dissolved zinc. The total metals analyses identified arsenic, lead and zinc at concentrations which exceeded the potential ARARs. Total zinc was detected at LF-1 at a concentration which exceeded the potential ARAR. At MW LF-2, total arsenic, total lead and total zinc were detected at concentrations which exceeded each compound's respective ARAR. Although LF-1 is most representative of site background concentrations, LF-2 is also considered upgradient of Site 3, Landfill 3. Therefore, the total metals concentrations, which exceeded the potential ARARs, were all detected at upgradient locations.

The dissolved metals analyses identified arsenic, lead and zinc in site groundwater samples. The concentration of dissolved zinc was the only compound detected above the potential ARAR. Dissolved zinc was detected in MW LF-1 (0.11 mg/l), which is considered an upgradient well, and MW LF-3 (0.14 mg/l), which is considered a downgradient well. The concentrations detected at the upgradient and downgradient MWs were comparable.

The detection of dissolved arsenic in groundwater is the only compound from the total and dissolved metals analyses which was not assigned a potential ARAR. In the absence of an ARAR for dissolved arsenic, the baseline risk assessment will determine the significance of the compound in groundwaters.

The groundwater samples were analyzed for chlorides, nitrates as nitrogen, sulfates and fluorides. Chlorides were detected in all five groundwater samples at concentrations ranging from 10.6 to 25.3 mg/l. The results indicate that groundwater data from all five sampling locations were below the potential chlorides ARAR of 50 mg/l. Although nitrates were only detected at one sampling location (GW-201), its detection was considered a laboratory artifact after review of the associated QC blank data. Regardless of the QC problems, the concentrations of nitrates were below the potential ARAR in all samples collected from Site 3, Landfill 3. Sulfates were detected at three of the five groundwater sampling locations, and fluoride was detected in two of the five groundwater samples. The concentrations of sulfates and fluorides in the groundwater media are below the potential ARAR for each compound (50 mg/l and 5 mg/l, respectively).

## TABLE 5-1

## GROUNDWATER SAMPLES - FORT STORY, SITE 3

| Parameters | GW-201 | GW-201D[g] | GW-202 | LF-1 | LF-1D | LF-2 | LF-3 |
|---|---|---|---|---|---|---|---|
| Pesticides/PCBs (μg/l) | ND[a] | ND | ND | ND | ND | ND | ND |
| VOCs (μg/l) | | | | | | | |
| Carbon Disulfide | 5.4[b] | 7.1[b] | 3.2 | 33[b] | 33 | 26 | 14 |
| BNAs (μg/l) | ND[c] | ND[c] | ND | ND | ND | ND | ND |
| Total Metals (mg/l) | | | | | | | |
| Arsenic | ND[d] | ND[d] | ND | ND | ND | 0.15 | ND |
| Chromium | 0.015[b] | 0.013[b] | 0.03 | 0.028[e] | 0.026[e] | 0.019[e] | 0.017[e] |
| Copper | 0.017[b,e] | 0.011[b,e] | 0.016[e] | 0.022[e] | 0.017[e] | 0.054[e] | ND |
| Lead | 0.025[b] | 0.020[b] | 0.015 | 0.025 | 0.025 | 0.120 | 0.020 |
| Zinc | 0.038[e] | 0.030[e] | 0.051[e] | 0.56 | 0.60 | 2.6 | 0.10[e] |
| Dissolved Metals (mg/l) | | | | | | | |
| Arsenic | 0.009 | 0.008 | 0.008 | ND | ND | 0.086 | 0.007 |
| Lead | 0.002 | 0.002 | 0.002 | ND | ND | ND | 0.003 |
| Zinc | 0.022 | ND | 0.032 | 0.11 | 0.11 | 0.044 | 0.14 |
| Inorganics (mg/l) | | | | | | | |
| Chloride | 18 | 19.5 | 19.5 | 25.3 | 23.0 | 10.6 | 24.9 |
| Nitrate as Nitrogen | 0.06[e] | ND | ND | ND | ND | ND | ND |
| Sulfate | 3.6 | 3.0 | ND | 2.3 | 2.8 | 3.5 | ND |
| Fluoride | ND | ND | ND | 0.12 | 0.12 | 0.23 | ND |
| Cyanide (mg/l) | ND | ND | ND | ND | ND | ND | ND |
| Field Parameters[f] | | | | | | | |
| Temperature (°C) | 20.3 | 20.3 | 17.6 | 14.1 | 14.1 | 17.0 | 17.9 |
| pH | 5.9 | 5.9 | 6.1 | 5.4 | 5.4 | 6.1 | 5.4 |
| Conductivity (μmho) | 100 | 100 | 80 | 130 | 130 | 350 | 100 |
| Turbidity (NTU) | 307.2 | 307.2 | 361.2 | 792.8 | 792.8 | 683.2 | 420.4 |

(a) ND - not detected.
(b) Analytical results considered estimated, but above Method Reporting Level.
(c) Sample dilution increased reported detection limits.
(d) Analytical results considered estimated, but below Method Reporting Level.
(e) Analytical results considered suspect due to detection of compound in associated blank sample.
(f) Field parameters measured after purging, and prior to sampling.
(g) D - indicates a field duplicate sample.

**5.1.2.2 Surface Water Results.** Three surface water samples were collected from areas outside the perimeter of Site 3 (according to site boundaries identified from existing site maps), Landfill 3 to determine if the landfill is a source of contaminants in surface runoff and landfill leachate to adjacent areas. The surface water samples were analyzed for pesticides/PCBs, VOCs, BNAs, total metals, cyanide and common anions such as chlorides, nitrates, sulfates and fluorides. Four additional parameters, which included temperature, pH, conductivity, and turbidity, were measured in the field during the surface water sampling activities. Table 5-2 presents the results from the field measurements and the analytical samples for the three surface water samples at Site 3, Landfill 3.

The detection of DDT in SW-201 at a concentration of 0.08 µg/l was the only pesticide or PCB compound identified in Site 3, Landfill 3 surface waters. The concentration of DDT was greater than the designated ARAR. Toluene was the only VOC compound detected in the Site 3 surface water samples. The concentration of toluene in sample SW-203 (11 µg/l) was below the designated ARAR. Phenol and 4-methylphenol were two acid extractable compounds detected in sample SW-203 at concentrations of 5.2 and 35 µg/l, respectively. Regulatory guidance for 4-methylphenol was not available, so the significance of the compound in surface waters will be determined in the baseline risk assessment. The concentration of phenol was above the potential ARAR.

The total metals analysis identified copper, mercury, lead and zinc in one or more surface water samples. Mercury was detected in SW-203 at a concentration of 0.2 µg/l, which is greater than the potential ARAR. Lead was detected in samples SW-201 and SW-203 at concentrations of 0.085 mg/l and 0.03 mg/l, respectively. The lead concentration in SW-201 was greater than the potential ARAR of 0.050 mg/l. The concentration of zinc in all three surface water samples exceeded the potential ARAR of 0.047 mg/l. Although the total metals analysis detected copper in all three surface water samples at concentrations above the potential ARAR, the QC review of the analytical results, which is presented in the *Quality Control Summary Report (QCSR)* (JMM, 1991a), identified laboratory blank contamination in the associated copper results. As a result, the detection of copper above potential ARAR is not considered representative of copper in surface waters.

Cyanide was not detected in the three surface water samples analyzed as part of this RI. The analysis for chlorides, nitrates, sulfates and fluorides detected chlorides in all three samples and fluorides in two of the three samples. The concentrations of fluorides were below the potential ARARs, and a potential ARAR for chlorides was not identified for site surface waters.

### 5.1.3 Summary of Contamination at Site 3, Landfill 3

The groundwater and surface water samples collected at Site 3, Landfill 3, were analyzed for pesticides, PCBs, VOCs, BNAs, metals, cyanide and inorganics. The analytical results indicate that metal compounds were consistently detected in site media at concentrations above selected potential ARARs. In groundwater samples, total arsenic, total lead and total zinc were detected at two MWs above ARARs, but both MWs were considered upgradient of Site 3, Landfill 3. The dissolved metals analyses identified zinc in both downgradient (LF-3) and upgradient (LF-1) MWs. A significant increase in the dissolved zinc concentrations in the downgradient MW was not observed when compared to the results from the upgradient MW. The surface water results provided additional data, which also identified metals as the primary type of compounds present in the site media. With the exception of metals concentrations which exceeded selected potential ARARs, the concentration of phenol (SW-203) was the only other compound above the selected potential ARAR. In all cases where compounds exceeded selected potential ARARs, the concentrations were not significantly above the selected potential ARARs. Therefore, the evaluation into the nature and extent of groundwater contamination at Site 3, Landfill 3 did not identify the landfill as the source of significant contamination to site groundwaters and surface waters.

TABLE 5-2

SURFACE WATER SAMPLES - FORT STORY, SITE 3

| Parameters | SW-201 | SW-202 | SW-203 |
|---|---|---|---|
| Pesticides/PCBs (µg/l) | | | |
| p,p'DDT | 0.08[a] | ND[b,c] | ND[c] |
| VOCs (µg/l) | | | |
| Toluene | ND | ND | 11[d] |
| BNAs (µg/l) | | | |
| Phenol | ND[c] | ND[c] | 5.2[a] |
| 4-Methylphenol | ND[c] | ND[c] | 35[a] |
| Metals (mg/l) | | | |
| Copper | 0.042[f] | 0.017[f] | 0.024[f] |
| Mercury | ND | ND | 0.0002 |
| Lead | 0.085 | ND | 0.03 |
| Zinc | 0.38 | 0.064 | 0.053 |
| Cyanide (mg/l) | ND | ND | ND |
| Inorganics (mg/l) | | | |
| Fluoride | 0.11 | 0.15 | ND |
| Chloride | 22.3 | 22.9 | 29.3 |
| Field Parameters[e] | | | |
| Temperature (°C) | 28.4 | 22.9 | 29.3 |
| pH | 6.7 | 6.1 | 6.9 |
| Conductivity (µmho) | 140 | 155 | 140 |
| Turbidity (NTU) | 28.4 | 124.4 | 120.6 |

(a) Analytical results considered estimated, but above Method Reporting Level.
(b) ND - not detected.
(c) Analytical results considered estimated, but below Method Reporting Level.
(d) Sample dilution increased reported detection limits.
(e) Field parameters measured after purging, and prior to sampling.
(f) Analytical results considered suspect due to detection of compound in associated blank sample

## 5.2 SITE 3A, POND ADJACENT TO LANDFILL 3

Due to the close proximity of the pond, JMM's RI and previous studies have investigated the interrelationship between Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3. Previous investigations by whom hypothesized that the shallow groundwater in the vicinity of the landfill, as well as surface water runoff, may transport contaminants from Landfill 3 to the Site 3A pond (ESE, 1988). In order to investigate this possibility, samples of the pond sediments and surface water were collected.

### 5.2.1 Previous Investigations at Site 3A

In conjunction with the groundwater investigation discussed in Section 5.1.1, USAEHA investigated the surface water and sediments in the pond located adjacent to Landfill 3 to determine if the landfill leachate may be adversely affecting the water quality of the pond. Three surface water and three sediment samples were collected along a transect across the center of the pond. Analytical results for surface water and sediment samples are presented in Appendix B, Tables B-4 and B-5, respectively. Ambient water quality criteria established by the Commonwealth of Virginia is also presented in Table B-4. None of the metals exceeded the ambient water quality criteria, with the exception of iron and zinc. However, these compounds are naturally occurring in soils and their concentrations exceed the criteria only slightly. An evaluation of the analytical results determined the following characteristics of the pond: slightly acidic, very soft, trace levels of several metals present, low dissolved solids and turbidity, and moderate levels of nitrogen and phosphorous (ESE, 1988).

Analytical results from the sediment samples indicated the presence of low levels of trace metals, DDD and DDE, as indicated in Table B-5 of Appendix B. The pesticides DDD and DDE were likely a degradation byproduct of DDT, commonly used for mosquito control, especially in marshy areas (ESE, 1988). USAEHA concluded that leachate from Landfill 3 does not appear to be impacting water quality of the pond located adjacent to Landfill 3. In addition, USAEHA recommended restricting fishing in the pond until metals analyses in the fish tissue indicate safe levels (USAEHA, 1977).

### 5.2.2 Current Investigation at Site 3A

The investigations at Site 3A involved the assessment of surface water and sediment contamination. JMM collected five sediment samples and three surface water samples. The sediment samples were collected using a Vibracore rig, as described in Section 2.5. The surface water samples were collected using a point source bailer, as outlined in Section 2.4.

**5.2.2.1 Sediment Results.** The sediment samples were collected from beneath the pond. The samples were analyzed for pesticides/PCBs, VOCs, BNAs, total fuel hydrocarbons - heavy fraction (TFH-H), metals, EP Toxicity (EP Tox) metals and cyanide. Table 5-3 presents the analytical results for sediment samples at Site 3A. Pesticides/PCB, VOC, BNAs TFH-H, EP Tox metals analyses did not detect target compounds in the five sediment samples.

The metals analyses identified chromium, copper, lead and zinc compounds in the sediment media. The concentration of metals detected in the sediment samples ranged from 1.5 to 3.2 mg/kg for chromium, 1.0 to 1.4 mg/kg for copper, 1.0 to 3.8 mg/kg for lead, and 1.5 to 3.0 mg/kg for zinc. Potential ARARs for metals detected in sediment media were not established in Section 4.0.

The analysis of sediment samples identified cyanide in one sample (0.39 mg/kg) at a concentration that is greater than the method reporting limit. Because an ARAR for cyanide was not established, decisions related to cyanide as a potential compound of concern will not be determined based on

TABLE 5-3

SEDIMENT SAMPLES - FORT STORY, SITE 3A

| Parameters | SD-201 | SD-202 | SD-203 | SD-204 | SD-205 |
|---|---|---|---|---|---|
| Pesticides/PCBs (mg/kg) | ND [a,b] | ND[b] | ND[b] | ND[b] | ND[b] |
| VOCs (mg/kg) | ND | ND | ND | ND | ND |
| BNAs (mg/kg) | ND | ND | ND[b] | ND | ND |
| TFH-H (mg/kg) | ND | ND | ND | ND | ND |
| Metals (mg/kg) | | | | | |
| Chromium | 1.8 | 3.2 | 1.5 | ND | 1.7 |
| Copper | ND | 1.2 | 1.0 | 1.4 | 1.2 |
| Lead | 2.5 | 3.8 | 1.5 | 1.3 | 1.0 |
| Zinc | ND | 3.0[c] | ND | 2.6[c] | 1.5[c] |
| EP Tox Metals (mg/l) | ND | ND | ND | ND | ND |
| Cyanide | ND | ND | 0.39 | ND | ND |
| Total Solids (%) | 83 | 85 | 78 | 78 | 69 |

(a) ND - not detected.
(b) Analytical results considered estimated, but below Method Reporting Level.
(c) Analytical results considered suspect due to detection of compound in associated blank sample.

ARARs. However, the cyanide was detected in only one sediment sample at a relatively low concentration, which indicates that significant contamination does not exist at the site.

**5.2.2.2 Surface Water.** Three surface water samples were collected from Site 3A, Pond Adjacent to Landfill 3, and the samples were analyzed for pesticides/PCBs, VOCs, BNAs, TFH-H, metals, cyanide, and inorganics such as chloride, nitrate, sulfate and fluoride. Table 5-4 presents the results of the surface water analyses. The analytical data did not identify target compounds in samples submitted for pesticide/PCB, BNA, TFH-H and cyanide analysis. Acetone was detected in one VOC surface water sample (SW-206) at a concentration of 16 µg/l. Although acetone was not detected in the associated quality control blank samples, the EPA guidance on data validation provides allowances for cases where suspected contaminants such as acetone are detected. Specifically, analytical data may be qualified when there is little or no contamination in the associated blank samples (EPA, 1988e). Since acetone was found at a relatively low level, the acetone detected in sample SW-206 is considered a laboratory artifact. The metals data indicated that lead and zinc were detected in one or more surface water samples. Lead was detected at a concentration of .004 mg/l, which is below the potential ARAR. Although zinc was detected in all three surface water samples, the concentrations were below the potential ARAR for zinc in surface waters.

### 5.2.3 Summary of Contamination at Site 3A, Pond Adjacent to Landfill 3

Results from sediment and surface water samples collected from Site 3A, Pond Adjacent to Landfill 3, do not indicate that significant contamination is present in site media. Although the analytical results identified chromium, copper, lead and zinc in sediment samples, all concentrations of these metals were relatively low. The detection of cyanide in sample SD-203 is not considered significant since the 0.39 mg/kg concentration does not substantially exceed the 0.10 mg/kg detection limit for cyanide.

In surface water samples, the metals results were all below the selected potential ARARs. The VOC analyses detected acetone in one surface water sample, but this detection is considered a potential lab contaminant and a selected potential ARAR for the acetone was not identified. Although the 16 µg/l acetone concentration is relatively low, the significance of the acetone was not determined. The inorganic results identified chlorides, sulfates and nitrates as nitrogen in surface waters. The results, however, did not identify significant contamination for these parameters. In summary, the levels of compounds detected in site media do not indicate that contamination exists at the site.

TABLE 5-4

SURFACE WATER SAMPLES - FORT STORY, SITE 3A

| Parameters | SW-204 | SW-205 | SW-206 |
|---|---|---|---|
| Pesticides/PCBs (μg/l) | ND[(a)] | ND | ND |
| VOCs (μg/l) | | | |
| Acetone | ND | ND | 16 |
| BNAs (μg/l) | ND | ND | ND |
| TFH-H (mg/l) | ND | ND | ND |
| Metals (mg/l) | | | |
| Lead | 0.004 | ND | ND |
| Zinc | 0.022 | 0.02 | 0.020 |
| Cyanide (mg/l) | ND | ND | ND |
| Inorganics (mg/l) | | | |
| Chloride | 35 | 32 | 32 |
| Sulfate | 11 | 4.7 | 5.1 |
| Nitrate as Nitrogen | 0.3 | ND | ND |
| Field Parameters[(b)] | | | |
| Temperature (°C) | 28.9 | 28.9 | 28.9 |
| pH | 6.93 | 6.93 | 6.93 |
| Conductivity (μmho) | 120 | 120 | 120 |
| Turbidity (NTU) | 146.5 | 146.5 | 146.5 |

(a) ND - not detected
(b) Field parameters measured after purging; prior to sampling.

# Section 6

## 6.0 POTENTIAL CONTAMINANT TRANSPORT PATHWAYS

Compounds of concern discharged or released into site environmental media at an RI/FS project site could migrate via atmospheric, surface or subsurface transport pathways. Sections 6.1 and 6.2 discuss these potential contaminant transport pathways associated with Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3, located at Fort Story, Virginia. The significant contaminants transport pathways associated with Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3, are identified and evaluated in Section 7.0, Baseline Risk Assessment.

### 6.1 SITE 3, LANDFILL 3

Figure 6-1 presents the potential exposure pathways for installation personnel to chemical compounds associated with Site 3, Landfill 3, at Fort Story, Virginia. These transport pathways consist of possible sources, mechanisms of release, exposure routes and receptors. The likelihood of receptors being exposed to chemical compounds could change based on the movement of these compounds over time or by changing land use patterns or activities. For example, if the site were developed for military, residential or commercial purposes, construction workers would constitute a new potential receptor. Compounds detected at Site 3, Landfill 3, include DDT, toluene, phenol, 4-methylphenol, copper, mercury, lead, zinc, fluoride, and chloride in the ponded surface water, which had accumulated in the marshy area outside the perimeter of the landfill; and carbon disulfide, arsenic, chromium, copper, lead, zinc, chloride, sulfate and fluoride in the ground water located upgradient or downgradient of the landfill.

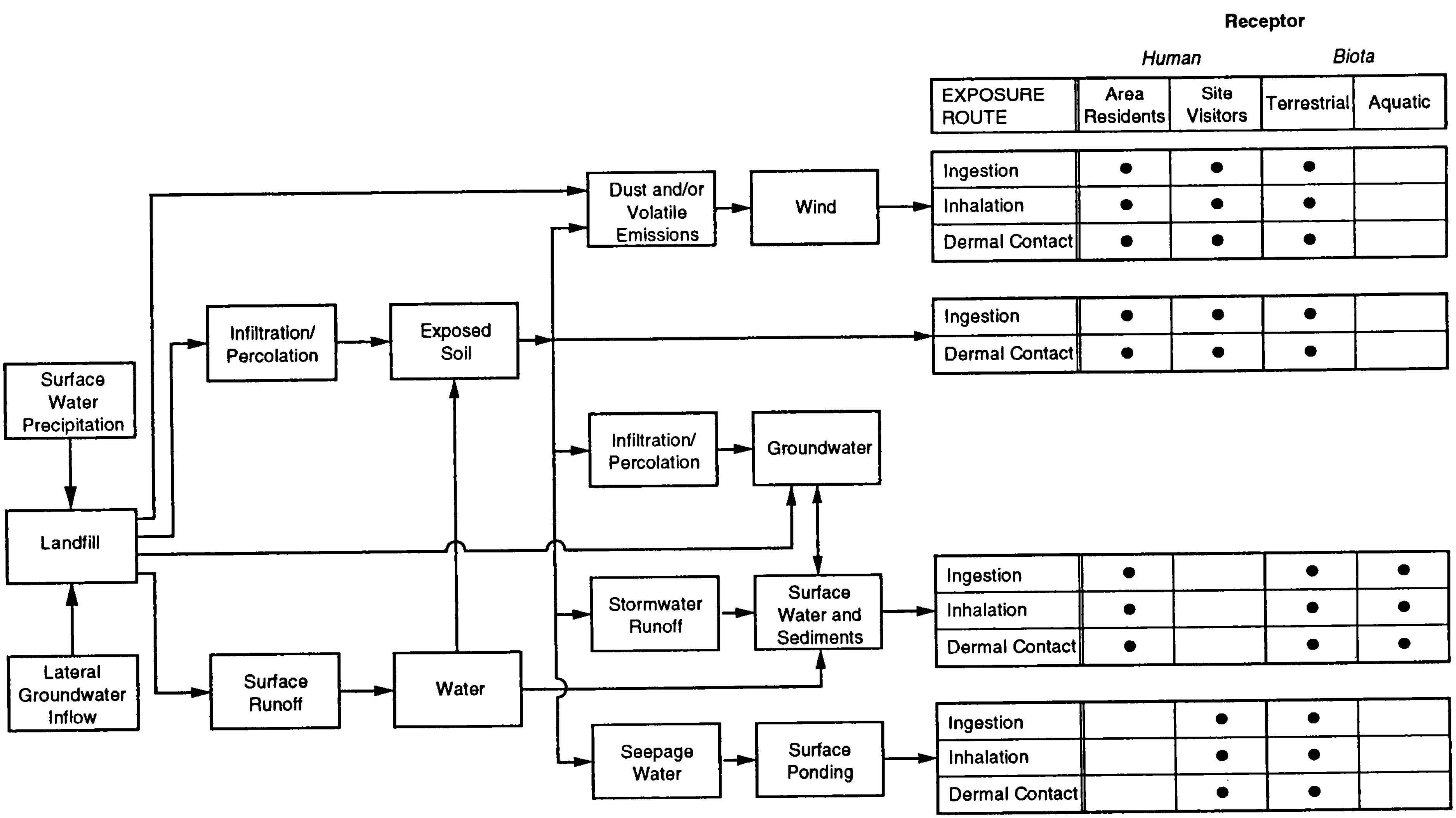
Surface water or precipitation contacting the fill material could cause chemical compounds present in the landfilled material to migrate into site soil via infiltration/percolation. Water percolating through the surface of the landfill could eventually saturate the fill material or soil; subsequently, these compounds could percolate to the groundwater or seep from the side of the landfill. Leachate seeps on slopes occur when surface water infiltrates the cover soil, migrates downward until a less permeable intermediate soil layer or refuse layer is encountered, and moves laterally until it seeps through the soil cover (EPA, 1982).

Additional chemical exposure pathways for Site 3, Landfill 3, which are presented in Figure 6-1, are described below.

- Surface water runoff traversing the landfill could carry chemical compounds into the surface water of the pond at Site 3A, Pond Adjacent to Landfill 3, or into low-lying runoff accumulation areas located southeast of the landfill. Compounds in site surface waters could result in ingestion or dermal contact exposure for area residents, or terrestrial or aquatic biota. Also, contaminated airborne vapors or particulates generated from exposed surface water and sediment could be inhaled by area residents or terrestrial or aquatic biota.

- Lateral groundwater inflow through the fill material could adversely affect groundwater quality by leachate (EPA, 1982). Compounds in site groundwater could result in inhalation, dermal contact or ingestion exposure for area residents, if these contaminants eventually discharge into local surface water bodies where people fish or swim. The groundwater associated with Site 3, Landfill 3, is not currently used for drinking water.

- Affected airborne vapors or particulate could be carried by wind across site boundaries and result in inhalation, ingestion or dermal contact exposure for area residents, site visitors or terrestrial biota.




| EXPOSURE ROUTE | Area Residents | Site Visitors | Terrestrial | Aquatic |
|---|---|---|---|---|
| Ingestion | ● | ● | ● | |
| Inhalation | ● | ● | ● | |
| Dermal Contact | ● | ● | ● | |

| EXPOSURE ROUTE | Area Residents | Site Visitors | Terrestrial | Aquatic |
|---|---|---|---|---|
| Ingestion | ● | ● | ● | |
| Dermal Contact | ● | ● | ● | |

| EXPOSURE ROUTE | Area Residents | Site Visitors | Terrestrial | Aquatic |
|---|---|---|---|---|
| Ingestion | ● | | ● | ● |
| Inhalation | ● | | ● | ● |
| Dermal Contact | ● | | ● | ● |

| EXPOSURE ROUTE | Area Residents | Site Visitors | Terrestrial | Aquatic |
|---|---|---|---|---|
| Ingestion | | ● | ● | |
| Inhalation | | ● | ● | |
| Dermal Contact | | ● | ● | |

JMM

Potential Exposure Pathways for Chemical Compounds Associated with Site 3, Landfill 3
Fort Story, VA

Figure 6-1

- Compounds in exposed soil could result in ingestion or dermal contact exposure for area residents, site visitors or terrestrial biota.

- Finally, seepage water from the side of the landfill could cause surface ponding in accessible (although densely vegetated) portions of the site. This could result in ingestion, inhalation or dermal contact exposure to chemical compounds for site visitors or terrestrial biota.

## 6.2 SITE 3A, POND ADJACENT TO LANDFILL 3

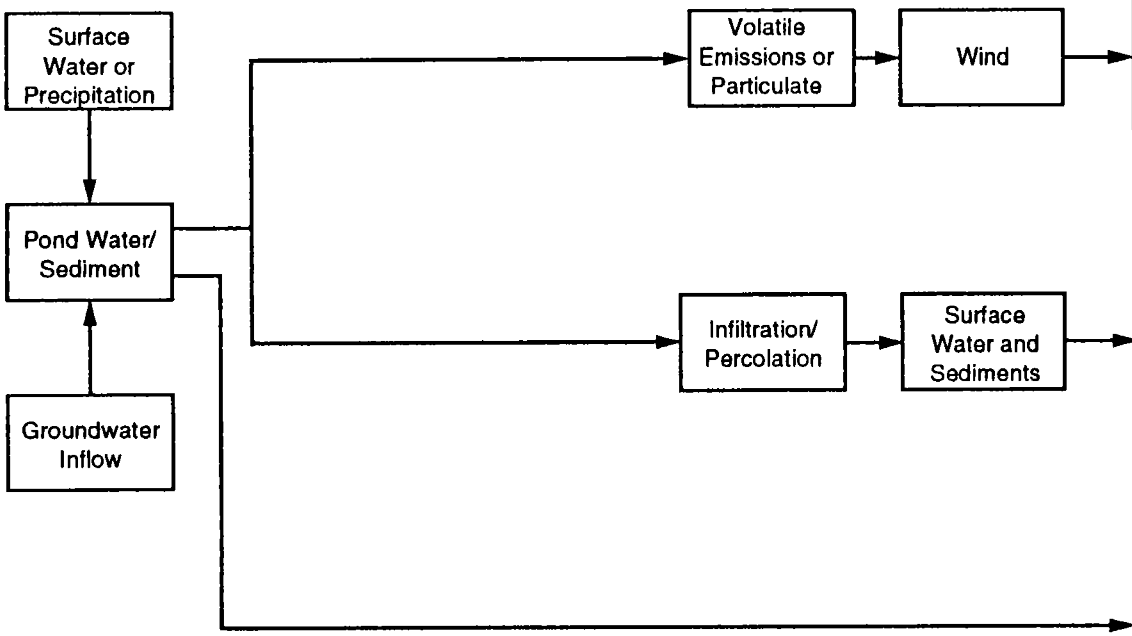
Figure 6-2 shows the potential exposure pathways for receptors to chemical compounds associated with Site 3A, Pond Adjacent to Landfill 3. These exposure pathways consist of possible sources, mechanisms of release, exposure routes and receptors. As is the case for Site 3, Landfill 3, the likelihood of receptors being exposed to chemical compounds could change based on the movement of these compounds over time or by changing land use patterns or activities. For example, if the site were developed for military, residential, or commercial purposes, construction workers would constitute a new potential receptor. Compounds detected at Site 3A, Pond Adjacent to Landfill 3, include acetone, lead, zinc, chloride, sulfate, and nitrate as nitrogen in the pond surface water; and chromium, copper, lead, zinc, and cyanide in pond sediment.

Surface water runoff or precipitation entering the pond, as well as groundwater inflow into the pond, could cause chemical compounds present in the pond to migrate into subsurface soil via infiltration/percolation. The affected subsurface soil would not pose an direct exposure threat to receptors since the soil is not exposed.

Additional chemical exposure pathways for Site 3A, Pond Adjacent to Landfill 3, which are presented in Figure 6-2, are described below.

- Compounds in site groundwater could discharge into local surface water bodies (e.g., Chesapeake Bay, Broad Bay), where people fish or swim, or into wetland areas. Affected surface waters could result in ingestion or dermal contact exposures for area residents or terrestrial or aquatic biota. In addition, site visitors or terrestrial or aquatic biota could be exposed to affected pond waters via ingestion or dermal contact.

- Affected airborne vapors could be carried by wind across site boundaries and result in inhalation, ingestion or dermal contact exposure for area residents, site visitors or terrestrial biota.




**Receptor**

*Volatile Emissions or Particulate → Wind:*

| EXPOSURE ROUTE | *Human* Area Residents | *Human* Site Visitors | *Biota* Terrestrial | *Biota* Aquatic |
|---|---|---|---|---|
| Ingestion | ● | ● | ● | |
| Inhalation | ● | ● | ● | |
| Dermal Contact | ● | ● | ● | |

*Infiltration/Percolation → Surface Water and Sediments:*

| EXPOSURE ROUTE | *Human* Area Residents | *Human* Site Visitors | *Biota* Terrestrial | *Biota* Aquatic |
|---|---|---|---|---|
| Ingestion | ● | | ● | ● |
| Inhalation | | | | |
| Dermal Contact | ● | | ● | ● |

*Pond Water/Sediment (direct):*

| EXPOSURE ROUTE | *Human* Area Residents | *Human* Site Visitors | *Biota* Terrestrial | *Biota* Aquatic |
|---|---|---|---|---|
| Ingestion | | ● | ● | ● |
| Inhalation | | | | |
| Dermal Contact | | ● | ● | ● |

JMM

Potential Exposure Pathways for Chemical Compounds Associated with Site 3A, Pond Adjacent to Landfill 3
Fort Story, VA

Figure 6-2

# Section 7

## 7.0 BASELINE RISK ASSESSMENT

This section presents a baseline public health and environmental risk assessment for the Fort Story RI/FS sites. The data presented in the earlier sections of this report are used to determine the most significant contaminants present, the different ways by which people, plants, and animals could come into contact with these contaminants, and the possibility of any harmful effects as a result of that contact.

## 7.1 INTRODUCTION

This portion of the risk assessment provides background information regarding the reasons why risk assessments are performed and the guidance documents which stipulate how to perform risk assessments. The basic structure of this risk assessment is described in the context of presenting a definition of the major elements of a risk assessment.

### 7.1.1 Purpose and Objectives

A baseline risk assessment is one of the interpretive links between the remedial investigation (RI) and the feasibility study (FS). It utilizes RI-generated information to evaluate the public health and environmental risks posed by the site and to provide a background with which to formulate goals used in selecting remedial alternatives in the FS.

The major objective of this risk assessment is to assess the magnitude and probability of actual or potential public health and environmental risks posed by chemical constituents identified by the RI field investigations and sampling programs. This risk assessment addresses the site baseline conditions, or "no action scenario," and is a preliminary assessment of the current and future risks represented by those baseline conditions, assuming no future remedial action is taken.

### 7.1.2 Scope of Assessment

Included in this assessment are all of the data collected during the current investigation within the Fort Story RI/FS sites. In order to maintain consistent data quality, the only data included in this risk assessment were collected by JMM during the RI site investigations. However, available data from previous reports were reviewed and found to be generally comparable to JMM data. Specific comparisons on a contaminant-by-contaminant basis are made in the Ecological Risk Assessment sections since environmental receptors are the only receptors likely to be affected.

### 7.1.3 Guidance Documents

The primary guidance documents consulted during development of this assessment are the *Risk Assessment Guidance for Superfund: Human Health Evaluation Manual and Environmental Evaluation Manual* (EPA, 1989a), and the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988b). Other documents used include the *Superfund Exposure Assessment Manual* (EPA, 1988c) and the *Exposure Factors Handbook* (EPA, 1989b). These documents, which describe various aspects of the risk assessment process as it applies to Superfund sites, were used as general guidance for the Fort Story RI/FS sites.

### 7.1.4 Risk Assessment Organization

A baseline risk assessment should include several basic elements, including identification of contaminants of concern, an exposure assessment, a toxicity assessment of the contaminants of concern, human risk characterization, and ecological risk characterization. These elements constitute the major topics addressed in this report. Each major sub-section of this section contains an element of the baseline risk assessment. Some of these elements are presented on a site-by-site basis and are included more than once.

Contaminants of concern (described in Sections 7.4, 7.6.1 and 7.7.1) are those contaminants responsible for the greatest risks based on contaminant concentration, areal extent, toxicity, frequency of detection and, in some instances, mobility. The contaminants of concern were selected for each contaminated medium at each site.

The exposure assessment (Sections 7.6.2 and 7.7.2) identifies potential human receptors and potential current and future pathways to those receptors at each site. An assessment of pathway completeness is made and human exposure to contaminants of concern is quantified for the complete pathways.

The general toxicity assessment (Section 7.5) describes the available toxicological data used to investigate the relationship between an administered dose and a predicted response (e.g., cancer incidence for a given receptor) for all contaminants of concern, including potential ecological effects.

The risk characterization (Sections 7.6.3 and 7.7.3) estimates the probability of an adverse health effect under the conditions of exposure defined in the exposure assessment.

The ecological risk characterization (Sections 7.6.4 and 7.7.4) characterizes the threat to the environment in much the same way that the previous sections characterize the threat to human health. Contaminants of environmental concern are identified based on their ecotoxicity. Environmental receptors and the potential pathways to those receptors are also identified. The potential receptors include plants and animals in the vicinity of the affected area. The ecological risks are characterized based on the probability of an adverse effect to one of these potential receptors.

Appendix C, Part I, contains detailed toxicological profiles for the contaminants of concern. Appendix C, Part II, presents detailed exposure calculations.

## 7.2 FIELD INVESTIGATIONS

Investigations into the environmental effects of Fort Story operations are described in this section.

### 7.2.1 Previous Investigations

Several investigations evaluated environmental impacts of activities at Fort Story before the current investigation. The following paragraphs provide brief descriptions of some of the reports reviewed during the course of this risk assessment.

**Landfill Study (USAEHA, 1977).** This study was performed to evaluate leachate problems at three sanitary landfills, including one at Fort Story. Each of these landfills was relatively close to either a freshwater pond or estuarine creeks. Field work included the installation and subsequent sampling of groundwater monitoring wells and surface water grab samples. Site 3, Landfill 3, Fort Story, was found to be located on highly permeable soil. Groundwater was slightly impacted. Elevated lead and zinc levels were found in the water. This study was useful to the current risk assessment since data for metals, pesticides and water quality parameters were presented for three surface water and three sediment samples in Site 3A, Pond Adjacent to Landfill 3.

**Update of the Initial Installation Assessment of Fort Story (ESE, 1988).** This report was performed as a follow-up to the 1980 initial Installation Assessment to determine the impact of new regulations as well as the status of contaminants at the site. This study noted that only one of three closed landfills had been investigated, Landfill 3 (JMM Site 3), in the Landfill Study summarized earlier (USAEHA, 1977). Recommendations included implementation of a water quality monitoring program to determine impacts of Landfill 3 on the downgradient pond (JMM Site 3A) and to initiate monitoring of the other two closed landfills. This report supplied a superior discussion of 1977 data. No new results were released.

**Geohydrologic Study, Fort Story (USAEHA, 1987).** This report provided additional groundwater data for the Fort Story Landfill (JMM Site 3). Old wells and newly installed wells were sampled to further define the movement of groundwater and the extent of contamination. The analytical data supplied in this report were reviewed for possible inclusion in the quantitative (public health) risk assessment data base. Because this data was comparable to that obtained by JMM during recent sampling (as part of the current investigation), this pre-existing data was not included in the database used to quantify risks.

**Potable/Recreational Water Study (USATHAMA, 1982).** This document provided an evaluation of the water supply to Fort Story and Fort Eustis. Although it contained no analytical results, it assisted in the development of risk assessment exposure pathways related to groundwater usage at Fort Eustis and Fort Story.

### 7.2.2 Current Investigation

The current investigation was undertaken as a portion of a larger task order covering several RI/FS sites at Fort Story as well as Fort Eustis. Surface water, groundwater and sediment samples were taken around a closed landfill, Site 3, Landfill 3, and at a pond near this landfill, Site 3A, Pond Adjacent to Landfill 3.

## 7.3 ENVIRONMENTAL SETTING

Fort Story is surrounded by the Atlantic Ocean, Chesapeake Bay and Seashore State Park. Each of these locations are within one mile of the two sites addressed in this report. Fort Story is primarily composed of sparsely vegetated coastal dunes; the more southern extent of the installation gives way to forested freshwater wetland areas that support a wide variety of plants and animals. A review of available information indicates the presence of over 600 animal and plant species in the Virginia Beach area (VA Department of Conservation & Historic Resources, VA Department of Game and Inland Fisheries, and VA Department of Agriculture and Human Services).

No animals of special concern within the state of Virginia, and no known plant or animal species of federal threatened or endangered status, exist at Fort Story. Nine plant species of state recommended special concern have been reported at Fort Story. These include: Virginia Beach pinweed (Lechea maritima), Baldwin spikerush (Eleocharis baldwinii), coast bedstraw (Galium hispidulum), spoon-leaved sundew (Drosera intermedia), long-leaf pine (Pinus palustrus), sand post oak (Quercus margerettae), purple bladderwort (Utricularia purpurea), freshwater cordgrass (Spartina pectinata), and sticky ground-cherry (Physalis viscosa). Generally, these species are common globally but have been recommended for state status of special concern due to the rarity of these species in Virginia.

Several special designated species are reported for the wildlife areas near Fort Story. Juveniles of several sea turtle species of federal or state endangered status are reported to sometimes forage along the bay and estuary shoreline of Virginia. The federal endangered species bald eagle (Haliaeetus leucocephalis) and peregrine falcon (Falco peregrinus) nest along the James and York rivers. The state endangered freshwater Eastern chicken turtle (Deirochelys reticularia) is found within Virginia only at Seashore State Park in still-water habitats like cypress swamps. The state endangered Eastern tiger salamander (Ambystoma tigrinum) is globally common but rare in

Virginia and has been found near seasonal woodland ponds. Other species of special concern that may nest, hunt or reside in the wildlife areas near or on Fort Story include the carpenter frog (Rana virgatipes), several heron species, the Eastern big-eared bat (Plecotus rafinesquii), the white-footed deer mouse (Peromyscus leucopus easti), and the Southeastern Dismal Swamp shrew (Sorex longirostris fisheri).

## 7.4 SELECTION OF CONTAMINANTS OF CONCERN

The initial step of the risk assessment was selecting site-specific contaminants of concern. Although numerous contaminants of potential concern are present in the soil and groundwater at the Fort Story RI/FS sites, some of them may dominate the health risks. Focusing on a manageable list of the most important contaminants was necessary to permit a concise analysis and presentation of this risk assessment. Contaminants of concern are a subgroup of the contaminants of potential concern, which include all analytes detected at Fort Story. These contaminants of concern are expected to dominate the health risks. The selection process described in this section was designed to choose those chemicals that are the most toxic and are anticipated to create the greatest human exposure. Contaminants of concern were selected for each medium of contamination, taking into account whether the chemicals were carcinogens or noncarcinogens. Section 7.5.1 contains information about the toxicological difference between carcinogens and noncarcinogens.

### 7.4.1 Data Considered

**Previous Investigations**. No data from previous investigations was used to select contaminants of concern for human health during the preparation of this risk assessment.

**Current Investigation.** The contaminants of concern selection process included the data collected by JMM during the RI site investigations. For this data, if contamination of Quality Assurance/Quality Control (QA/QC) blank samples (trip, method, source water or equipment blanks) occurred, the same analytes detected in the associated samples were generally eliminated if their concentrations were less than five times the blank concentrations (ten times for common laboratory contaminants-see JMM, 1991a). This process was not used for metals found in the laboratory method blanks since the data from samples other than those affected (i.e. samples with greater than five times the level in the method blank or in lab batches unaffected by method blank problems) indicated that the affected metals are likely to be present in the media sampled. The laboratory procedure utilizing Ottawa sand for solid matrix method blanks was most likely responsible for the presence of most of the metals in the soil and sediment method blanks. The metals released from the sand by digestion would not be present in any of the environmental samples since the Ottawa sand was not added to the field samples. In addition, the metals affected (copper and zinc) are significant components of the earth's crust and are relatively ubiquitous in the environment.

### 7.4.2 Contaminants of Concern Selection Process

The detailed process of selecting contaminants of concern was the same for aqueous media (ground and surface water) and solid media (soil and sediment). The process was based on the frequency of detection, toxicity and maximum concentration of a chemical in the contaminated medium of concern.

Further reductions in the number of contaminants of potential concern were made based on the frequency of occurrence. Contaminants detected less than 10 percent of the time do not adequately represent the extent of contamination in the environmental media nor the risks posed by any such contamination. Compounds that had been found in only one sample, but for which the total number of samples for that medium was low (i.e., less than nine samples), were considered further due to the small number of sample points. If compounds were detected in locations which appeared to be unrelated to sources of contamination on the site (i.e., upstream or upgradient of all of the potential sources), the compounds were dropped from consideration.

The toxicity of the compound was represented by its oral cancer slope factor (SF) or reference dose (RfD), depending on whether carcinogenic or noncarcinogenic indicator chemicals were being selected, respectively. Most SFs and RfDs were obtained from the Integrated Risk Information System (IRIS), searched in July 1991 and, if not available there, from the *Health Effects Assessment Summary Tables* (HEAST, 1991). Oral SFs and RfDs were used instead of the corresponding inhalation values because they exist for more chemicals; however, inhalation data was reviewed to ensure that contaminants with significantly greater inhalation than oral toxicity were not omitted as contaminants of concern. Compounds were also classified according to whether they were volatile organic compounds (VOCs), metals, pesticides/polychlorinated biphenyls, or base/neutral and acid extractable compounds (BNAEs). These classifications correspond to the different general fate and transport properties of the compounds.

Contaminants for which no SFs were available, or contaminants classified in Category D (not classified as to carcinogenicity) in EPA's weight of evidence classification, were excluded from consideration as carcinogenic contaminants of concern.

An index was developed to rank environmental contaminants according to their relative potentials to create health risks. This index was calculated by taking the maximum detected concentration of each contaminant and dividing it by the oral reference dose (RfD) or taking the product of the maximum concentration and the oral SF. When added together, contaminants for which the maximum multiplied by the SF made up greater than 99 percent of the total of all indices were selected for consideration as carcinogenic contaminants of concern (those defined by EPA as Class A, B or C carcinogens). Similarly, contaminants for which the maximum divided by the RfD (added together) made up greater than 99 percent of the total noncarcinogenic index were selected for consideration as noncarcinogenic contaminants of concern. The values generated can be compared to potentially acceptable levels, but these indices do not represent real risks. Each value is a refined index that allows for selection of the contaminants that may pose a health threat at this site.

In order to concentrate this risk assessment on the compounds that have the greatest potential to cause a long-term health effect, only site-related compounds with the highest carcinogen and reference dose indices were chosen for quantitative evaluation. The discussion in the following sections describes the rationale behind the choices of some compounds of potential special interest on a site-by-site basis. The carcinogenic and noncarcinogenic contaminants of concern chosen represent at least 95 percent of all of their respective indices for site-related contaminants.

Compounds selected as contaminants of concern are shown in bold in the tables in the section for each site. Compounds not selected that are not discussed in the contaminants of concern section for each site were dismissed on the basis of low indices and/or low frequency of detection.

## 7.5 TOXICITY ASSESSMENT

This section of the baseline risk assessment provides information on the human health effects of site-specific contaminants of potential concern and provides a basis for the risk characterization presented in sections 7.6 and 7.7. Sections 7.6.4 and 7.7.4 provide information on environmental effects.

Evaluation of a chemical's potential for toxicity involves the examination of available data that relate observed toxic effects to the doses at which they occur. Generally, two categories of effects are considered in this part of a quantitative risk assessment:

- The potential for chemicals to initiate or promote cancers
- The potential acute or chronic non-carcinogenic effects of chemicals

In addition, qualitative information is provided on the potential for chemicals to cause developmental and reproductive health effects.

A wide variety of factors must be considered in using health effects data in qualitative or quantitative risk assessments. As discussed in later subsections, a variety of relationships may exist between dose and effects. Some chemicals display thresholds (i.e., doses below which the chemical does not cause an effect). In general, non-carcinogenic (acute or chronic systemic) effects are considered to have threshold dose values, while carcinogenic effects are considered not to have thresholds. Toxicity studies on non-carcinogenic effects focus on identifying where this threshold occurs. The threshold can be related to a RfD. A chronic RfD is an estimate of a daily exposure level for which people, including sensitive individuals, do not have an appreciable risk of suffering significant adverse health effects. Exposure doses above an RfD could cause adverse health effects. Studies of carcinogenicity tend to focus on identifying the slope of the linear portion of a curve of dose vs. response, where the specific response is the probability of cancer resulting. A plausible upper-bound value of the slope is called the SF. The product of the SF and the exposure dose is an estimate of the risk of developing cancer. In accordance with current EPA policy concerning carcinogens, any dose, no matter how small, has some associated response. This is more conservative than assuming a threshold effect in which a slope factor would only be applicable above a certain minimum dose. In this assessment, the assumption of no threshold was applied to all probable carcinogens. Table 7-1 defines the EPA categories of carcinogens.

Tables 7-2 and 7-3 summarize slope factors and reference doses for the contaminants of concern listed in Sections 7.6.1 and 7.7.1. Table 7-3 summarizes chronic and subchronic reference doses. Subchronic RfDs are appropriate for exposure durations ranging from two weeks to seven years (EPA, 1989a). Chronic RfDs are applicable to exposure durations greater than seven years. For this risk assessment, all exposures were considered to be long term (i.e., longer than seven years). Note that chronic RfDs are frequently an order of magnitude lower than the subchronic RfDs.

Developmental and reproductive toxicity can be important, particularly because the exposure durations required for this type of toxic endpoint are substantially shorter than are typically associated with carcinogenic effects or systemic effects from chronic exposure. Within this category are: teratogenesis, which is the potential to cause birth defects; reproductive toxicity, which can involve decreased fertility or decreases in the percentages of conceptions that lead to birth; and embryotoxicity, which can lead to decreased birth weight and size. Compounds exhibiting developmental and reproductive toxicity do not necessarily require a threshold dose in order to cause an effect. In this sense, these effects are more similar to carcinogenesis than systemic toxicity. In some cases, a compound will only cause developmental and reproductive effects if the exposure occurs when a woman is pregnant; other compounds appear to have a latency period before causing toxic effects. The toxicity profiles presented in Appendix C, Part I, describe the available evidence for teratogenicity, embryotoxicity, and reproductive effects.

Appendix C, Part I, provides toxicological profiles for all of the contaminants of concern. Primary sources of data for health effects of compounds of concern include:

- The EPA's *Integrated Risk Information System (IRIS) Data Base;* a computer search of the data base was made for the compounds of concern as part of this project.

## TABLE 7-1

## EPA WEIGHT-OF-EVIDENCE CATEGORIES FOR POTENTIAL CARCINOGENS

| EPA Category | Description of Category | Description of Evidence |
|---|---|---|
| Category A | Human Carcinogen | Sufficient evidence from epidemiology studies to support a causal association between exposure and human cancer. |
| Category B1 | Probable Human Carcinogen | Limited evidence of carcinogenicity in humans from epidemiology studies. |
| Category B2 | Probable Human Carcinogen | Sufficient evidence of carcinogenicity in animals, inadequate evidence of carcinogenicity in humans. |
| Category C | Possible Human Carcinogen | Limited evidence of carcinogenicity in animals; no data for humans. |
| Category D | Not Classified | Inadequate evidence of carcinogenicity in animals. |
| Category E | No Evidence of Carcinogenicity | No evidence for carcinogenicity in at least two adequate animal tests or in both epidemiology and animal studies. |

Source: EPA, 1989a.

TABLE 7-2

SLOPE FACTORS FOR CONTAMINANTS OF CONCERN

| Contaminant | Ingestion Slope Factor (mg/kg/day)-1 | Weight of Evidence Category | Source | Inhalation Slope Factor (mg/kg/day)-1 | Weight of Evidence Category | Source |
|---|---|---|---|---|---|---|
| Chromium (hexavalent) | — | — | — | 41 | A | I |
| Copper | — | — | — | — | — | — |
| Lead | — | B2 | I | — | B2 | I |
| Zinc | — | D | — | — | — | — |

I - IRIS, searched July 1991.
H - HEAST, 1991.

TABLE 7-3

REFERENCE DOSES FOR CONTAMINANTS OF CONCERN

| Contaminant | Chronic Reference Dose (mg/kg/day) | | | | Subchronic Reference Dose (mg/kg/day) | | | |
|---|---|---|---|---|---|---|---|---|
| | Ingestion | Source | Inhalation | Source | Ingestion | Source | Inhalation | Source |
| Chromium (hexavalent) | 0.005 | I | 0.0000006 | I | 0.02 | H | 0.000006 | H |
| Copper | 0.04 | H | — | — | 0.04 | H | — | — |
| Lead | — | — | — | — | — | — | — | — |
| Zinc | 0.2 | H | — | — | 0.2 | H | — | — |

I - IRIS, searched July 1991.
H - HEAST, 1991.

- Agency for Toxic Substances and Disease Registry (ATSDR) profiles for selected compounds (see multiple references under U.S. Public Health Service).

These profiles give an indication of how strong the evidence is for the RfDs and SFs, as well as a summary of the toxic effects associated with each compound.
The remainder of this section of the RI/PHEA is a site-by-site description of how the risk assessment process was applied and an evaluation of potential public health and environmental effects related to the RI/FS sites.

## 7.6 SITE 3, LANDFILL 3

This section describes the details of the risk assessment process as it was applied to Site 3, Landfill 3.

### 7.6.1 Selection of Contaminants of Concern for Site 3

Section 7.4 described the selection process for contaminants of concern. Tables 7-4 through 7-6 present the potential contaminants of concern evaluated using this process for Site 3, Landfill 3. Table 7-4 shows the noncarcinogenic selection process results, while the results for carcinogenic contaminants of concern are shown in Table 7-5. Contaminants shown in bold on the tables were selected as contaminants of concern. Table 7-6 shows the frequency of detection for all contaminants of potential concern. The information shown in these tables was used to choose these metals as contaminants of concern: chromium, copper, lead and zinc. Lead was chosen because it was above the previously promulgated maximum contaminant level (MCL) of 50 parts per billion (ppb) in some samples. Carbon disulfide in groundwater was assumed to be due to natural processes since it was present in all wells (see Section 5). The substances p,p'-DDT, mercury, 4-methylphenol, phenol, and toluene were found in only one surface water sample and were not found in the groundwater around Landfill 3 which is the source under investigation. This low frequency of detection is only one of several factors considered in the contaminant-of-concern selection process. Review of all these selection criteria, as delineated earlier in Section 7.4.2, resulted in elimination of p,p'-DDT, mercury, 4-methylphenol, phenol and toluene from consideration as contaminants of concern. Arsenic was not chosen as a contaminant of concern since it was found only once in a well which is upgradient of Landfill 3. This low detection frequency contributed to elimination of arsenic as a potential contaminant of concern.

### 7.6.2 Exposure Assessment

This section of the risk assessment identifies and describes potential receptors and reviews possible pathways related to the contaminants of concern identified in various media at Site 3, Landfill 3.

**7.6.2.1 Receptor Definition.** Four groups of potential receptors were considered in this exposure assessment: Fort Story personnel, future on-site construction workers, future residents living within Site 3, and animals or plants in the area. Animal and plant receptors are discussed in Section 7.6.4. The Facilities Coordinator for Fort Story has estimated that there are 25,000 day-time employees at Fort Story (Longmire, 1990). Although residential areas within a one-mile radius of Site 3 include areas of Fort Story and Virginia Beach (see Figure 1-3), these communities are hydraulically upgradient. Although, the remedial investigation indicated that groundwater in the area is suspected to be tidally influenced, the groundwater gradient in the vicinity of Landfill 3 is not expected to change significantly. Therefore, impact to surrounding residential communities is negligible.

The area surrounding Site 3 consists of training center buildings for base personnel, an impact zone for a detonation area, and undeveloped marshland. Few people live in the vicinity due to the

## TABLE 7-4

## CALCULATION OF REFERENCE DOSE INDEX FOR POTENTIAL CONTAMINANTS OF CONCERN IN GROUND AND SURFACE WATER SITE 3, LANDFILL 3

| Matrix | Constituent | Maximum (ppm) | Oral RfD | RfD Index (Conc/RfD) | Percent Total RfD Index |
|---|---|---|---|---|---|
| GW | Carbon Disulfide | 0.033 | 0.1 | 0.330 | —(a) |
| GW | Arsenic | 0.15 | 0.001 | 150 | —(a) |
| GW | **Chromium** | 0.03 | 0.005 | 6.000 | **29.5** |
| GW | **Copper** | 0.054 | 0.04 | 1.350 | **6.63** |
| GW | **Lead** | 0.12 | NA | NC | **NC** |
| GW | **Zinc** | 2.6 | 0.2 | 13.0 | **63.9** |
| | | SITE RELATED TOTAL | | **20.350** | **100** |
| CONTAMINANTS OF CONCERN AS A PERCENT OF TOTAL INDEX | | | | | **100** |
| SW | p,p'-DDT | 0.00008 | 0.0005 | 0.160 | —(a) |
| SW | **Copper** | 0.042 | 0.04 | 1.05 | **34.8** |
| SW | **Lead** | 0.085 | NA | NC | **NC** |
| SW | Mercury | 0.0002 | 0.0003 | 0.667 | —(a) |
| SW | **Zinc** | 0.38 | 0.2 | 1.90 | **63.0** |
| SW | 4-Methylphenol | 0.0035 | 0.05 | 0.070 | —(a) |
| SW | Phenol | 0.0052 | 0.6 | 0.009 | 0.288 |
| SW | Toluene | 0.011 | 0.2 | 0.055 | 1.83 |
| | | SITE RELATED TOTAL | | **3.014** | **100** |
| CONTAMINANTS OF CONCERN AS A PERCENT OF TOTAL INDEX | | | | | **97.9** |

GW = Groundwater
SW = Surface Water
NA = Not Available
NC = Not Calculated

(a) This contaminant was not considered site-related so its index was not used in the total. This was done to avoid skewing the index (see text).

Note: Constituents selected as non-carcinogenic contaminants of concern are shown in bold.

TABLE 7-5

CALCULATION OF CARCINOGEN INDEX FOR POTENTIAL CONTAMINANTS OF CONCERN IN GROUNDWATER AND SURFACE WATER
SITE 3, LAND FILL 3

| Matrix | Constituent | Maximum (ppm) | Oral Carcinogen Class | Oral Slope Factor | Carcinogen Index (Conc x SF) | Percent Total Carcinogen Index |
|---|---|---|---|---|---|---|
| GW | Carbon Disulfide | 0.033 | NA | NA | NC | NC |
| GW | Arsenic | 0.15 | A | 1.75 | 2.63E-01 | —(a) |
| GW | Chromium | 0.03 | A | NA | NC | NC |
| GW | Copper | 0.054 | NA | NA | NC | NC |
| GW | Lead | 0.12 | B2 | NA | NC | NC |
| GW | Zinc | 2.6 | NA | NA | NC | NC |
| | | SITE RELATED TOTAL | | | NC | NC |
| SW | p,p'-DDT | 0.00008 | B2 | 0.34 | 2.72E-05 | —(a) |
| SW | Copper | 0.042 | NA | NA | NC | NC |
| SW | Lead | 0.085 | B2 | NA | NC | NC |
| SW | Mercury | 0.0002 | NA | NA | NC | NC |
| SW | Zinc | 0.38 | NA | NA | NC | NC |
| SW | 4-Methylphenol | 0.0035 | C | NA | NC | NC |
| SW | Phenol | 0.0052 | D | NA | NC | NC |
| SW | Toluene | 0.011 | NA | NA | NC | NC |
| | | SITE RELATED TOTAL | | | NC | NC |

GW = Groundwater
SW = Surface Water
NA = Not Available
NC = Not Calculated

(a) This contaminant was not considered site-related so its index was not used in the total. This was done to avoid skewing the index (see text).

Note: Constituents selected as non-carcinogenic contaminants of concern would be shown in bold.

TABLE 7-6

FREQUENCY OF DETECTION OF POTENTIAL CONTAMINANTS OF CONCERN IN GROUND AND SURFACE WATER FOR FORT STORY SITE 3, LANDFILL 3

| Matrix | Constituent | Maximum (ppm) | Sample Point | Total Number of Hits | Total Number of Samples | Percentage of Hits |
|---|---|---|---|---|---|---|
| GW | Carbon disulfide | 0.033 | LF-1 | 5 | 5 | 100 |
| GW | Arsenic | 0.15 | LF-2 | 1 | 5 | 20 |
| GW | Chromium | 0.03 | GW-202 | 5 | 5 | 100 |
| GW | Copper | 0.054 | LF-2 | 4 | 5 | 80 |
| GW | Lead | 0.12 | LF-2 | 5 | 5 | 100 |
| GW | Zinc | 2.6 | LF-2 | 5 | 5 | 100 |
| SW | p,p'-DDT | 0.00008 | SW-201 | 1 | 3 | 33.3 |
| SW | Copper | 0.042 | SW-201 | 3 | 3 | 100 |
| SW | Lead | 0.085 | SW-201 | 2 | 3 | 66.7 |
| SW | Mercury | 0.0002 | SW-203 | 1 | 3 | 33.3 |
| SW | Zinc | 0.38 | SW-201 | 3 | 3 | 100 |
| SW | 4-methyl Phenol | 0.0035 | SW-203 | 1 | 3 | 33.3 |
| SW | Phenol | 0.0052 | SW-203 | 1 | 3 | 33.3 |
| SW | Toluene | 0.011 | SW-203 | 1 | 3 | 33.3 |

GW = Groundwater
SW = Surface Water

relatively remote setting. Although a municipal water system (City of Norfolk) serves the entire area, one production well was identified at Fort Story during previous investigations (USATHAMA, 1982). This production well serves as contingency water source, which has not been required to date.

**7.6.2.2 Current Potential Exposure Pathways.** As part of this risk assessment, potential exposure pathways associated with the identified receptors have been evaluated to determine whether they are complete. For a complete exposure pathway, three components must exist: 1) a source of a contaminant, 2) a suitable receptor, and 3) a route through which the contaminant can migrate from the source to the receptor. The route can include a release to media other than the source, and the receptor must be engaged in an activity that allows contaminants to be absorbed into the body. The potential pathways are divided into those that may currently exist and those that may exist in the future. These potential pathways take into account the media where contaminants have been found, including groundwater and soil, and media into which they may be released, including air. Table 7-7 provides summaries of potential human exposure pathways associated with Site 3. Section 7.6.4 discusses exposure pathways for ecologically significant species.

Current potential exposure pathways are those that may exist as a result of the current extent of contamination, combined with existing land use and activity patterns.

**Shallow Aquifer.** Currently, no complete and significant exposure pathways involve groundwater from the shallow aquifer. At this time, no known shallow groundwater use occurs within the confines of Fort Story. Because Fort Story and the surrounding areas are serviced by the City of Norfolk Water District, it is unlikely that any production well is actually used as a drinking water supply except in the event of an emergency (USATHAMA, 1982). Analyses of groundwater samples collected from monitoring wells (MWs) located along the landfill boundary and downgradient have revealed various contaminants (such as metals and volatile solvents) in some of the samples, but most of the positive results are at concentrations below the corresponding maximum contaminant levels (MCLs). However, no known shallow groundwater users are downgradient of the landfill, resulting in no impact at this time. The pathway involving use of the shallow aquifer is not currently complete.

**Surface Water.** Recent surface water sampling activities in three low-lying areas with ponded surface water (essentially puddles; see Figure 2-1) conducted by JMM and described in Section 2 of this document indicate that some low-level surface water contamination exists at one or more sampling points in the marsh. Further, field observations indicate the surface water depths are relatively shallow (less than 12 inches). These data are also reviewed in greater detail in the Ecological Risk Assessment (Section 7.6.4). Contaminants detected consist of a few metals (copper, lead, mercury and zinc) as well as toluene, p,p'-DDT, phenol and 4-methylphenol although several of these do not appear to be related to Site 3, Landfill 3 (see Section 7.6.1). Consequently, no complete human exposure pathway exists for site-related constituents associated with the surface water at Site 3. Due to the short duration of an exposure and low levels of contamination, the exposure to trespassers is considered to be low.

**Soil.** Ingestion or inhalation of contaminated soil or dust from Site 3 is not currently considered to be a complete pathway. Surface soil was not sampled, but available information indicates that the landfill was covered with clean soil at closure. Surface soil in Site 3 is generally vegetated and vacant. As no invasive construction activities are occurring or planned for this area that would lead to contact with buried soil and apparently no surface soil contamination exists, no current potential for exposure to contaminants that may be in deeper soil exists.

Table 7-7

Current and Future Exposure Pathway Summary
Site 3, Landfill 3

| Medium | Scenario | Activity | Type of Exposure | Probability of Exposure | Potentially Significant Pathway |
|---|---|---|---|---|---|
| GW (Shallow Aquifer) | Residents, Workers | Use as Drinking Water Source | Ingestion, Bathing | None to Low | No, unlikely due to salinity. To be conservative, this pathway was evaluated anyway. |
| | Casual Visitor, Casual Fisherman | Use as Drinking Water Source | Ingestion, Bathing | None | No |
| SW | Casual Visitor | Swimming | Incidental Ingestion | None to Low | No (no swimming in low-lying marsh area) |
| | | | Dermal Contact | None to Low | No (no swimming in low-lying marsh area) |
| | | Wading | Incidental Ingestion | Low | No |
| | | | Dermal Contact | Low | No |
| | Casual Fisherman | Wading (fishing) | Incidental Ingestion | None | No (no fish in low-lying marsh area) |
| | | | Dermal Contact | None | No (no fish in low-lying marsh area) |
| | | Fishing | Fish Ingestion (bioaccumulation) | None | No (no fish in low-lying marsh area) |
| SD | Casual Visitor | Wading | Incidental Ingestion | Low | No, due to low probability of exposure |
| | | | Dermal Contact | Low | No, due to low probability of exposure |
| | Casual Fisherman | Wading | Incidental Ingestion | None | No (no fish) |
| | | | Dermal Contact | None | No (no fish) |
| Soil | Residents | Living in hypothetical on-site home | Incidental Ingestion | Low | No (assumed clean) |
| | | | Dermal Contact | Low | No (assumed clean) |
| | | | Incidental Inhalation | Low | No (assumed clean) |
| | Construction Workers | Building hypothetical on-site home | Incidental Ingestion | Low | No data on deeper soil |
| | | | Dermal Contact | Low | No data on deeper soil |
| | | | Incidental Inhalation | Low | No data on deeper soil |
| | Casual Visitor | Walking | Incidental Ingestion | Low | No (assumed clean) |
| | | | Dermal Contact | Low | No (assumed clean) |
| | | | Incidental Inhalation | Low | No (assumed clean) |

**Air.** VOCs in the ground or surface water could diffuse upward and migrate to locations where the contaminants may be inhaled by humans. However, as the concentrations detected in both surface and groundwater samples are relatively low and not indicative of an adequate source for upward diffusion, this diminishes the significance of the potential pathway. Further, the VOC toluene found in one Site 3 surface water sample is not considered to be site-related since it was not found in any other surface water or groundwater samples. No direct discharges of groundwater are known. VOCs in groundwater passing under the marsh may be partially sealed from the surface by organic rich sediments usually found in marshes. The carbon disulfide found in all of the area wells appears to be naturally occurring. In addition, people generally spend little time within Site 3 and the downgradient marsh area. Consequently, this pathway is not considered complete.

**Summary of Current Potential Exposure Pathways.** Currently no complete, significant exposure pathways are associated with Site 3, Landfill 3.

**7.6.2.3 Future Potential Exposure Pathways.** Future potential exposure pathways are those that are not complete but could become complete in the future or those that are complete but exposure may increase in the future. The most common means by which a pathway could become complete are by the movement of contaminants over time or by changing land use patterns or activities. The potential for Site 3, Landfill 3, to be used for non-military purposes, as well as the nature of any such nonmilitary uses, is indeterminate. Potential exposure pathways were evaluated for constructing additional houses on-base directly on Site 3, Landfill 3, and installing wells in the shallow aquifer to supply these hypothetical houses with domestic water, as well as potential migration of contaminants to the deep aquifer.

**Shallow Aquifer.** If a well were installed in the shallow aquifer on Site 3, Landfill 3, for domestic purposes (e.g. to supply water for a house built on the landfill), the water could be used for showering and for drinking water, which would complete the pathway between the shallow aquifer and on-base residents. Since Fort Story is serviced by the City of Norfolk Water District, Fort Story is unlikely to place a drinking water well in the shallow aquifer, much less install one in the landfill at the center of suspected contamination. However, if the Army were to relinquish part or all of Fort Story, new residents might install wells in these locations. These residents, however, would be most likely to hook up to municipal water since the shallow aquifer is saline and unpalatable. Although this scenario will be analyzed, the aquifer yields water at a low rate and thus is not necessarily suitable for domestic purposes, especially since more prolific aquifers are at greater depths.

**Deep Aquifer.** The pathway between the shallow aquifer and underlying deeper aquifers (and, potentially, downgradient personnel in the vicinity of Site 3, Landfill 3) is not likely to be completed in the future. The presence of an underlying aquitard precludes downward migration of contaminants. Thus, while contaminants can possibly move through the aquitard and while it is not known if such movement occurs, the site-specific conditions for Site 3, Landfill 3, indicate that no significant contamination of the deep aquifer is likely.

**Surface Water.** Only low levels of contaminants exist in the Site 3, Landfill 3, area surface water (small ponds). These surface waters are also very shallow and most likely impacted by periods of precipitation. For these reasons, surface water is not considered further in the exposure assessment.

**Soil.** Future exposure to contaminants assumed to be present in subsurface landfill material and soil could occur if the contaminated material became exposed in the future through construction activities. Construction activity could involve dermal contact and incidental ingestion of contaminated soils and inhalation of fugitive dust. No current evidence regarding the level of contamination that might be present within the landfill exists. Thus, associated potential future exposures cannot be quantitatively evaluated. Therefore, excavation of Site 3, Landfill 3, may be of potential concern.

**Air.** The primary air pathways that could become complete in the future involve migration of VOCs into the basement of hypothetical house built on the landfill. Currently, the VOCs were detected in water that is sufficiently far from buildings with basements so they do not pose a threat. In addition, no present structures are located downgradient. However, if a new home were built on top of Site 3, Landfill 3, and if VOCs are present in the shallow groundwater and/or landfill material, this pathway may be significant. However, because no data exists to confirm or deny the presence of volatiles in the landfill material it is impossible to adequately address such a pathway. It will not be further addressed in this report. No surface discharges of groundwater contaminated by Site 3, Landfill 3, are known, so the air pathway is not considered complete (nor is it expected to become complete) under current groundwater flow conditions.

**Summary of Potential Future Exposure Pathways.** Exposure to contaminants in the shallow groundwater on base through its potential future use as a domestic water supply will be evaluated, but is unlikely to occur since the shallow aquifer is saline and may not yield adequate water for this to become a reality. Exposure to contaminants in the landfill should future excavation activities occur is also a potential concern. Subsurface migration of VOCs into buildings located over the landfill may also be a future exposure pathway.

**7.6.2.4 Quantification of Exposure Pathways.** This section presents a quantitative analysis of the maximum reasonable exposures that people could receive from the pathways that were deemed complete and significant in the previous sections. Under a reasonable maximum exposure scenario, an estimate is made of the maximum exposure that a single receptor is likely to encounter. The exposure scenarios are conservative but within the range of possible exposures. Appendix C, Part II, presents details of the exposure calculations.

The result of this section is the estimation of doses or intakes related to exposure. A dose is the estimated average amount of contaminant taken into the body per day, divided by body weight. Note that the dose calculated is for the period of exposure only. In the risk characterization section (Section 7.6.3), this dose will in some cases be converted to a weighted or lifetime average dose, where the dose is weighted as a function of the exposed period in an individual's life. Generally weighting is based on a 30-year residence time within a 70-year lifetime thus giving a factor of 30/70, but some scenarios involve a different exposure duration assumption. Without such weighting, the average dose represents an annualized daily dose and, in the present section, is referred to as the unweighted dose.

**Future Domestic Use of Water On Base.** If the Army were to close Fort Story in the future without performing a remedial action at Site 3, Landfill 3, residential housing could be constructed above areas with contaminated groundwater. If a resident were to use the shallow aquifer for his or her domestic water supply, exposure could result from ingestion of contaminants in the drinking water and dermal contact with contaminants during showering.

To determine the reasonable maximum exposure, contaminant concentrations in shallow groundwater were averaged for all five wells sampled by JMM. Where a compound was not detected, it was assumed to be present at half the detection limit. The concentration of each contaminant in a given well was taken as the concentration found during the JMM RI site investigation. The average concentration of each contaminant was taken as the upper 95 percent confidence interval about the mean (95 percent CI average) for all wells, as determined by the Student t test statistical procedure. Concentrations of the contaminants are assumed to be the same in the future as they are now. This assumption overestimates the concentrations of most compounds, due to effects such as leaching, dispersion and dilution these concentrations would be expected to decrease over time.

**Drinking Water Exposure.** The dose received from ingestion of water from a hypothetical well was estimated using Equation C-1 in Appendix C, Part II. Standard exposure parameters from EPA (EPA, 1989b) were used in this equation. Appendix C also provides inputs for the equation. Table 7-8 presents the resulting unweighted doses for the different groundwater contaminants of concern in Site 3, Landfill 3. Since the carbon disulfide detected in site groundwater samples was not considered significant site related contamination, no volatile components were evaluated in the potable water scenario. Thus no shower exposures via inhalation or dermal contact were considered since the metals chosen as contaminants of concern are not volatile and do not readily cross the outer layer of the skin (Klaassen, et al., 1986).

**Future Exposure to Soils.** Since no soil contamination is expected in the surface soil on the landfill, and no data is available for the landfill contents, no future exposure to contaminated soil could be quantitatively evaluated.

**7.6.2.5 Uncertainty Analysis.** This section describes the uncertainties associated with the exposure calculations presented in Section 7.6.2. The major assumptions underlying the models, the quality and suitability of the models, and the assumptions used in selecting the major inputs to the models are examined.

**Drinking Water Exposure.** The greatest uncertainty with the drinking water ingestion scenario is whether or not groundwater from the shallow aquifer will be used for this purpose in the future. While use of the shallow groundwater is possible, higher quality aquifers with much better yields exist at reasonable depths, making the shallow aquifer a relatively undesirable source of water. In addition, water service is available from the nearby municipal water district. The scenario assumed that current contaminant concentrations will persist in the future.

An additional uncertainty related to potential future groundwater exposure is related to the location of the future well relative to the contaminant concentrations used to evaluate this scenario. If the well is located closer to the actual source, the actual concentrations and resultant exposures may be higher, while the concentrations and exposures would be expected to be lower if the well were farther away from the source. The existing groundwater monitoring wells are located near the downgradient boundary of the landfill. This data was used for the risk assessment in the absence of wells installed inside the landfill boundaries. Therefore, the data used is considered representative of constituents leaving the landfill.

### 7.6.3 Risk Characterization

This section of the baseline risk assessment describes how the exposures calculated in Section 7.6.2 were converted into estimates of health risks. The two basic types of health risks were described in Section 7.4. These are the non-threshold carcinogenic risks, which are presumed to linearly increase as a function of dose at all doses, and the chronic non-carcinogenic effects, which are presumed to require a minimum (threshold) contaminant dose in order to occur. This section addresses these risks separately.

**7.6.3.1 Carcinogenic Risks.** The incremental carcinogenic risk is calculated for each exposure scenario in this section. The basic equation for calculating this risk is:

$$\text{Risk} = \text{Dose} \times \text{SF}$$

where SF is the slope factor in units of $(mg/kg/day)^{-1}$. A risk of $1 \times 10^{-6}$ is the target residual risk

## TABLE 7-8

## ESTIMATED EXPOSURE TO CONTAMINANTS IN GROUNDWATER SITE 3, LANDFILL 3

| Compound | 95% CI Average Concentration (μg/l) | Unweighted Ingestion Dose (mg/kg/day) |
|---|---|---|
| Chromium | 28 | 8.00E-04 |
| Copper | 42 | 1.20E-03 |
| Lead | 79 | 2.30E-03 |
| Zinc | 1600 | 4.60E-02 |

level for a Superfund site according to the NCP, although a residual risk as high as 1 x $10^{-4}$ can be acceptable under some circumstances. These risk guidelines may be used to gauge the risks at this site but they may not be applicable from a regulatory perspective since this is not a Superfund site.

The exposure dose used for estimating the cancer risk is the unweighted dose estimated in Section 7.6.2 multiplied by the ratio of the number of years of exposure to the 70 years of the average lifetime. This dose is called the lifetime average dose. For scenarios involving a residential population, the exposure duration was estimated to be 30 years. Since 90 percent of the American population lives in one home for less than 30 years (EPA, 1989b), this is a conservative assumption. Table 7-2 listed the slope factors.

**7.6.3.2 Chronic Health Risks.** The potential for chronic (non-carcinogenic) health effects was calculated in the form of hazard indices for each compound. A hazard index is the ratio of the dose due to exposure to the dose above which a compound may cause a health effect. The maximum dose considered to cause no adverse health effects is the RfD. Table 7-3 compiled RfDs for the different contaminants. If the total hazard index (which is the sum of the individual hazard indices for each uptake route) is less than one, no adverse health effects are likely to occur. If the total hazard index exceeds one, then health effects are possible through that uptake route. Because the incidence of chronic health effects depends on the dose received during the time of exposure (rather than the total lifetime dose that is applicable when estimating a cancer risk), the unweighted exposure doses calculated in Section 7.6.2 are appropriate for calculating hazard indices.

**7.6.3.3 Quantification of Health Risks.** The following sections present the estimated health risks associated with the potential exposures for Site 3, Landfill 3.

**Potential Drinking Water Exposure On Base.** Future residents living on Fort Story could be exposed to contaminants in the shallow aquifer through drinking water, although this is highly unlikely. Tables 7-9 and 7-10 present potential hazard indices and cancer risks associated with this pathway. For this scenario, the total hazard index was estimated to equal 0.4 with no attendant cancer risk since no carcinogenic contaminants of concern exist. The hazard index is less than one, so it is not considered significant. The main source of the non-carcinogenic risks are zinc and chromium.

**7.6.3.4 Uncertainty Analysis.** The total uncertainty associated with a risk estimate is the combination of the uncertainties associated with the exposure estimates and the uncertainties in the toxicity evaluation. Section 7.6.2 discusses the specific uncertainties associated with the exposure estimates. The discussion presented here focuses on the uncertainties in the toxicity evaluation and gives a perspective on the overall effect of uncertainties on the risk estimates for Site 3, Landfill 3. This discussion is of particular importance because the quantitative risk numbers presented in the previous discussion do not reflect the uncertainties presented here.The most important uncertainties associated with the toxicity evaluation are the absence of a quantitative dose-response relationship for developmental and reproductive effects, and the absence of slope factors and reference doses for some contaminants of concern. The developmental and reproductive toxicity of the contaminants of concern has generally not been quantitatively accounted for in performing the risk assessment because the dose-response relationship has generally not been characterized for the contaminants of concern. Another factor that could lead to an underestimate of the total potential risk at the site is the lack of RfDs or SFs for some contaminants of concern. In particular, the hazard index associated with exposure to contaminants in groundwater does not include the contribution of lead. Lead is also the only contaminant of concern which is classified as a carcinogen by the oral route. However, no slope factor has been developed for this metal.

## TABLE 7-9

## POTENTIAL FUTURE EXPOSURE TO CONTAMINANTS IN SITE 3, LANDFILL 3, GROUNDWATER: HAZARD INDEX

| Compound | Oral RfD (mg/kg/day) | Unweighted Ingestion Dose (mg/kg/day) | Hazard Index |
|---|---|---|---|
| Chromium | 5.00E-03 | 8.00E-04 | 0.16 |
| Copper | 4.00E-02 | 1.20E-03 | 0.03 |
| Lead | NA | 2.30E-03 | NC |
| Zinc | 2.00E-01 | 4.60E-02 | 0.23 |
| | | **TOTAL** | **0.42** |

NA = Not Available
NC = Not Calculated

TABLE 7-10

POTENTIAL FUTURE EXPOSURE TO CONTAMINANTS IN SITE 3, LANDFILL 3, GROUNDWATER: CANCER RISK

| Compound | Oral SF (mg/kg/day)-1 | Lifetime Average Ingestion Dose (mg/kg/day) | Cancer Risk |
|---|---|---|---|
| Chromium | NA | 3.43E-04 | NC |
| Copper | NA | 5.14E-04 | NC |
| Lead | NA | 9.86E-04 | NC |
| Zinc | NA | 1.97E-02 | NC |

NA = Not Available
NC = Not Calculated

This risk assessment overestimates the potential risks associated with the site in many ways. It is critical to remember that the risks associated with the future exposure pathways are only meaningful if the pathways are completed. For the pathways involving using shallow groundwater within the landfill area for drinking water, the probability that the pathway will be completed is very low.

The calculated exposures represent the reasonable maximum exposure that can be expected. Most of the parameters used in calculating the exposure, including the exposure point concentrations (the 95 percent CI averages from the field sample results), were selected with only a five to ten percent probability (based on current knowledge) that the resulting exposure would be underestimated as a result of that single choice of parameter. Concentrations of most contaminants are expected to decrease.

The slope factors are upper bound values for a fit of carcinogenicity data to a specific mathematical function (of which the function selected is generally conservative with respect to other mathematical functions that fit the data equally well). The slope factors and reference doses incorporate safety factors when extrapolating from animal data to humans (including sensitive individuals), although animals may be more sensitive to a given compound than people. Slope factors and reference doses typically have safety factors of 100 to 1,000.

**7.6.3.5 Summary of Risks.** Of the potential exposure pathways evaluated, none would produce significant risks.

### 7.6.4 Ecological Risk Evaluation for Site 3, Landfill 3

This section addresses the potential impacts and risks to aquatic and terrestrial biota associated with existing conditions at Fort Story Site 3, Landfill 3.

**7.6.4.1 Potential Pathways and Receptors.** Table 7-11 provides potential exposure pathways and associated ecological receptors at Site 3, Landfill 3. Of the several receptor-route pathways presented, only contact with ponded surface water in low-lying wetland areas downgradient of the landfill are considered complete and possibly significant. Landfill impact via this pathway requires that contaminants are present at the landfill, leaching into groundwater and released to downgradient surface water.

Section 7.3 provides a discussion of wildlife in the Fort Story area. Based on available fauna and flora inventories for the site, receptors of greatest significance are the nine plants of state-recommended special concern recorded as present at Fort Story. It is unknown whether these species occur in the area downgradient of Site 3, Landfill 3. Additionally several federal and/or state special designation species are reported to nest, hunt or reside in areas near Fort Story. Of these, the wider ranging bird species such as the bald eagle, the peregrine falcon and herons could utilize the site.

**7.6.4.2 Contaminants of Potential Environmental Concern.** Three rounds of samples have been collected at Site 3 Landfill. AEHA collected groundwater samples in 1977. In 1986, sampling of existing wells was attempted but two of three wells were not functional. Four additional wells to monitor Site 3 leachate movement were installed in 1988. JMM collected groundwater and surface water samples from the landfill and surrounding wetlands in 1990. All samples were analyzed for VOCs, BNAs, pesticides and metals. USAEHA 1977 and 1987 data coincide with JMM data; JMM data for Site 3, Landfill 3 are provided in Section 5. All compounds detected in Site 3, Landfill 3 samples were retained for consideration of ecological risks.

Table 7-11

Ecological Pathways
Fort Story - Site 3 Landfill

| Medium | Potential Receptors | Exposure Route | Comments |
|---|---|---|---|
| Soil | Deer<br>Rodents<br>Birds | Browsing<br>Burrowing<br>Feeding on Rodents | Landfill capped (assumed 2 ft of soil) with clean soil thus pathways expected to be incomplete. |
| Groundwater Discharge to pond or surrounding wetlands | None | None | No direct exposure. See Surface Water entry for Site 3 and Site 3A. |
| Surface Water in downgradient forested wetlands | Animals using wetlands<br><br>Vegetation | Ingestion/Dermal Contact<br><br>Transpiration | Many species of invertebrates, amphibians, reptiles, birds, and mammals utilize forested wetlands. This pathway will be qualitatively discussed using surface water and groundwater data from the area. |
| Soil in downgradient wetlands | Vegetation<br><br>Animals using wetlands | Transpiration<br><br>Ingestion/Dermal Contact | Contamination of these soils by landfill runoff prior to capping is possible; however, no areas of stressed vegetation have been noted. This pathway is not considered significant. |

#### 7.6.4.3 Toxicity of Contaminants of Potential Environmental Concern.

The following sections review the levels of contaminants found at the site to published values that are considered potentially acceptable.

**Groundwater and Surface Water.** The potential biological effects of contaminants of concern in groundwater and surface water were evaluated by comparing the observed contaminant concentrations to Drinking Water Standards (DWS). Conservative assumptions used in the development of these standards lead to risk-based DWS protective of sensitive subpopulations of humans and are over-protective of the general population. The comparison of site data to these standards is used as a reasonable screening level assessment of risk to terrestrial biota. Table 7-12 presents the maximum concentrations of compounds detected at Site 3 and corresponding DWS.

#### 7.6.4.4 Evaluation of Potential Risks.

Comparison of site data with DWS shows that lead content in one of seven groundwater samples and one of three surface water samples exceed the DWS. The significance of these exceedances is limited by the low number of samples in which exceedances are reported, the small margin by which these samples exceeded the DWS for lead,and the low likelihood that wildlife in the area would obtain a significant portion of water intake from a ponded area with elevated concentrations of lead. Considering that assumptions used in the development of DWS include the consumption of two liters of water per day over a 70-year lifetime and the relatively limited intake of water by wildlife, significant impacts to wildlife are not expected.

No DWS for the five organic compounds are reported in Table 7-12. However, risks to biota occasionally encountering these compounds at concentrations such as those observed are not expected. Toluene and phenol concentrations are below available Ambient Water Quality Criteria (AWQC). These criteria are derived to be protective of a broad spectrum of aquatic organisms, thus concentrations below these values should pose no risk to biota occasionally encountering ponded water. Observed 4-methyl phenol concentrations were far below the AWQC for phenol that would likely be sufficient criteria for the toxicologically similar 4-methyl phenol. The observed value for p,p'-DDT is below the acute AWQC for this compound so occasional exposure would also not be expected to impact ecological receptors. Carbon disulfide is the only one of these organic compounds consistently detected in more than one sample. This compound is naturally occurring; biogenic carbon disulfide emission from soils and it was detected at comparable concentrations at other Fort Story landfills (i.e., Landfill 1 and 2). Further, the concentrations reported are below concentrations producing biological effects in fish and man (Verschueren, 1983). Therefore, carbon disulfide was not selected as a site related contaminant for the human health or ecological risk assessment.

## 7.7 SITE 3A, POND ADJACENT TO LANDFILL 3

This section describes the details of the risk assessment process as it was applied to Site 3A.

### 7.7.1 Selection of contaminants of concern for Site 3A

Section 7.4 describes the selection process for contaminants of concern. Tables 7-13 through 7-15 present the potential contaminants of concern evaluated using this process. Table 7-13 shows the noncarcinogenic selection process results, while the results for carcinogenic contaminants of concern are shown in Table 7-14. The frequency of detection is shown in Table 7-15. The information shown in these tables was used to choose zinc as the only contaminant of concern for Site 3A surface water. Copper, chromium, lead and zinc were selected for Site 3A sediment. Since the contamination that may be present in the Site 3A pond due to the presence of Landfill 3 is assumed to come from the Site 3 groundwater, the selection of contaminants of concern for Site 3A can be influenced by the contaminants of concern in the secondary source medium (Site 3 groundwater).

TABLE 7-12

SURFACE WATER DATA SUMMARY FOR
ECOLOGICAL ASSESSMENT - FORT STORY, SITE 3

| Constituent | Surface Water Maximum (ppm) | Times Detected in 3 Samples | Groundwater Maximum (ppm) | Times Detected in 5 Samples | Drinking Water Standard (ppm) |
|---|---|---|---|---|---|
| Arsenic | not detected | not detected | 0.15 | 1 | 0.05 |
| Chromium | not detected | not detected | 0.03 | 5 | 0.05 |
| Copper | 0.042 | 3 | 0.054 | 4 | 1 |
| Lead | 0.085 | 2 | 0.12 | 5 | 0.05 |
| Mercury | 0.0002 | 1 | not detected | not detected | 5 |
| Zinc | 0.38 | 3 | 2.6 | 5 | 5 |
| Carbon Disulfide | not detected | not detected | 0.033 | 5 | |
| Toluene | 0.011 | 1 | not detected | not detected | |
| Phenol | 0.0052 | 1 | not detected | not detected | |
| 4-Meyhylphenol | 0.0035 | 1 | not detected | not detected | |
| p,p'-DDT | 0.00008 | 1 | not detected | not detected | |

TABLE 7-13

CALCULATION OF REFERENCE DOSE INDEX FOR POTENTIAL CONTAMINANTS OF CONCERN IN SURFACE WATER AND SEDIMENT, SITE 3A

| Matrix | Constituent | Maximum (ppm) | Oral RfD | RfD Index (Conc/RfD) | Percent Total RfD Index |
|---|---|---|---|---|---|
| SW | Acetone | 0.016 | 0.1 | 0.160 | —[a] |
| SW | Lead | 0.004 | NA | NC | NC |
| SW | **Zinc** | 0.022 | 0.2 | 0.110 | **100** |
| | | SITE RELATED TOTAL | | **0.110** | **100** |
| CONTAMINANTS OF CONCERN AS A PERCENT OF TOTAL INDEX | | | | | **100** |
| SD | **Chromium** | 3.2 | 0.005 | 640 | **92.8** |
| SD | **Copper** | 1.4 | 0.04 | 35 | **5.07** |
| SD | **Lead** | 3.8 | NA | NC | **NC** |
| SD | **Zinc** | 3 | 0.2 | 15 | **2.17** |
| | | TOTAL | | **690** | **100** |
| CONTAMINANTS OF CONCERN AS A PERCENT OF TOTAL INDEX | | | | | **100** |

SW = Surface Water
SD = Sediment
NA = Not Available
NC = Not Calculated

(a) This contaminant was not considered site-related so its index was not used in the total. This was done to avoid skewing the index (see text).

Note: Constituents selected as non-carcinogenic contaminants of concern are shown in bold.

TABLE 7-14

CALCULATION OF CARCINOGEN INDEX FOR POTENTIAL CONTAMINANTS OF CONCERN IN SURFACE WATER AND SEDIMENT, SITE 3A

| Matrix | Constituent | Maximum (ppm) | Oral Carcinogen Class | Oral Slope Factor | Carcinogen Index (Conc x SF) | Percent Total Carcinogen Index |
|---|---|---|---|---|---|---|
| SW | Acetone | 0.016 | NA | NA | NC | NC |
| SW | Lead | 0.004 | B2 | NA | NC | NC |
| SW | **Zinc** | 0.022 | NA | NA | NC | NC |
| | | | | TOTAL | NC | NC |
| CONTAMINANTS OF CONCERN AS A PERCENT OF TOTAL INDEX | | | | | | NC |
| SD | **Chromium** | 3.2 | A | NA | NC | NC |
| SD | **Copper** | 1.4 | NA | NA | NC | NC |
| SD | **Lead** | 3.8 | B2 | NA | NC | NC |
| SD | **Zinc** | 3 | NA | NA | NC | NC |
| | | | | TOTAL | NC | NC |
| CONTAMINANTS OF CONCERN AS A PERCENT OF TOTAL INDEX | | | | | | NC |

SW = Surface Water
SD = Sediment
NA = Not Available
NC = Not Calculated

Contaminants of concern are shown in bold.

## TABLE 7-15

## FREQUENCY OF DETECTION OF POTENTIAL CONTAMINANTS OF CONCERN IN SURFACE WATER AND SEDIMENT FOR FORT STORY, SITE 3A

| Matrix | Constituent | Maximum (ppm) | Sample Point | Total Number of Hits | Total Number of Samples | Percentage of Hits |
|---|---|---|---|---|---|---|
| SW | Acetone | 0.016 | SW-206 | 1 | 3 | 33.3 |
| SW | Lead | 0.004 | SW-204 | 1 | 3 | 33.3 |
| SW | Zinc | 0.022 | SW-204 | 3 | 3 | 100 |
| SD | Chromium | 3.2 | SD-202 | 4 | 5 | 80 |
| SD | Copper | 1.4 | SD-204 | 4 | 5 | 80 |
| SD | Lead | 3.8 | SD-202 | 5 | 5 | 100 |
| SD | Zinc | 3 | SD-202 | 3 | 5 | 60 |

SW = Surface Water
SD = Sediment

### 7.7.2 Exposure Assessment

This section of the risk assessment identifies and describes potential receptors and reviews possible pathways related to the contaminants of concern identified in various media at Site 3A.

**7.7.2.1 Receptor Definition.** Four groups of potential receptors were considered in this exposure assessment: Fort Story personnel, future on-site construction workers, future residents living within the Site 3A area, and animals or plants in the area. Section 7.7.4 discusses animal and plant receptors. Section 7.6 describes the population of Fort Story. Although residential areas within a one-mile radius of Site 3A include portions of Fort Story and Virginia Beach (see Figure 3-1), these communities are hydraulically upgradient. The area surrounding Site 3A, consists of marshy lowlands with few gathering points (e.g. buildings or other facilities) for base personnel.

**7.7.2.2 Current Potential Exposure Pathways.** As part of this risk assessment, potential exposure pathways associated with the identified receptors have been evaluated to determine whether they are complete. For a complete exposure pathway, three components must exist: 1) a source of a contaminant, 2) a suitable receptor, and 3) a route through which the contaminant can migrate from the source to the receptor. The route can include a release to media other than the source, and the receptor must be engaged in an activity that allows contaminants to be absorbed into the body. The potential pathways are divided into those that may currently exist and those that may exist in the future. These potential pathways take into account the media where contaminants have been found, including surface water and sediment, and media into which they may be released, including air. Table 7-16 provides a summary of potential human exposure pathways associated with Site 3A. Section 7.7.4 discusses exposure pathways for ecologically significant species. Current potential exposure pathways are those that may exist as a result of the current extent of contamination, combined with existing land use and activity patterns.

**Surface Water and Sediments.** Recent surface water and sediment sampling activities conducted in Site 3A described in Section 3 of this document indicate some low-level surface water and sediment contamination at one or more sampling points in the pond. These data are also reviewed in greater detail in the Ecological Risk Assessment (Section 7.7.4). Contaminants detected consist of a few metals (lead and zinc in water, and copper, chromium, lead and zinc in sediments). As described in Section 5, the acetone found in one sample of Site 3A surface water is assumed to be due to external contamination of the sample. Aquatic activities such as fishing are known to occur in this pond. Although a boat was tied to the shore during the JMM site visit, fisherman may wade in the water while fishing. Consequently, a complete human exposure pathway for site-related constituents is associated with the water and sediments of this pond.

**Fish Ingestion.** Fishermen are known to visit Site 3A. The fish caught could be consumed.

**Air.** VOCs in the surface water could potentially diffuse upward and migrate to locations where the contaminants may be inhaled by humans. However, no site-related VOCs are assumed to be present in Site 3A surface water, and people generally spend very little time within Site 3A. Consequently, this pathway is not complete.

**Summary of Current Potential Exposure Pathways.** Currently two complete, significant exposure pathways are within Site 3A: exposure to surface water and sediments via direct contact and ingestion of potentially contaminated fish.

**7.7.2.3 Future Potential Exposure Pathways.** Future potential exposure pathways are those that are not currently complete but could become complete in the future or those that are currently complete but exposure may increase in the future. The most common means by which a

## Table 7-16

## Fort Story Exposure Pathway Summary at Site 3A, Pond Adjacent to Landfill 3

| Medium | Scenario | Activity | Type of Exposure | Probability of Exposure | Potentially Significant Pathway |
|---|---|---|---|---|---|
| GW | Residents, Workers | Use as Drinking Water Source | Ingestion, Bathing | None to Low | No (refer to Site 3) |
| | Casual Visitor, Casual Fisherman | Use as Drinking Water Source | Ingestion, Bathing | None to Low | No (refer to Site 3) |
| SW | Residents, Workers | Use as Drinking Water Source | Ingestion, Bathing | None to Low | No |
| | Casual Visitor | Swimming | Incidental Ingestion | None to Low | No |
| | | | Dermal Contact | None to Low | No |
| | | Wading | Incidental Ingestion | Moderate | Yes |
| | | | Dermal Contact | Moderate | Yes |
| | Casual Fisherman | Wading/Fishing | Incidental Ingestion | Moderate | Yes (same as Casual Visitor) |
| | | | Dermal Contact | Moderate | Yes (same as Casual Visitor) |
| | | Fishing | Fish Ingestion (bioaccumulation) | Moderate | Yes |
| SD | Casual Visitor | Wading | Incidental Ingestion | Moderate | Yes |
| | | | Dermal Contact | Moderate | Yes |
| | Casual Fisherman | Wading/Fishing | Incidental Ingestion | Moderate | Yes |
| | | | Dermal Contact | Moderate | Yes |

GW = Groundwater
SW = Surface Water
SD = Sediment

pathway could become complete are by the movement of contaminants over time or by changing land use patterns or activities. At this time, the potential for Fort Story Site 3A to be used for non-military purposes, as well as the nature of any such non-military uses, is indeterminate. Potential exposure pathways were evaluated for constructing additional houses on-base in the Site 3 sub-sections earlier in this section. If this occurs, a change could occur in the frequency of use of Site 3A for fishing, but this is considered unlikely due to the proximity to other, better fishing areas such as large rivers and the ocean. Since Site 3A is located in a low-lying wetland area it is unlikely that any homes will be built immediately adjacent to the pond.

**Surface Water and Sediments.** Currently, only low levels of contaminants exist in the Site 3A surface water and sediments. Evidence suggests that contamination in the surface water should increase in the future. Furthermore, the water is murky and chlorinated swimming pools are available on-base, so swimming is unlikely. However, fishing occurs in this pond. For this reason, surface water and sediments are considered in the exposure assessment under current pathways.

**Fish Ingestion.** Future exposure to fish is assumed to be similar to the current fishing scenario, as explained earlier.

**Air.** The primary air pathways that could become complete in the future involve inhalation of VOCs volatilizing from surface water. However, since no site-related VOCs are assumed to be present in Site 3A, this pathway will not be further addressed.

**Summary of Potential Future Exposure Pathways.** Exposure to contaminants in the surface water and sediment while fishing (by wading in the water) and the ingestion of potentially contaminated fish are the only likely future pathways.

**7.7.2.4 Quantification of Exposure Pathways.** This section presents a quantitative analysis of the maximum reasonable exposures that people could potentially receive from the pathways that were deemed complete and significant in the previous sections. Under a reasonable maximum exposure scenario, an estimate is made of the maximum exposure that a single receptor is likely to encounter. The exposure scenarios are conservative but within the range of possible exposures. Appendix C, Part II, presents details of the exposure calculations.

The result of this section is the estimation of doses or intakes related to exposure. A dose is the estimated average amount of contaminant taken into the body per day, divided by body weight. Note that the dose calculated is for the period of exposure only. In the risk characterization section (Section 7.7.3), this dose will in some cases be converted to a weighted or lifetime average dose, where the dose is weighted as a function of the exposed period in an individual's life. Generally, weighting is based on a 30-year residence time within a 70-year lifetime, thus giving a factor of 30/70. But some scenarios involve a different exposure duration assumption. Without such weighting, the average dose represents an annualized daily dose and, in this section, is referred to as the unweighted dose.

**Surface Water and Sediment Exposure.** This type of exposure is assumed to occur through wading. The doses calculated for this route are shown in Table 7-17 for surface water and Table 7-18 for sediment.

**Fish Ingestion.** Table 7-19 shows exposures calculated for this pathway.

**7.7.2.5 Uncertainty Analysis.** This section describes the uncertainties associated with the exposure calculations presented in Section 7.7.2. The major assumptions underlying the models, the quality and suitability of the models, and the assumptions used in selecting the major inputs to the models are examined.

TABLE 7-17

ESTIMATED EXPOSURE TO CONTAMINANTS
IN SURFACE WATER, SITE 3A

| Compound | 95% CI Average Concentration (μg/l) | Unweighted Ingestion Dose (mg/kg/day) | Unweighted Dermal Dose (mg/kg/day) |
|---|---|---|---|
| Zinc | 21 | 8.22E-07 | * |

*Penetration Factor of Metals = 0

## TABLE 7-18

## ESTIMATED EXPOSURE TO CONTAMINANTS IN SEDIMENT, SITE 3A

| Compound | 95% CI Average Concentration (mg/kg) | Unweighted Ingestion Dose (mg/kg/day) | Unweighted Dermal Dose (mg/kg/day) |
|---|---|---|---|
| Chromium | 2.69 | 2.11E-07 | 2.35E-05 |
| Copper | 1.33 | 1.05E-07 | 1.17E-05 |
| Lead | 3.00 | 2.34E-07 | 2.62E-05 |
| Zinc | 2.97 | 2.33E-07 | 2.60E-05 |

## TABLE 7-19

## ESTIMATED EXPOSURE TO CONTAMINANTS IN FISH AND SHELLFISH, SITE 3A

| Compound | 95% CI Average Concentration (mg/kg) | Unweighted Fish Ingestion Dose (mg/kg/day) |
|---|---|---|
| Chromium | 2.691 | 2.73E-04 |
| Copper | 1.335 | 1.35E-04 |
| Lead | 2.995 | 3.04E-04 |
| Zinc | 2.971 | 3.01E-04 |

**Surface Water and Sediment Exposure.** The greatest uncertainty with the surface water and sediment exposures calculated are related to the actual frequency of contact and the amount of contaminant that crosses the skin barrier during contact. In addition, the fact that Site 3A sediment samples, except for the VOC fraction, were composited from six-foot deep (or greater) cores means that the data derived from these samples may not represent the surficial layers to which waders, fishermen and biota are going to be exposed.

**Fish Ingestion Exposure.** The major uncertainty involved in the fish ingestion scenario is the actual concentrations of contaminants in the fish. Sediment concentrations were used as a worst-case scenario. Since metals, in general, do not bioconcentrate, it is unlikely that the fish in the pond will contain levels as high as the sediments. Thus the levels used to calculate the risk are likely to be overestimates.

### 7.7.3 Risk Characterization

This section of the baseline risk assessment describes how the exposures calculated in Section 7.7.2 were converted into estimates of health risks. Two basic types of health risks exist, which were described in Section 7.4. These are the non-threshold carcinogenic risks, which are presumed to linearly increase as a function of dose at all doses, and the chronic non-carcinogenic effects, which are presumed to require a minimum (threshold) contaminant dose in order to occur. This section addresses these risks separately.

**7.7.3.1 Carcinogenic Risks.** The incremental carcinogenic risk is calculated for each exposure scenario in this section. Section 7.6.3 explains the basic equation for calculating this risk. Dermal exposure was assumed to affect the same target organs as oral exposure, and therefore the oral SF was used for this exposure route.

The exposure dose used for estimating the cancer risk is the unweighted dose estimated in Section 7.7.2 multiplied by the ratio of the number of years of exposure to the 70 years of the average lifetime. This dose is called the lifetime average dose. For scenarios involving a residential population, the exposure duration was estimated to be 30 years. Since 90 percent of the American population lives in one home for less than 30 years (EPA, 1989b), this is a conservative assumption. Table 7-2 listed the slope factors used.

**7.7.3.2 Chronic Health Risks.** The potential for chronic (non-carcinogenic) health effects was calculated in the form of hazard indices for each compound. A hazard index is the ratio of the dose due to exposure to the dose above which a compound may cause a health effect. The maximum dose considered to cause no adverse health effects is the RfD. Table 7-3 compiled RfDs for the different contaminants. If the total hazard index (which is the sum of the individual hazard indices for each uptake route) is less than one, then no health effects are likely to occur. If the total hazard index exceeds one, then health effects are possible through that uptake route. The oral RfD was applied to dermal exposure for the same reason that the oral SF was used for this route. Because the incidence of chronic health effects depends on the dose received during the time of exposure (rather than the total lifetime dose that is applicable when estimating a cancer risk), the unweighted exposure doses calculated in Section 7.7.2 are appropriate for calculating hazard indices.

**7.7.3.3 Quantification of Health Risks.** The following sections present the estimated health risks associated with the potential exposures for Site 3A.

**Surface Water and Sediment Exposure.** Surface water and sediment contact was estimated based on the assumptions presented in Appendix C, Part II. Tables 7-20 and 7-21 present potential hazard indices and cancer risks associated with the surface water. Tables 7-22 and 7-23 present potential non-carcinogenic and carcinogenic risks for sediment. The hazard index estimation for surface water is about 0.000004, with no cancer risk expected. For the sediment contact scenario, the total hazard index was estimated to equal 0.005, which is not significant. The main source of the non-carcinogenic risks is chromium (dermal contact). No attendant carcinogenic risks exist since there are no carcinogenic contaminants of concern.

**Fish Ingestion.** Hazard indices and cancer risk estimates are presented in Tables 7-24 and 7-25. The resulting hazard index was estimated to equal 0.06, which is not significant. No carcinogenic contaminants of concern are in this pathway, thus no carcinogenic risks are calculated. Chromium was assumed to be in its hexavalent oxidation state when making these risk estimates, which means that since this form of chromium is unlikely in Site 3A soil/sediment and thus in fish, they may be significant overestimates.

The overall hazard index was calculated without an RfD for lead. For a fish concentration of 3 mg/kg, blood level concentration calculated by EPA's Biokinetic Model did not exceed the acceptable benchmark for lead in children. It should be noted that the Biokinetic Model does not specifically address exposure to sediments. As an alternative, the sediment data were entered into the model as soil data.

**7.7.3.4 Uncertainty Analysis.** The total uncertainty associated with a risk estimate is the combination of the uncertainties associated with the exposure estimates and the uncertainties in the toxicity evaluation. Section 7.3.5 discusses the specific uncertainties associated with the exposure estimates. The discussion presented in this section focuses on the uncertainties in the toxicity evaluation and gives a perspective on the overall effect of uncertainties on the risk estimates for Site 3A. The discussion presented in this section is of particular importance because the quantitative risk numbers presented in the previous discussion do not reflect the uncertainties presented here.

The most important uncertainties associated with the toxicity evaluation are the absence of a quantitative dose-response relationship for developmental and reproductive effects, and the absence of slope factors and reference doses for some contaminants of concern as discussed earlier.

This risk assessment overestimates the potential risks associated with the site in many ways. It is critical to remember that the risks associated with the future exposure pathways are only meaningful if the pathways are still completed.

In most cases the calculated exposures represent the reasonable maximum exposure that can be expected. Most of the parameters used in calculating the exposure, including the exposure point concentrations, were selected so that there was only a five to 10 percent probability (based on current knowledge) that the resulting exposure would be underestimated as a result of that single choice of parameter. Concentrations of most contaminants are expected to decrease.

The slope factors are upper bound values for a fit of carcinogenicity data to a specific mathematical function (of which the function selected is generally conservative with respect to other mathematical functions that fit the data equally well). Both the slope factors and reference doses incorporate safety factors when extrapolating from animal data to humans (including sensitive individuals), although animals may be more sensitive to a given compound than people. Slope factors and reference doses typically have safety factors of 100 to 1,000.

TABLE 7-20

POTENTIAL PRESENT EXPOSURE TO CONTAMINANTS IN SITE 3A SURFACE WATER: HAZARD INDEX

| Compound | Oral RfD (mg/kg/day) | Unweighted Ingestion Dose (mg/kg/day) | Hazard Index |
|---|---|---|---|
| Zinc | 0.2 | 8.22E-07 | 4.1E-06 |

TABLE 7-21

POTENTIAL PRESENT EXPOSURE TO CONTAMINANTS
IN SITE 3A SURFACE WATER: CANCER RISK

| Compound | Oral SF (mg/kg/day)-1 | Lifetime Average Ingestion Dose (mg/kg/day) | Cancer Risk |
|---|---|---|---|
| Zinc | NA | 3.52E-07 | NC |

## TABLE 7-22

## POTENTIAL PRESENT EXPOSURE TO CONTAMINANTS IN SITE 3A SEDIMENT: HAZARD INDEX

| Compound | Oral RfD (mg/kg/day) | Unweighted Ingestion Dose (mg/kg/day) | Hazard Index | Unweighted Dermal Dose (mg/kg/day) | Hazard Index | Total Hazard Index |
|---|---|---|---|---|---|---|
| Chromium | 0.005 | 2.11E-07 | 4.22E-05 | 2.35E-05 | 0.0047 | 0.005 |
| Copper | 0.04 | 1.05E-07 | 2.63E-06 | 1.17E-05 | 0.00029 | 0.0003 |
| Lead | NA | 2.34E-07 | NC | 2.62E-05 | NC | NC |
| Zinc | 0.2 | 2.33E-07 | 1.17E-06 | 2.60E-05 | 0.00013 | 0.0001 |
| | | | | | **TOTAL** | **0.005** |

NA = Not Available
NC = Not Calculated

TABLE 7-23

POTENTIAL PRESENT EXPOSURE TO CONTAMINANTS IN SITE 3A SEDIMENT: CANCER RISK

| Compound | Oral SF (mg/kg/day)-1 | Lifetime Average Ingestion Dose (mg/kg/day) | Cancer Risk | Lifetime Average Dermal Dose (mg/kg/day) | Cancer Risk | Total Cancer Risk |
|---|---|---|---|---|---|---|
| Chromium | NA | 9.04E-08 | NC | 1.01E-05 | NC | NC |
| Copper | NA | 4.50E-08 | NC | 5.01E-06 | NC | NC |
| Lead | NA | 1.00E-07 | NC | 1.12E-05 | NC | NC |
| Zinc | NA | 9.99E-08 | NC | 1.11E-05 | NC | NC |

NA = Not Available
NC = Not Calculated

TABLE 7-24

POTENTIAL PRESENT EXPOSURE TO CONTAMINANTS IN SITE 3A FISH TISSUE: HAZARD INDEX

| Compound | Oral RfD (mg/kg/day) | Unweighted Ingestion Dose (mg/kg/day) | Hazard Index |
|---|---|---|---|
| Chromium | 5.00E-03 | 2.73E-04 | 0.05 |
| Copper | 4.00E-02 | 1.35E-04 | 0.003 |
| Lead | NA | 3.04E-04 | NC |
| Zinc | 2.00E-01 | 3.01E-04 | 0.002 |

NA = Not Available
NC = Not Calculated

TABLE 7-25

POTENTIAL PRESENT EXPOSURE TO CONTAMINANTS IN SITE 3A FISH TISSUE: CANCER RISK

| Compound | Oral SF (mg/kg/day)-1 | Lifetime Average Ingestion Dose (mg/kg/day) | Cancer Risk |
|---|---|---|---|
| Chromium | NA | 1.17E-04 | NC |
| Copper | NA | 5.79E-05 | NC |
| Lead | NA | 1.30E-04 | NC |
| Zinc | NA | 1.29E-04 | NC |

NA = Not Available
NC = Not Calculated

The slope factors for all of the carcinogens were derived under the assumption that no threshold dose exists for carcinogenic effects. This assumption is based on the theory that cancer is caused by mutations to DNA, that cancer risks increase in direct proportion to the number of mutations, and consequently, cancer risks for a chemical that acts directly on the DNA (or is "genotoxic") will increase in direct proportion to the chemical dose.

**7.7.3.5 Summary of Risks.** Of the potential exposure pathways evaluated, surface water and sediment and ingestion of fish, none are expected to pose a significant risk to public health. Hazard index estimations for dermal exposure to surface water and sediment are several orders of magnitude below the benchmark of one, thus, indicating little potential for adverse impacts to public health.

Future worst-case exposure calculations for fish ingestion assumed that concentrations detected in the sediment would correspond to levels in edible fish tissue. The detected metals, chromium, copper, lead and zinc would not be expected to bioconcentrate, therefore, levels in fish tissue would be relatively lower than those detected in sediment (Eisler, 1986; Connell, et al., 1984; EPA, 1986). In addition, chromium, copper and zinc are considered essential nutrients to biological organisms further reducing their significance to public health. This overestimate of risk via ingestion of fish did not produce a significant public health risk.

### 7.7.4 Ecological Risk Evaluation for Site 3A

This section addresses the potential impacts and risks to aquatic and terrestrial biota associated with existing conditions at Fort Story Site 3A Pond.

**7.7.4.1 Potential Pathways and Receptors.** Possibly significant pathways at Site 3A involve the contact of aquatic organisms with pond water and/or sediments and the use of the pond by terrestrial organisms. Table 7-26 provides these potential exposure pathways and associated ecological receptors at Site 3A. Plants and wildlife can be affected by contacting or ingesting contaminants from water or sediments. Contaminated sediments can also affect ecological receptors by serving as a source that can maintain contaminant concentrations in surface waters. Discharge to the pond by groundwater migrating from the upgradient past Landfill 3 is possible. However, chemical data for shallow groundwater (depth approximately 8 feet) in the area, as reviewed in section 7.6, does not pose a contaminant source problem for the pond.

Section 7.3 provides a discussion of wildlife in the Fort Story area. Species of greatest concern at Site 3A, Pond Adjacent to Landfill 3 are the aquatic organisms that have primary contact with pond water and sediments. No field studies documenting species present in Site 3A were found; however, the man-made pond was created for recreational fishing use and likely contains small freshwater fish such as bass and perch. Other possible receptors include terrestrial animals visiting the pond and several federal and/or state special designation species reported to nest, hunt or reside in areas near Fort Story. Of these, the wider ranging bird species such as the bald eagle, the peregrine falcon and herons could utilize the site. Additionally, nine plants of state-recommended special concern recorded as present at Fort Story could be impacted by pond water contaminants via discharge of shallow groundwater and migration to areas where these species exist.

Table 7-26

Ecological Pathways
Fort Story - Site 3A, Pond Adjacent to Landfill 3

| Medium | Potential Receptors | Exposure Route | Comments |
|---|---|---|---|
| Sediment | Aquatic organisms | Ingestion/Dermal Contact | This pathway will be qualitatively discussed using Site 3A sediment data and comparison of this data to literature values of chemical concentrations in sediments indicating biological effects. |
| Surface Water | Aquatic organisms | Ingestion/Dermal Contact | This pathway will be qualitatively discussed using Site 3A surface water data and comparison of this data to literature values indicating chemical concentration limits protective of aquatic organisms and wildlife. |
| | Terrestrial organisms | Ingestion | |

**7.7.4.2 Contaminants of Potential Environmental Concern.** Two rounds of samples have been collected at Site 3A, Pond Adjacent to Landfill 3. AEHA collected sediment and surface water samples in 1977 and JMM collected sediment and surface water samples from the pond in 1990. AEHA sediment samples were analyzed for pesticides and metals and surface water samples were analyzed for metals. JMM sediment and surface water samples were analyzed for VOCs, BNAEs, pesticides, and metals. JMM data for Site 3A is provided in Section 5. Low levels of DDD, DDT, arsenic, and cadmium reported in AEHA data were not detected in JMM samples collected 13 years later. This could be due to the low, near detection limit levels of these compounds reported in 1977; the burial of contaminated sediments by decomposing leaf and twig litter from surrounding vegetation the absence of continued contaminant input; or, the natural in-situ degradation or cycling and thus reduced concentration of these compounds. Only compounds detected in the 1990 Site 3A samples were retained for consideration of ecological risks.

**7.7.4.3 Toxicity of Contaminants of Potential Concern.** The following sections review the levels of contaminants found at the site and provide comparisons with published values which are considered potentially acceptable.

**Surface Water.** The potential biological effects of contaminants of concern in surface water were evaluated by comparing the observed contaminant concentrations to AWQC chronic and acute freshwater values. The purpose of the criteria is to protect freshwater plants and animals. These criteria are designed to be protective of a broad spectrum of species, and contaminant concentrations above a criteria threshold do not imply that ecological harm is necessarily occurring. The criteria are presented to assist in identifying which of the contaminants of potential concern are the most significant. Table 7-27 presents the maximum concentrations of compounds detected at Site 3A Pond and corresponding AWQC.

To allow for consideration of potential impacts to terrestrial biota ingesting or contacting Site 3A water, DWS are also provided in Table 7-27. As discussed in section 7.6.4.6, comparison of site data to these standards should be over-protective of wildlife.

**Sediment.** No formal toxicity criteria exist for sediments. Values determined by Long and Morgan (1990) based on the review of numerous published and unpublished studies of biological effects of sediment contaminants were used to evaluate Site 3A sediment contaminant data. As with AWQC, these sediment effect values were determined using toxicological and other biological effects data for a broad spectrum of species and contaminant concentrations above a given effects value do not imply that ecological harm is necessarily occurring. The criteria are presented to assist in identifying which of the contaminants of potential concern are the most significant. Table 7-28 presents the maximum concentrations of compounds detected at Site 3A and corresponding sediment effects values.

**7.7.4.4 Evaluation of Potential Risks.** Comparison of site surface water data with AWQC and DWS shows that of the compounds detected in 1990 surface water samples, none of the concentrations reported exceed values considered to be protective of humans, wildlife and aquatic organisms. Thus, impacts to organisms residing in or utilizing pond Site 3A water are not expected. Similarly, comparison of 1990 site sediment data with sediment effects values demonstrates that site sediment values are at least an order of magnitude below the low effects values reported by Long and Morgan. Thus neither sediment or surface water data from Site 3A indicate a potential for impacts to ecological receptors.

TABLE 7-27

SURFACE WATER DATA SUMMARY FOR ECOLOGICAL ASSESSMENT
FORT STORY - SITE 3A, POND ADJACENT TO LANDFILL 3

| Constituent | Maximum (ppm) | Total Number of Hits | Total Number of Samples | Freshwater Acute Criteria (mg/l) | Freshwater Chronic Criteria (mg/l) | Drinking Water Standard (ppm) |
|---|---|---|---|---|---|---|
| Lead | 0.004 | 1 | 3 | 0.082 | 0.0032 | 0.05 |
| Zinc | 0.022 | 3 | 3 | 0.32 | 0.047 | 5 |
| Acetone | 0.016 | 1 | 3 | no data | no data | no data |

TABLE 7-28

SEDIMENT DATA SUMMARY FOR ECOLOGICAL ASSESSMENT
FORT STORY - SITE 3A, POND ADJACENT TO LANDFILL 3

| Constituent | Maximum (ppm) | Total Number of Samples | Sediment Effects Range Low (ppm) | Sediment Effects Range Medium (ppm) |
|---|---|---|---|---|
| Chromium | 3.2 | 5 | 80 | 145 |
| Copper | 1.4 | 5 | 70 | 390 |
| Lead | 3.8 | 5 | 35 | 110 |
| Zinc | 3 | 5 | 120 | 270 |

Source (sediment effects): Values determined by Long and Morgan in "The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program."

# Section 8

# 8.0 CONCLUSIONS AND RECOMMENDATIONS

The Remedial Investigation (RI) and Public Health/Environmental Assessment (PHEA) for the two Fort Story sites, Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3, is intended to complete these objectives: characterize the nature and extent of contamination, analyze chemical exposure pathways, develop a baseline human health and environmental assessment, and establish whether site remedial actions are necessary. This section draws conclusions concerning the nature and extent of groundwater, surface water and sediment contamination at Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3, and the possible human health or environmental risks associated with chemical compounds of concern.

## 8.1 SITE 3, LANDFILL 3

Landfill 3 was utilized from 1962 to 1974 as a sanitary landfill. Several earlier investigations completed at this site determined that trace metals were present in groundwater and recommended additional sampling of groundwater. JMM investigated the site groundwater by collecting five groundwater samples and analyzing the samples for pesticides/polychlorinated biphenyls (PCBs); volatile organic compounds (VOCs); base/neutral/acid extractable organic compounds (BNAs); total metals; dissolved metals; cyanide; and common anions such as chlorides, nitrates as nitrogen, sulfates and fluorides. The surface water samples were analyzed for pesticides/PCBs, VOCs, BNAs, total metals, cyanide and the common anions.

### 8.1.1 Conclusions

JMM's conclusions from the RI/PHEA performed for Site 3, Landfill 3, address contaminant levels in site media that exceed selected potential applicable or relevant and appropriate requirements (ARARs) and site exposure pathways posing significant human health or environmental risks.

**8.1.1.1 Site Characterization.** Based on JMM's results from depth-to-water measurements from the five monitoring wells (MWs) sampled during the RI, JMM concludes that the general regional groundwater flow direction is southwesterly toward Broad Bay. However, influences from tidal fluctuations and from a groundwater divide traversing the Fort Story Installation could cause components of groundwater flow to the Atlantic Ocean (located east of the sites) or to the Chesapeake Bay (located north of the sites).

Although the major component of groundwater flow from the landfill at Site 3 appears to be away from the pond at Site 3A, groundwater flow from beneath the landfill could be discharging into the pond at Site 3A. Also, groundwater could be discharging into local surface water bodies.

**8.1.1.2 Environmental Contamination.** The analytical results indicate that metal compounds were consistently detected in site media at concentrations above selected potential ARARs. In groundwater samples, total arsenic, total lead and total zinc were detected at two MWs above ARARs, but both MWs were considered upgradient of Site 3, Landfill 3. The dissolved metals analyses identified zinc in both downgradient (LF-3) and upgradient (LF-1) MWs. A significant increase in the dissolved zinc concentrations in the downgradient MW was not observed when compared to the results from the upgradient MW. The surface water results provided additional data, which also identified metals as the primary type of compounds present in the site media. With the exception of metals concentrations which exceeded selected potential ARARs, the concentration of phenol (SW-203) was the only other compound above the selected potential ARAR. The detection of phenol, however, was considered a laboratory artifact, so the phenol in surface water was not considered site related. In all cases where metals exceeded selected potential ARARs, the concentrations were not significantly above the selected potential ARARs.

JMM's selected potential ARARs for groundwater and surface water are relatively conservative standards that are protective of human health for fish consumption and/or drinking water ingestion exposures. Therefore, the evaluation of all existing site data has determined that no significant environmental contamination appears to have emanated from the landfill at Site 3.

**8.1.1.3 Risk Assessment.** JMM's baseline public health assessment for Site 3, Landfill 3, identified chromium, copper, lead and zinc as contaminants of concern. Specifically, copper and zinc are designated as contaminants of concern for surface water and groundwater, whereas chromium and lead are designated as contaminants of concern only in groundwater. These contaminants posed the highest carcinogenic and reference dose indices of all compounds detected in Site 3, Landfill 3, environmental media.

JMM's exposure analysis for Site 3, Landfill 3, concluded that all current pathways of exposure are incomplete. Therefore, all current pathways do not pose significant human health risk and were not evaluated quantitatively. For example, the shallow aquifer is not used as a potable water supply due to potential low water yields and its unsuitability for domestic water usage; hence, ingestion of drinking water by base personnel or others is not a viable exposure pathway. As a future worst-case exposure scenario, JMM postulated that the Site 3, Landfill 3, area at Fort Story would be developed for residential or commercial use, and that residents would obtain domestic water from the shallow aquifer. However, this scenario is highly unlikely to become viable. The shallow aquifer is saline and would not yield sufficient water quality for consumptive use. Also, the Installation has not indicated any possibility of future transfer or development of Site 3, Landfill 3, property.

For the potential future drinking water exposure at Site 3, Landfill 3, JMM estimates that the total hazard index is equivalent to 0.4, with no attendant cancer risk. This hazard index is considered to be insignificant.

JMM considers that the most significant pathway for ecological exposure posed by Site 3, Landfill 3, is contact of wildlife with contaminants present in ponded surface waters located in the low-lying wetland areas downgradient of the landfill. Several federal or state special-designation species, including the bald eagle, peregrine falcon and herons, are reported to reside, hunt or nest in the Fort Story area. Also, nine plants of state-recommended special concern are present at Fort Story.

JMM's examination of this pathway has concluded that significant impacts to wildlife are not likely at Site 3, Landfill 3. This conclusion is based on the relatively benign concentrations of lead found in site surface water and groundwater, compared to drinking water standards, and the low likelihood that wildlife in the area would obtain a significant portion of water intake from a ponded area with elevated lead concentrations. In addition, the drinking water standards are based on consumption of two liters of water per day over a 70-year lifetime; wildlife would have relatively limited intake of drinking water.

**8.1.1.4 Summary.** JMM concludes that Site 3, Landfill 3, is not likely to pose any significant human health or environmental risks in its current state. Also, in a worst-case future exposure scenario where the site is developed and the shallow aquifer is used as a domestic water supply, the human health risk would again be considered insignificant.

### 8.1.2 Recommendations

Despite that certain metal compounds are present in site surface water and groundwater at levels above the selected potential chemical-specific ARARs, the human health and environmental risks associated with possible exposures to these compounds of concern are considered insignificant.

Therefore, JMM considers the "No Action" scenario where no remedial action is undertaken to be appropriate for Site 3, Landfill 3.

## 8.2 SITE 3A, POND ADJACENT TO LANDFILL 3

Site 3A is a man-made pond located south of Landfill 3. As part of U.S. Army Environmental Health Agency's (USAEHA) investigation in 1977, three surface water and three sediment samples were collected at locations along a transect across the center of the pond (ESE, 1988). JMM collected additional data from pond surface water and sediments by collecting five sediment and three surface water samples. The sediment samples were analyzed for pesticides, PCBs, VOCs, BNAs, TFH-H, metals, EP toxicity metals and cyanide. The surface water samples were analyzed for pesticides, PCBs, VOCs, BNAs, TFH-H, metals cyanide and common anions. The analysis performed during the USAEHA investigation did not include VOCs, BNAs, TFH-H, EP toxicity metals (sediments) and cyanide.

### 8.2.1 Conclusions

JMM's conclusions from the RI/PHEA performed for Site 3A, Pond Adjacent to Landfill 3, address contaminant levels in site media that exceed selected potential ARARs and site exposure pathways posing significant human health or environmental risks.

**8.2.1.1 Site Characterization.** JMM has concluded that surface water in the pond at Site 3A is receiving groundwater inflow from upgradient areas and is essentially an expression of the groundwater. Also, the pond probably is not hydraulically connected to Landfill 3.

**8.2.1.2 Environmental Contamination.** Results from sediment and surface water samples collected from Site 3A, Pond Adjacent to Landfill 3, do not indicate that significant contamination is present in site media. Although the analytical results identified chromium, copper, lead and zinc in sediment samples, all concentrations of these metals were relatively low. The detection of cyanide in sample SD-203 is not considered significant since the 0.39 mg/kg concentration does not exceed the to-be-considered criteria established for cyanide in Section 4.0.

In surface water samples, the metals results were all below the selected potential ARARs. The VOC analyses detected acetone in one surface water sample, but a selected potential ARAR for the acetone was not identified. Although the 16 µg/l acetone concentration is relatively low, it was considered a laboratory artifact and not identified as a contaminant of concern during the baseline risk assessment. The inorganic results identified chlorides, sulfates and nitrates as nitrogen in surface waters. The results, however, did not identify significant contamination for these parameters. In summary, the levels of compounds detected in site media do not indicate that contamination exists at the site.

**8.2.1.3 Risk Assessment.** JMM's baseline public health assessment for Site 3A, Pond Adjacent to Landfill 3, identified copper, chromium, lead and zinc as contaminants of concern. Specifically, zinc is designated as a contaminant of concern in surface water and sediment in Pond 3A; and copper, chromium, lead and zinc as contaminants of concern in pond sediment.

JMM's exposure analysis concluded that pond surface water and sediment currently pose viable exposure pathways for humans, via dermal contact while fishing or wading in the pond and possible ingestion of contaminated fish. These exposure pathways are considered viable as future pathways in the event that the Site 3A area undergoes development, and recreational use of the pond becomes more predominant.

For pond surface water/sediment and fish, the primary source of non-carcinogenic risks is chromium. No attendant carcinogenic risks exist since there are no carcinogenic contaminants of concern. For ingestion of pond surface water, the hazard index for chromium was estimated to be equivalent to $4.0 \times 10^{-6}$, with no expected cancer risk. For dermal contact with sediment, the total hazard index for chromium was estimated to equal 0.005. For the ingestion of fish, the hazard index for chromium was 0.05. All estimated hazard indices are considered insignificant.

JMM's baseline environmental assessment for Site 3A, Pond Adjacent to Landfill 3, considers that the contact of aquatic organisms with pond water and/or sediments and the use of the pond by terrestrial organisms are significant ecological exposure pathways. Plants and wildlife could be affected by contacting or ingesting contaminants from water or sediments. Contaminated sediments could also affect ecological receptors by serving as a source for maintaining contaminant concentrations in surface waters.

Species of greatest concern at Pond 3A are the aquatic organisms that have primary contact with pond water and sediments. This man-made pond was created for recreational fishing use and likely contains small freshwater fish such as bass and perch. Other possible receptors include terrestrial animals visiting the pond and several federal or state special designation species reported to nest, hunt or reside in areas near Fort Story. Of these, the wider ranging bird species bald eagle, peregrine falcon and herons could utilize the site. Additionally, nine plants of state-recommended special concern present at Fort Story could be impacted by pond water contaminants via recharge of shallow groundwater and migration to areas where these species exist.

JMM evaluated the potential biological effects of contaminants of concern in surface water by comparing observed contaminant concentrations to Ambient Water Quality Criteria (AWQC) values for chronic and acute freshwater. To allow for consideration of potential impacts to terrestrial biota ingesting or contacting Pond 3A water, JMM also compared observed contaminant concentrations to Federal or State Maximum Contaminant Levels (MCLs). No formal toxicity criteria exist for sediments. However, JMM used sediment criteria determined by studies of Long and Morgan (1990) as a reference base.

JMM's comparison of site surface water data with AWQC and MCLs reveals that none of these concentrations exceed those values considered to be protective of humans, wildlife and aquatic organisms. Similarly, site sediment concentrations are at least one order of magnitude below the low effects values reported by Long and Morgan. Therefore, JMM concludes that neither sediment nor surface water data from Pond 3A indicate a potential for significant impacts to ecological receptors.

**8.2.1.4 Summary.** JMM concludes that Site 3A, Pond Adjacent to Landfill 3, is not likely to pose any significant human health or environmental risks in its current state. Also, in future exposure scenarios where recreational use of the pond becomes more predominant, the human health risk would again be considered insignificant.

### 8.2.2 Recommendations

Despite that certain metal compounds are present in surface water and sediment in the pond at Site 3A at concentrations above the selected potential chemical-specific ARARs, the human health and environmental risks associated with possible exposures to these compounds of concern are considered insignificant.

Therefore, JMM considers the "No Action" scenario where no remedial action is undertaken to be appropriate for Site 3A, Pond Adjacent to Landfill 3.

# Section 9

## 9.0 SUMMARY OF FINDINGS

This section of the report summarizes JMM's findings regarding the contaminants detected in site environmental media, potential sources of contamination, and the assessment of human health and environmental risks posed by compounds of concern in environmental media at Landfill 3 and the Pond Adjacent to Landfill 3.

JMM's RI/PHEA findings and recommendations are discussed below and summarized in Table 9-1.

*Landfill 3*

The landfill has not contributed to significant contamination of site groundwater and surface waters, despite the detection of metals in the groundwater and metals and phenol in ponded water located in the marshy area south of the landfill. No significant human health or environmental risks are associated with current or potential future worst-case exposures to compounds of concern detected in site environmental media. No further investigation or remedial action is recommended for this site.

*Pond Adjacent to Landfill 3*

No significant contamination is present in the pond surface water or sediment despite the detection of metals and cyanide in the pond sediment and the detection of metals and acetone in the pond surface water. No significant human health or environmental risks are associated with current or potential future worst-case scenarios to compounds of concern detected in site environmental media. No further investigation or remedial action is recommended for this site.

# Appendix A

# APPENDIX A

## Geotechnical Information

# Monitoring Well Boring Lithologic Logs

DATE STARTED 3/23/90 COMPLETED 3/23/90 PROJECT FT. STORY RI/FS
SITE NUMBER 3 SITE NAME LANDFILL 3 COORDINATES N221720, E2728432
GROUND ELEVATION 10.07 FEET, NGVD GEOLOGIST MARK SHUPE

| DEPTH (feet) | SAMPLE | SAMPLE INTERVAL (ft) | BLOWS/ 6 IN | PID (ppm) | GRAPHIC LOG | SOIL CLASS | GEOLOGIC DESCRIPTION | COMMENTS |
|---|---|---|---|---|---|---|---|---|
| | LITH | 0-2 | 1 4 7 5 | 35.4 | | SM | SAND (SM), quartz, brown, medium-fine grained, subrounded, poor sorting, silty; water table encountered at 2 feet. | PID Instrumentation OVM 580B Thermo Environmental Instruments, Inc. 10.2 eV Lamp PID Background=0.0 ppm. |
| | GEO | 2-4 | 5 6 5 4 | 64.1 | | | SAND(SP), quartz, tan, medium-fine grained, subrounded, well sorted. | |
| 5 | LITH | 4-6 | 16 32 25 15 | 72.0 | | SP | SAND (SP), quartz, tan-light gray, subrounded-subangular, medium-fine, well sorted. | |
| | LITH | 8-10 | 16 32 25 15 | 48.0 | | | SAND (SP), quartz, tan, subrounded-subangular, medium-fine grained. | |
| 10 | | | | | | | Total depth of boring=11.5 feet. | |
| 15 | | | | | | | | |
| 20 | | | | | | | | No analytical samples were collected from this boring. |
| 25 | | | | | | | | GEO=Geotechnical<br>LITH=Lithology<br>▼ =Water table during drilling |

JMM James M. Montgomery Consulting Engineers, Inc.

DRILLER HARDIN AND HUBER, INC.
METHOD OF DRILLING HOLLOW STEM AUGER
HOLE DIAMETER 8 1/4 INCHES
TOTAL DEPTH 11.5 FEET
WELL COMPLETION DEPTH 11.5 FEET
WELL DIAMETER 2 INCHES
WELL MATERIAL SCHEDULE 40 PVC

DATE STARTED 3/24/90 COMPLETED 3/24/90 PROJECT FT. STORY RI/FS

SITE NUMBER 3 SITE NAME LANDFILL 3 COORDINATES

GROUND ELEVATION 11.01 FEET, NGVD GEOLOGIST MARK SHUPE N222166, E2727831

| DEPTH (feet) | SAMPLE | SAMPLE INTERVAL (ft) | BLOWS/ 6 IN | PID (ppm) | GRAPHIC LOG | SOIL CLASS | GEOLOGIC DESCRIPTION | COMMENTS |
|---|---|---|---|---|---|---|---|---|
| | LITH | 0-2 | 1 1 3 2 | 20.2 | | | SAND (SP), quartz, tan-light gray, medium-fine grained, subangular-subrounded, well sorted; water table encountered at 2 feet. | PID Instrumentation OVM 580B Thermo Environmental Instruments, Inc. 10.2 eV Lamp PID Background=0.0 ppm. |
| | LITH | 2-4 | 2 2 3 4 | 35.0 | | | SAND (SP), quartz, dark brown, medium-fine, well sorted. | |
| 5 | GEO | 4-6 | 2 2 3 5 | 45.2 | | SP | SAND (SP), quartz, tan, fine-medium, subrounded, well sorted. | |
| | LITH | 8-10 | 3 2 5 4 | 38.1 | | | SAND (SP), quartz, tan-light gray, fine-medium grained, subrounded-subangular. | |
| 10 | | | | | | | | |
| | | | | | | | Total depth of boring=11 feet. | |
| 15 | | | | | | | | |
| 20 | | | | | | | | No analytical samples were collected from this boring. |
| | | | | | | | | GEO=Geotechnical |
| 25 | | | | | | | | LITH=Lithology |
| | | | | | | | | ▼ =Water table during drilling |

JMM James M. Montgomery Consulting Engineers, Inc.

DRILLER HARDIN AND HUBER, INC. WELL COMPLETION DEPTH 11.0 FEET

METHOD OF DRILLING HOLLOW STEM AUGER WELL DIAMETER 2 INCHES

HOLE DIAMETER 8 1/4 INCHES WELL MATERIAL SCHEDULE 40 PVC

TOTAL DEPTH 11 FEET

# DRILLING LOG

*(The proponent of this form is HSHB-ES)*

PROJECT FORT STORY
DATE 6 OCT 87

LOCATION SANITARY LANDFILL
DRILLERS MANERS

COAST ARTILLERY RD, ACROSS FROM BLDG
RIPPEY

DRILL RIG MOBILE
BORE HOLE No. 1 (WELL No. LF-1)

| DEPTH | SAMPLE TYPE / BLOWS PER 6 IN | DESCRIPTION | REMARKS |
|---|---|---|---|
| 1 FT | | Soft, light brown, medium sand. Little or no fines Some organic matter | 24-hr water level: 8.08 ft from ground surface |
| 4 FT | | Slightly darker brown medium sand Slightly damp | |
| 7 FT | | Medium sand, no fines | |
| 8½ FT | | Saturated sand, dark brown few fines | |
| 12 FT | | Dark wet sand, more fines (dark clay) | |
| 15 FT | | — BOTTOM OF HOLE — | |

AEHA Form 130, 1 Nov 82

*Replaces HSHB Form 78, 1 Jun 80, which will be used.*

# DRILLING LOG

*(The proponent of this form is HSHB-ES)*

PROJECT: FT STORY  DATE: 6 OCT 87

LOCATION: SANITARY LANDFILL NEAR FILL ENTRANCE, BY HYDRANT  DRILLERS: D. MANERS, P. RIPPEY

DRILL RIG: MOBILE  BORE HOLE: No. 3 (WELL LF-2)

| DEPTH | SAMPLE TYPE / BLOWS PER 6 IN | DESCRIPTION | REMARKS |
|---|---|---|---|
| 1 FT – 2½ FT | | Dark Brown, slightly damp medium sand. Little or no fines | 24-hr water level: 8.6 feet from ground surface. |
| 2½ FT – 5 FT | | Lighter brown medium sand, dry, little or no fines | |
| 5 FT – 8 FT | | Alternating brown and gray sands. Few pebbles | |
| 8 FT – 9½ FT | | Damp, slightly darker brown sand | |
| 9½ FT – 10 FT | | Gray wet sands - quartz. No fines | |
| 10 FT – 11 FT | | Dark gray/brown very wet sand | |
| 11 FT – 12 FT | | Saturated sand | |
| 12 FT – 14 FT | | Saturated blocky dark gray to black sand. Some silt. | |
| 14 FT – 15 FT | | Dark black sand, with silt and clay — BOTTOM OF HOLE — | |

AEHA Form 130, 1 Nov 82

*Replaces HSHB Form 78, 1 Jun 80, which will be used.*

# DRILLING LOG

*(The proponent of this form is HSHB-ES)*

PROJECT: FT STORY  DATE: 6 OCT 87

LOCATION: SANITARY LANDFILL NEAR POND  DRILLERS: D. MANERS, P. RIPPEY

DRILL RIG: MOBILE  BORE HOLE: No. 4 (WELL NO. LF-3)

| DEPTH | SAMPLE TYPE / BLOWS PER 6 IN | DESCRIPTION | REMARKS |
|---|---|---|---|
| 1 FT | | Dark brown, damp, medium sand. few fines | 24-hr water level: 3.92 feet from ground surface. |
| . FT | | Darker brown, moist, medium sand, fines increasing | Unable to install filter pack, bentonite or concrete. Walls of hole caved in immediately after removal of auger. |
| 6 FT | | Dark gray to black moist sand, fines | |
| 8 FT | | Very dark black organic material. Silty fine mud of low viscosity - "flowing" | Well will probably yield unsatisfactory samples because of location in peat bog. |
| 10 FT | | | |
| 1½ FT | | – BOTTOM OF HOLE – | |

AEHA Form 130, 1 Nov 82

*Replaces HSHB Form 78, 1 Jun 80, which will be used.*

# DRILLING LOG

*(The proponent of this form is HSHB-ES)*

PROJECT: FT STORY
DATE: 7 OCT 87
LOCATION: SANITARY LANDFILL
NORTHWEST OF FILL, ALONG SANDTRAIL
DRILLERS: D. MANES
P. RIPPEY
DRILL RIG: MOBILE B24 (TRACK MOUNTED)
BORE HOLE: No. 5 (WELL LF-4)

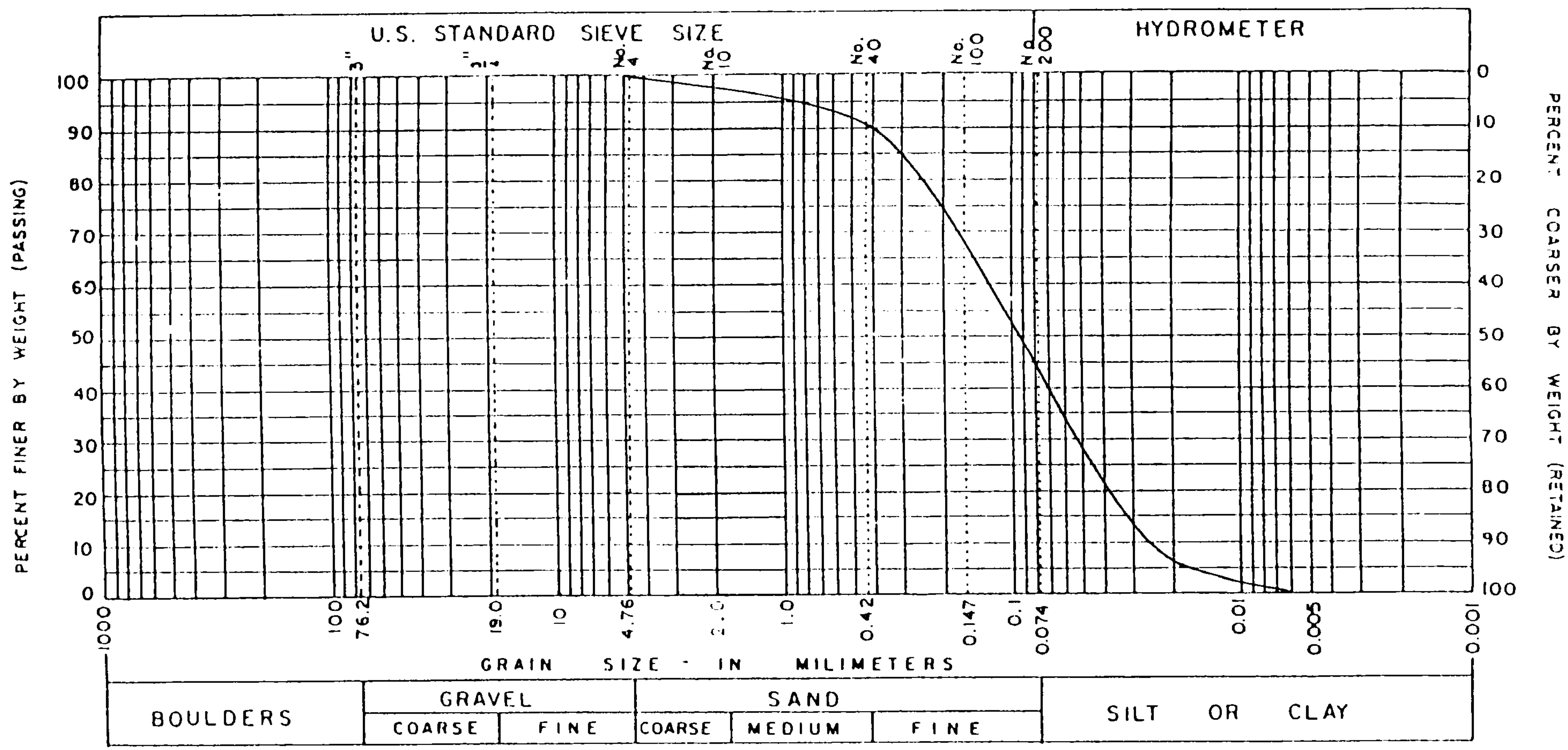
| DEPTH | SAMPLE TYPE / BLOWS PER 6 IN | DESCRIPTION | REMARKS |
|---|---|---|---|
| 1 FT | | Gray, damp, medium sand no fines | 24-hr water level: 5.6 feet from ground surface |
| 2 FT | | Brown, damp, medium sand no fines | |
| 3 FT | | Darker brown sand | |
| 4 FT | | Slightly moist light brown medium sand, few fines | |
| 6 FT | | Grayish / light brown slightly moist medium sand, few fines | |
| 8½ FT | | moist grayish-brown sand few fines | |
| 9 FT | | Blocks of very moist gray sand | 9 FT - 15 FT Strong smell of sulfur |
| 10 FT | | Saturated gray medium sand | |
| 15 FT | | - BOTTOM OF HOLE - | |

AEHA Form 130, 1 Nov 82

*Replaces HSHB Form 78, 1 Jun 80, which will be used.*

# Geotechnical Grain Size Analyses

| PROJECT: Fort Story | | LOCATION: Virginia Beach, VA | |
|---|---|---|---|
| BORING NO. Site 3 | SAMPLE NO. S3MW201 | DEPTH: 4 | CONTRACT NO. 90-075 |



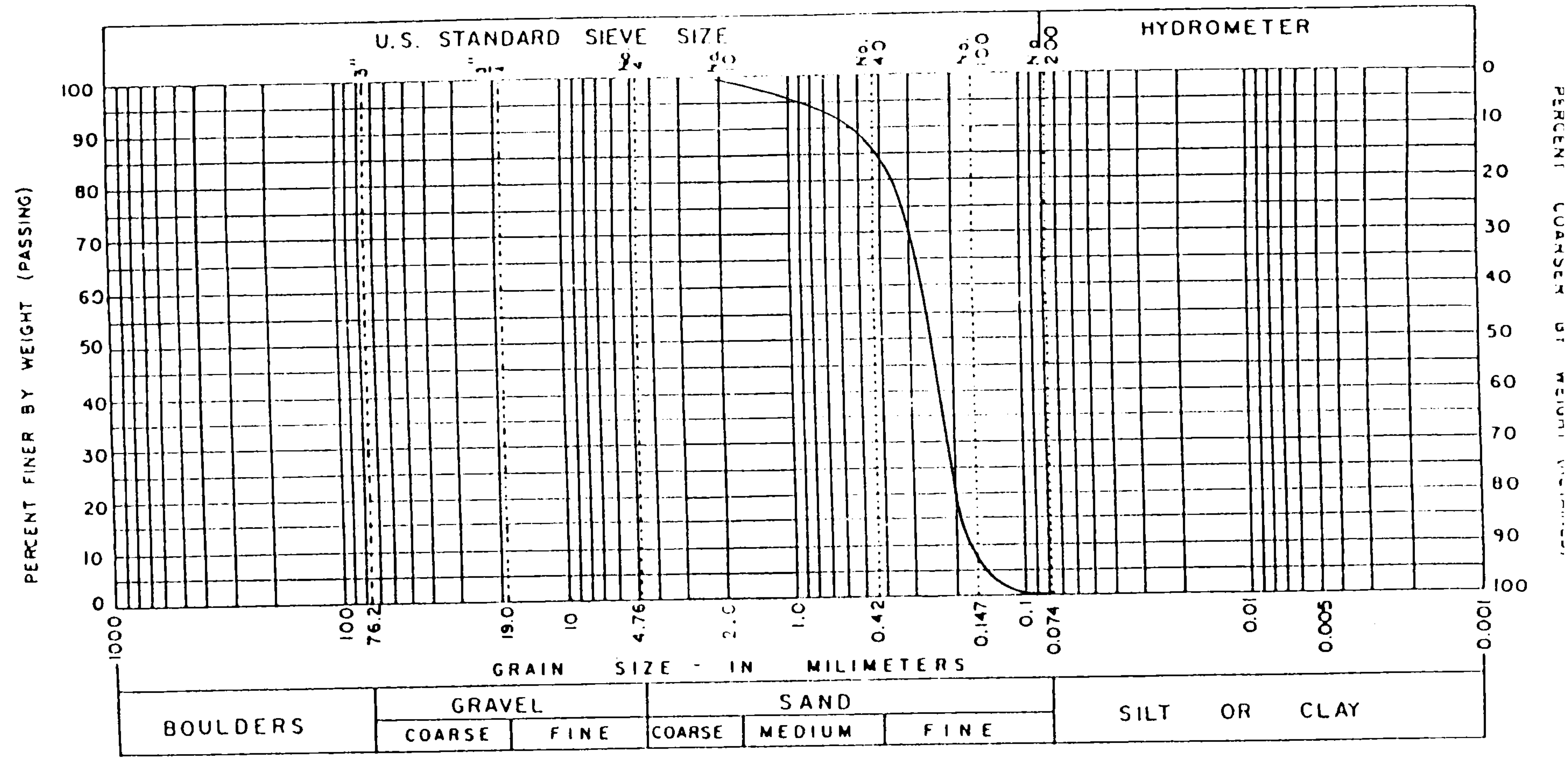

| SAMPLE NO. | DEPTH | L.L. | P.I. | M.C. | Unified | Soil Description |
|---|---|---|---|---|---|---|
| S3MW201 | 4 | - | N.P. | 21.5 | SM | Brown silty sand |

Earth Engineering & Sciences, I

## GRAIN-SIZE DISTRIBUTION

| TESTED BY: RMP | DATE: 7-12-90 |
|---|---|
| CHECKED BY: PAD | SHEET No. 10 OF ___ |

| PROJECT: Fort Story | | LOCATION: Virginia Beach, VA. | |
|---|---|---|---|
| BORING NO. Site 3 | SAMPLE NO. S3MW202 | DEPTH: 6' | CONTRACT NO. 90-075 |




| SAMPLE NO. | DEPTH | L.L. | P.I. | M.C. | Unified | Soil Description |
|---|---|---|---|---|---|---|
| S3MW202 | 6' | - | N.P. | 23.5 | SP | Tan sand |

Earth Engineering & Sciences,

GRAIN-SIZE DISTRIBUTIO

| | |
|---|---|
| TESTED BY: RMP | DATE: 7-12-90 |
| CHECKED BY: PAD | SHEET No. 11 OF |

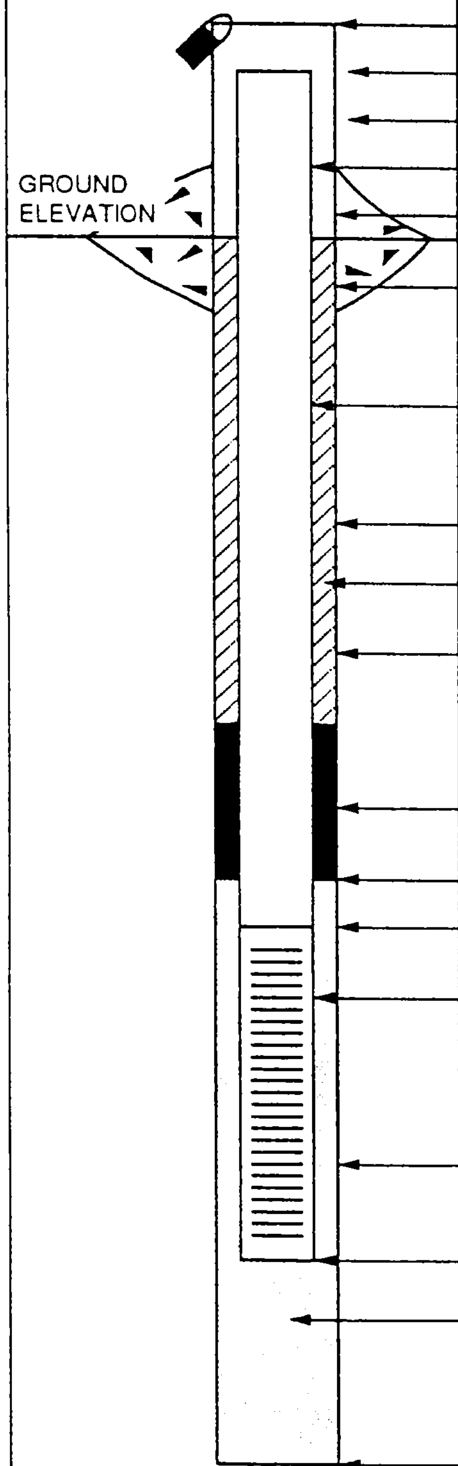
# Monitoring Well Construction Summary Sheets

Consulting Engineers, Inc.

# MONITORING WELL SHEET

PROJECT: Fort Story RI/FS
LOCATION: Site 3
PROJECT NO.: 1868.0401
BORING: MW-201
GROUND ELEVATION: 10.07 Feet, NGVD
DATE: 3/23/90
FIELD GEOLOGIST: Mark Shupe

DRILLER: Hardin and Huber Inc.
DRILLING METHOD: Hollow Stem Auger
DEVELOPMENT METHOD: Bailing/Pumping



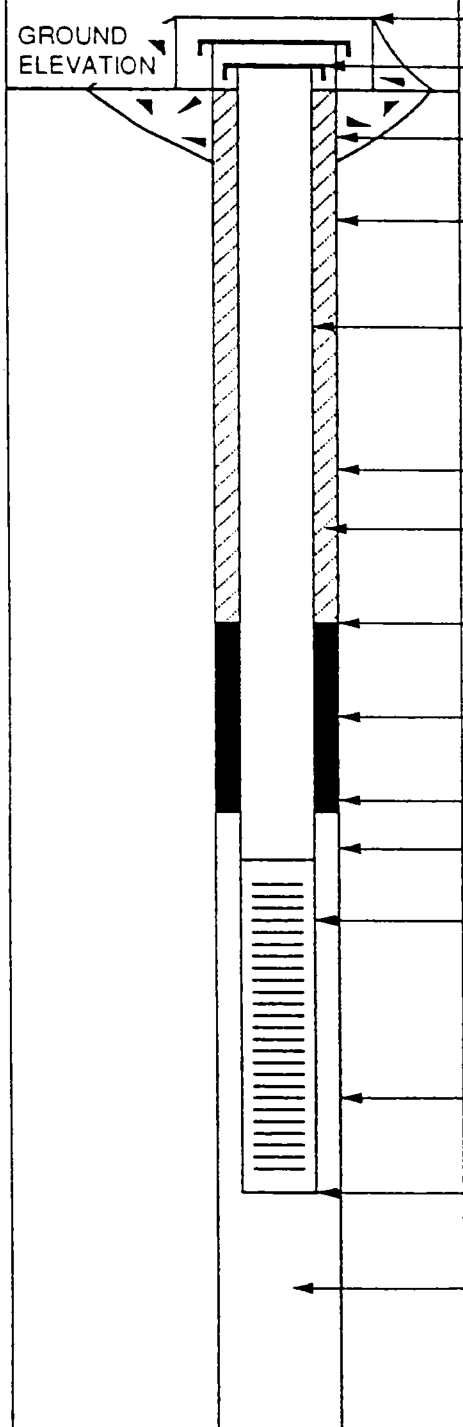

| | |
|---|---|
| ELEVATION OF TOP OF SURFACE CASING: | 12.19 ft. |
| ELEVATIONS OF TOP OF RISER PIPE: | 12.03 ft. |
| STICK-UP TOP OF SURFACE CASING: | 2.12 ft. |
| STICK-UP RISER PIPE: | 1.96 ft. |
| TYPE OF SURFACE SEAL: Cement Grout | |
| I.D. OF SURFACE CASING: 4 inch | |
| TYPE OF SURFACE CASING: Steel | |
| RISER PIPE I.D.: 2 inch | |
| TYPE OF RISER PIPE: Schedule 40 PVC | |
| BOREHOLE DIAMETER: 8 1/4 inch | |
| TYPE OF BACKFILL: Cement Grout | |
| ELEVATION/DEPTH OF SEAL: | 0.75 ft. |
| TYPE OF SEAL: Bentonite Pellets | |
| DEPTH TO TOP OF SAND PACK: | 1.25 ft. |
| ELEVATION/DEPTH TOP OF SCREEN: | 1.5 ft. |
| TYPE OF SCREEN: Schedule 40 PVC | |
| SLOT SIZE X LENGTH: 0.020 inch X 10 feet | |
| I.D. OF SCREEN: 2 inch | |
| TYPE OF SAND PACK: No. 2 Morie Filter Sand | |
| ELEVATION/DEPTH BOTTOM OF SCREEN: | 11.5 ft. |
| ELEVATION/DEPTH BOTTOM OF SANDPACK: | N/A |
| TYPE OF BACKFILL BELOW OBSERVATION WELL: Formation | |
| ELEVATION/DEPTH OF HOLE: | 11.5 ft. |

Consulting Engineers, Inc.

# MONITORING WELL SHEET

PROJECT: Fort Story RI/FS
LOCATION: Site 3
PROJECT NO: 1868.0401
BORING: MW-202
GROUND ELEVATION: 11.01 Feet, NGVD
DATE: 3.24.90
FIELD GEOLOGIST: Mark Shupe

DRILLER: Hardin and Huber Inc.
DRILLING METHOD: Hollow Stem Auger
DEVELOPMENT METHOD: Bailing/Pumping




| | |
|---|---|
| ELEVATION OF TOP OF SURFACE CASING: | 11.01 ft. |
| ELEVATIONS OF TOP OF RISER PIPE: | 10.77 ft. |
| TYPE OF SURFACE SEAL: | Cement Grout |
| I.D. OF SURFACE CASING: | 8 inch |
| TYPE OF SURFACE CASING: | Steel |
| RISER PIPE I.D.: | 2 inch |
| TYPE OF RISER PIPE: | Schedule 40 PVC |
| BOREHOLE DIAMETER: | 8 1/4 inches |
| TYPE OF BACKFILL: | Cement Grout |
| ELEVATION/DEPTH OF SEAL: | 0.5 ft. |
| TYPE OF SEAL: | Bentonite |
| DEPTH TO TOP OF SAND PACK: | 0.7 ft. |
| ELEVATION/DEPTH TOP OF SCREEN: | 1.0 ft. |
| TYPE OF SCREEN: | Schedule 40 PVC |
| SLOT SIZE X LENGTH: | 0.02 inch X 10 feet |
| I.D. OF SCREEN: | 2 inch |
| TYPE OF SAND PACK: | No. 2 Morie Filter Sand |
| ELEVATION/DEPTH BOTTOM OF SCREEN: | 11.0 ft. |
| ELEVATION/DEPTH BOTTOM OF SANDPACK: | N/A |
| TYPE OF BACKFILL BELOW OBSERVATION WELL: | Formation |
| ELEVATION/DEPTH OF HOLE: | 11.0 ft. |

# Monitoring Well Development Sheets

Earth Engineering & Sciences, Inc.

# Monitoring Well Development Sheet MW-201

Project: FORT STORY IRP Location: SITE 3

Project No. 1368.0401 Dates: 4/3/90 & 4/6/90

Field Geologists: GEORGE TOWSON & DIANE ENGLAND

Barrel ID: S3 MW 201 DEV $H_2O$ No. of Barrels: 3 · 55 gal

Initial Development Method BAILING Init. Dev. Date: 4/3/90

Initial Volume Removed: 50 Time Started: 1315 Finished: 1700

Initial Team Members: D. ENGLAND & Joe (H. & H.)

Water Level (Initial): 4.8

Total Depth (BOH): 8.6

Designed Depth: 11.0

Depth of Sediment: 2.4

Water Level After Initial Development: 4.8

BOH After Initial Development: 10.1

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Final Development Method: PUMPING Fin. Dev. Date: 4-4-90

Final Volume Removed: 156 gal Time Start: 1615 Finished: 1700

Final Team Members: GEORGE TOWSON & D. ENGLAND

Water Level Start: 4.8 Finished: 4.8 Ph: ____ EC: ____ T°C: ____

Total Depth Start: 10.3 Finished: 11.3

$O_2$, TOX, Lel and Organic Vapor Problems Encountered: NONE

Action: ☒ None Needed
☐ Need:

Earth Engineering & Sciences, Inc.

| Date | Time | Initial Development | Final Development | Depth to Water (ft.) | Total Depth (ft) | Design Depth (ft.) | Estimated Sediment Thickness (ft.) | Air Surging | Bailing | Pumping | Flow Rate (gal/min) | Well Volume (gal.) | Total Vol. of Develop. Water | Water Temp. (°C)* | pH | EC (μΩ)* | Turbidity (Ntu) | Team Members |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4-3-90 | 1315 | | | 4.8 | 8.6 | 11.0 | 2.4 | | ✓ | | .5 | | 0 | | | | | D. ENGLAND<br>Doc (H&H) |
| | 1700 | | | 4.8 | 10.1 | | 0.9 | | ✓ | | | | 50gal | | | | | |
| 4-4-90 | 1615 | | | 4.8 | 10.3 | 11.0 | 0 | | | ✓ | 2 | 6.31 | 52 | 13.2 | 6.10 | 81 | | G. TOWSON<br>D. ENGLAND |
| | 1630 | | | | | | | | | ✓ | 2 | | 55 | 13.2 | 6.02 | 79 | | |
| | 1635 | | | | | | | | | ✓ | 2 | | 60 | 11.8 | 5.71 | 79 | | |
| | 1640 | | | | | | | | | ✓ | 2 | | 70 | 11.8 | 5.91 | 79 | | |
| | 1645 | | | | | | | | | ✓ | 5 | | 80 | 11.8 | 5.86 | 75 | | |
| | 1650 | | | | | | | | | ✓ | 5 | | 105 | 11.2 | 5.79 | 75 | | |
| | 1655 | | | | | | | | | ✓ | 5 | | 130 | 11.2 | 5.82 | 75 | | |
| | 1700 | | | 4.8 | 11.3 | 11.0 | | | | ✓ | 5 | | 155 | 11.2 | 5.81 | 75 | | G. TOWSON<br>D. ENGLAND |
| 4-10 | | | | 4.80 | 11.3 | 11.0 | | | ✓ | | .5 | | 156 | 12.0 | 5.91 | 78 | 175.8 | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | | | | | |

* in Hole

Location: FORT STORY LANDFILL #3

Site #: 3

TURBIDITY TAKEN AFTER 2.0 Hrs From Removal of ...

JMM JAMES M. MONTGOMERY, CONSULTING ENGINEERS, INC.

BY ______ DATE ______ CLIENT ______ SHEET 1 OF 1

CHKD. BY ______ DESCRIPTION FORT STORY JOB NO. ______

Well No. 201 Date: 4-3-90
Site No. 3

BEFORE SURGING

Depth to Water (DTW) = 4.8

Total Depth (TD) = 8.6

Design Total Depth = 11.0

Calculated depth of sediment = 2.4

~~SURGING~~ Bailing

Time begin = ~~5~~ 1315

Time end = 1700

Development water clarity = Brown and cloudy

Estimated volume of development water : 50 gal.

Discharge rate during development =

AFTER SURGING

Depth to Water : 4.8

Total Depth - 10.1

* Calculated depth of sediment · 1 foot+

* We were able to clean out the sand & reach the bottom of the well several times but the sand quickly flowed back into the well.

1650 - first time reached bottom of well -

T. 12°C pH 7.0

conductivity 85 µmhos

Engineering & Sciences, Inc.

# Monitoring Well Development Sheet MW 202

Project: FORT STORY Location: SITE #3

Project No. 1568. ~~640~~ Dates: 4-2 + 4-4-90

Field Geologists: G. TOWSON & D ENGLAND

Barrel ID: S3 MW 202 No. of Barrels: 3 · 55 gal

Initial Development Method: BAILING Init. Dev. Date: 4-2-90

Initial Volume Removed: 55 gal Time Started: 0800 Finished: 1145

Initial Team Members: D. ENGLAND & Doc Ferrari

Water Level (Initial): 2.0

Total Depth (BOH): 6.0

Designed Depth: 11.0

Depth of Sediment: 5.0

Water Level After Initial Development: 2.0

BOH After Initial Development: 10.4

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Final Development Method: Pumping Fin. Dev. Date: 4-4-90

Final Volume Removed: 160 gal Time Start: 1630 Finished: 1700

Final Team Members: G. TOWSON

Water Level Start: ~~10.4~~ 2.1 Finished: 2.4 Ph: 5.51 EC: 75 T°C: 11.2

Total Depth Start: 10.4 Finished: 10.93

$O_2$, TOX, Lel and Organic Vapor Problems Encountered: NONE

Action:
- ☒ None Needed
- ☐ Need:

Earth Engineering & Sciences, Inc.

| Date | Time | Initial Development | Final Development | Depth to Water (ft.) | Total Depth (ft) | Design Depth (ft.) | Estimated Sediment Thickness (ft.) | Air Surging | Bailing | Pumping | Flow Rate (gal/min) | Well Volume (gal.) | Total Vol. of Develop. Water | Water Temp. (°C) | pH | EC (μΩ) | Turbidity (Ntu) | Team Members |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4-4-90 | 1630 | | ✓ | 2.1 | 10.4 | 11.0 | .6 | | | ✓ | 2 | 7.8 | 55 | 12.1 | 5.53 | 78 | | G. Towson |
| | 1645 | | ✓ | | | | | | | ✓ | 5 | | 85 | 11.2 | 5.79 | 75 | | |
| | 1650 | | ✓ | | | | | | | ✓ | 5 | | 110 | 11.8 | 5.82 | 80 | | |
| | 1655 | | ✓ | | | | | | | ✓ | 5 | | 135 | 11.2 | 5.78 | 75 | | |
| | 1700 | | ✓ | 2.4 | 10.93 | | 0 | | | ✓ | 5 | | 160 | 11.2 | 5.81 | 75 | ~~6.5~~ | |
| 4-10 | | | | | 10.93 | 11.0 | 0 | | ✓ | | .5 | | 161 | 11.4 | 5.69 | 79 | 6.9 | G. Towson<br>D. England |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | | | | | |

Location: Ft Story

Site #: 3

# Monitoring Well Development Photographs


Site Number: 3
Well Number: MW-201

Site Number: 3
Well Number: MW-202

# In Situ Permeability Data

RAW DATA

WELL # S3MW201

WELL DIAMETER= 8.25 INCHES
CASING DIAMETER= 2.00 INCHES
VOLUME OF WATER= .28 GALLONS
LENGTH OF AQUIFER TESTED= 20.00 FEET
VALUE OF HO= 1.72 FEET
STATIC WATER LEVEL= 3.80 FEET
LENGTH OF SCREEN= 10.00 FEET
WATER TABLE TO BOTTOM OF WELL= 9.05 FEET

SLUG TEST DATA:

| TIME | WATER LEVEL (FEET) | TIME SINCE TEST BEGAN (MINUTES) |
|---|---|---|
| 18.58. 6 | 4.07 | .10 |
| 18.58. 7 | 4.00 | .12 |
| 18.58. 8 | 3.96 | .13 |
| 18.58. 9 | 3.93 | .15 |
| 18.58.10 | 3.90 | .17 |
| 18.58.11 | 3.89 | .18 |
| 18.58.12 | 3.88 | .20 |
| 18.58.13 | 3.87 | .22 |

WELL # S3MW201

WELL DIAMETER= 8.25 INCHES
CASING DIAMETER= 2.00 INCHES
VOLUME OF WATER REMOVED OR ADDED TO WELL= .28 GALLONS
LENGTH OF AQUIFER TESTED= 20.00 FEET
VALUE OF HO= 1.72 FEET
STATIC WATER LEVEL= 3.80 FEET

SLUG TEST DATA:

| TIME SINCE TEST BEGAN (MINUTES) | WATER LEVEL (FEET) | DRAWDOWN (FEET) | HEAD RATIO | RECIPROCAL TIME (1/MINUTES) |
|---|---|---|---|---|
| .10 | 4.07 | .27 | .157 | 10.000 |
| .12 | 4.00 | .20 | .117 | 8.571 |
| .13 | 3.96 | .16 | .093 | 7.500 |
| .15 | 3.93 | .13 | .076 | 6.667 |
| .17 | 3.90 | .10 | .058 | 6.000 |
| .18 | 3.89 | .09 | .052 | 5.455 |
| .20 | 3.88 | .08 | .047 | 5.000 |
| .22 | 3.87 | .07 | .041 | 4.615 |

WELL # S3MW201

--------------------

PERMEABILITY BASED ON COOPER. BREDEHOEFT, AND PAPADOPULOS METHOD

PERMEABILITY=1.76E-04/ MATCH TIME (IN MINUTES)
STORAGE COEF= 5.88E-02* ALPHA
COMPUTER CALCULATES
ALPHA=1.00E-05 MATCH TIME= 1.30E-02
PERMEABILITY= 1.36E-02 CM/SEC
STORAGE COEF=5.88E-07
CORRELATION NUMBER= 1.00

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PERMEABILITY BASED ON REGRESSION FIT OF HEAD RATIO DATA

HVORSLEV PERMEABILITY=3.58E-04 / LAG TIME
BOUWER PERMEABILTY=9.15E-04 * -SLOPE

COMPUTER CALCULATES
PERMEABILITY VARIES MORE THAN 20% DEPENDING ON THEEQUATION USED

FOR X ON Y: HVORSLEV PERMEABILITY=2.28E-02 CM/SEC
BOUWER PERMEABILITY=4.55E-03CM/SEC
FOR Y ON X: HVORSLEV PERMEABILITY=1.83E-02 CM/SEC
BOUWER PERMEABILITY=4.67E-03 CM/SEC
AVERAGE HVORSLEV PERMEABILITY=2.03E-02 CM/SEC
AVERAGE BOUWER PERMEABILITY=4.61E-03 CM/SEC
REGRESSION STATISTICS
X ON Y
INTERCEPT= -.35
SLOPE= -5.0
Y ON X
INTERCEPT= -.33
SLOPE= -5.1
CORRELATION COEFFICIENT= -.99
CALCULATIONS INDICATE THAT A VALUE OF 1.13 FEET FOR HO
OR A VALUE OF 2.466 INCHES FOR EFFECTIVE CASING DIA.
MAY YIELD BETTER RESULTS

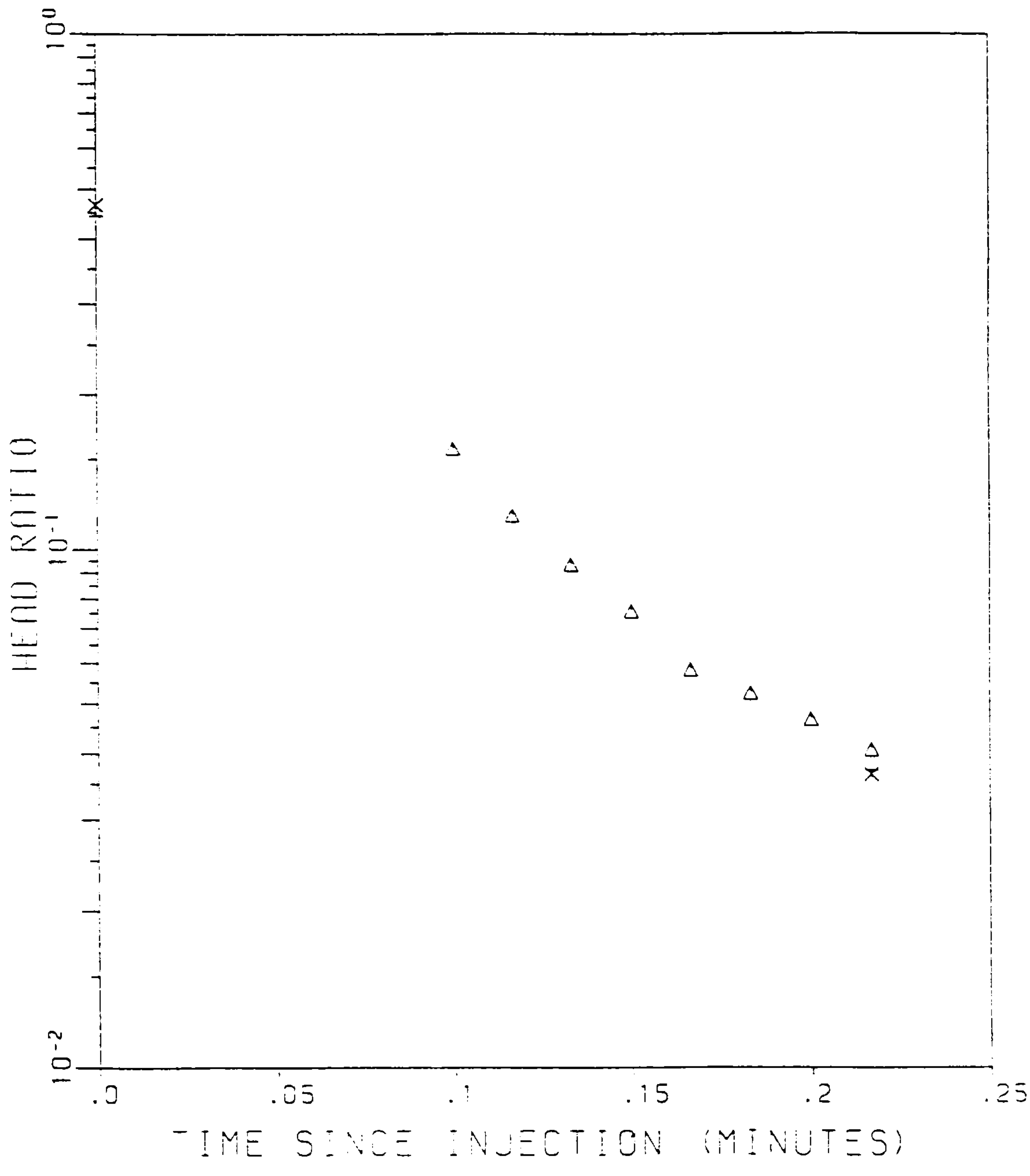
--------------------

PERMEABILITY BASED ON REGRESSION FIT OF DATA - FERRIS & KNOWLES METHOD

INSUFFICIENT DATA POINTS WITH RECIPROCAL TIMES LESS THAN .300
NUMBER OF USABLE DATA POINTS= 0

| WELL # | PERMEABILITY METHOD 1 | PERMEABILITY METHOD 2 | STORAGE COEF METHOD 2 | PERMEABILITY METHOD 3 | PERMEABILITY METHOD 4 |
|---|---|---|---|---|---|
| S3MW201 | 2.03E-02 | 1.36E-02 | 5.88E-07 | .00 | 4.61E-03 |

* METHOD 1 IS HVORSLEV
METHOD 2 IS COOPER, BREDEHOEFT, AND PAPADOPULOS
METHOD 3 IS FERRIS AND KNOWLES
METHOD 4 IS BOUWER




SLUG TEST OF WELL S3MW201
LOG HEAD RATIO VS TIME

SITE 3. LANDFILL 3. WELL S3MW201
TUE 10-30-1990 08:08:18.74

RAW DATA

WELL # S3MW202

WELL DIAMETER= 8.25 INCHES
CASING DIAMETER= 2.00 INCHES
VOLUME OF WATER= .28 GALLONS
LENGTH OF AQUIFER TESTED= 20.00 FEET
VALUE OF HO= 1.72 FEET
STATIC WATER LEVEL= 2.36 FEET
LENGTH OF SCREEN= 10.00 FEET
WATER TABLE TO BOTTOM OF WELL= 8.66 FEET

SLUG TEST DATA:

| TIME | WATER LEVEL (FEET) | TIME SINCE TEST BEGAN (MINUTES) |
|---|---|---|
| 17.39. 2 | 3.16 | .04 |
| 17.39. 3 | 2.80 | .05 |
| 17.39. 4 | 2.59 | .07 |
| 17.39. 5 | 2.48 | .09 |
| 17.39. 6 | 2.42 | .10 |
| 17.39. 7 | 2.40 | .12 |
| 17.39. 8 | 2.39 | .14 |
| 17.39. 9 | 2.39 | .15 |
| 17.39.10 | 2.38 | .17 |
| 17.39.11 | 2.38 | .19 |
| 17.39.12 | 2.38 | .20 |
| 17.39.13 | 2.38 | .22 |
| 17.39.14 | 2.38 | .24 |
| 17.39.15 | 2.38 | .25 |
| 17.39.16 | 2.38 | .27 |
| 17.39.17 | 2.38 | .29 |
| 17.39.18 | 2.38 | .30 |
| 17.39.23 | 2.37 | .39 |
| 17.39.28 | 2.37 | .47 |
| 17.39.33 | 2.37 | .55 |

WELL # S3MW202

WELL DIAMETER= 8.25 INCHES
CASING DIAMETER= 2.00 INCHES
VOLUME OF WATER REMOVED OR ADDED TO WELL= .28 GALLONS
LENGTH OF AQUIFER TESTED= 20.00 FEET
VALUE OF H0= 1.72 FEET
STATIC WATER LEVEL= 2.36 FEET

SLUG TEST DATA:

| TIME SINCE TEST BEGAN (MINUTES) | WATER LEVEL (FEET) | DRAWDOWN (FEET) | HEAD RATIO | RECIPROCAL TIME (1/MINUTES) |
|---|---|---|---|---|
| .04 | 3.16 | .80 | .466 | 27.273 |
| .05 | 2.80 | .44 | .256 | 18.750 |
| .07 | 2.59 | .23 | .134 | 14.286 |
| .09 | 2.48 | .12 | .070 | 11.538 |
| .10 | 2.42 | .06 | .035 | 9.677 |
| .12 | 2.40 | .04 | .023 | 8.333 |
| .14 | 2.39 | .03 | .017 | 7.317 |
| .15 | 2.39 | .03 | .017 | 6.522 |
| .17 | 2.38 | .02 | .012 | 5.882 |
| .19 | 2.38 | .02 | .012 | 5.357 |
| .20 | 2.38 | .02 | .012 | 4.918 |
| .22 | 2.38 | .02 | .012 | 4.545 |
| .24 | 2.38 | .02 | .012 | 4.225 |
| .25 | 2.38 | .02 | .012 | 3.947 |
| .27 | 2.38 | .02 | .012 | 3.704 |
| .29 | 2.38 | .02 | .012 | 3.468 |
| .30 | 2.38 | .02 | .012 | 3.297 |
| .39 | 2.37 | .01 | .006 | 2.586 |
| .47 | 2.37 | .01 | .006 | 2.128 |
| .55 | 2.37 | .01 | .006 | 1.807 |

WELL # S3MW202

--------------------

PERMEABILITY BASED ON COOPER. BREDEHOEFT, AND PAPADOPULOS METHOD

```
          PERMEABILITY=1.76E-04/ MATCH TIME (IN MINUTES)
          STORAGE COEF= 5.88E-02* ALPHA
     COMPUTER CALCULATES
          ALPHA=1.00E-05 MATCH TIME= 6.91E-03
          PERMEABILITY= 2.55E-02 CM/SEC
          STORAGE COEF=5.88E-07
          CORRELATION NUMBER=   .99
```

--------------------

PERMEABILITY BASED ON REGRESSION FIT OF HEAD RATIO DATA

```
          HVORSLEV PERMEABILITY=3.58E-04 / LAG TIME
          BOUWER PERMEABILTY=9.06E-04 * -SLOPE

     COMPUTER CALCULATES
          HVORSLEV PERMEABILITY=8.40E-03 CM/SEC
          BOUWER PERMEABILITY=1.46E-02 CM/SEC
               REGRESSION STATISTICS
                    X ON Y
                      INTERCEPT=  .25
                      SLOPE= -16.
                    Y ON X
                      INTERCEPT=  .26
                      SLOPE= -16.
                    CORRELATION COEFFICIENT=-1.00
     CALCULATIONS INDICATE THAT A VALUE OF   3.28 FEET FOR HO
          OR A VALUE OF    1.447 INCHES FOR EFFECTIVE CASING DIA.
          MAY YIELD BETTER RESULTS
```

--------------------

PERMEABILITY BASED ON REGRESSION FIT OF DATA - FERRIS & KNOWLES METHOD

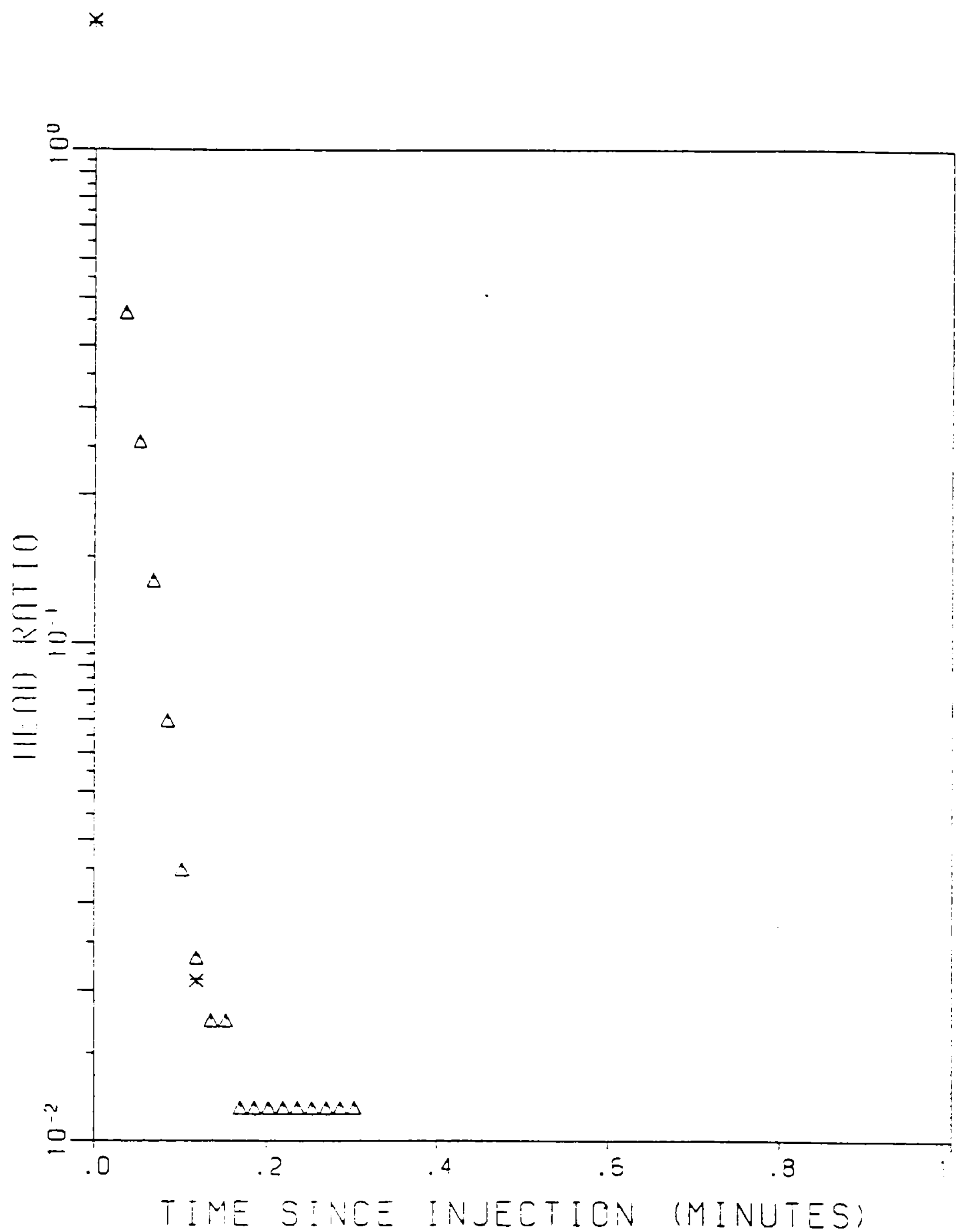
```
     INSUFFICIENT DATA POINTS WITH RECIPROCAL TIMES LESS THAN .300
  NUMBER OF USABLE DATA POINTS= 0
```

| WELL # | PERMEABILITY METHOD 1 | PERMEABILITY METHOD 2 | STORAGE COEF METHOD 2 | PERMEABILITY METHOD 3 | PERMEABILITY METHOD 4 |
|---|---|---|---|---|---|
| S3MW202 | 8.40E-03 | 2.55E-02 | 5.88E-07 | .00 | 1.46E-02 |

* METHOD 1 IS HVORSLEV
METHOD 2 IS COOPER, BREDEHOEFT, AND PAPADOPULOS
METHOD 3 IS FERRIS AND KNOWLES
METHOD 4 IS BOUWER

SITE 3. LANDFILL 3. WELL S3MW202

TUE 10-30-1990 08:13:21.65




# SLUG TEST OF WELL S3MW202

LOG HEAD RATIO VS TIME

# Groundwater Sampling Logs

# GROUNDWATER SAMPLING LOG



## FORT STORY

CLIENT USACE
SITE 3
WELL NUMBER MW 201
JOB NUMBER 1868.041

TOTAL WELL DEPTH 14'
WELL DIAMETER 2"
BOREHOLE DIAMETER 8 3/4"

MIN NUMBER WELL VOL TO BE PURGED 3
VOL PER VERTICAL FT CASING (GAL) .95
VOL PER FT BOREHOLE (LESS CASING)(GAL) ____

STATIC WATER LEVEL (FT) 3.8
STANDING WATER COLUMN (FT) ~~[illegible]~~ 10.2

AMT ONE WELL VOL (GAL) 9.6
TOTAL GAL TO BE PURGED 28.8

PURGING SYSTEM TEFLON BAILER
SAMPLING SYSTEM TEFLON BAILER

| DATE | TIME | AMOUNT PURGED (GAL) | FIELD PARAMETERS MEASURED: EC | pH | TEMP | TURBIDITY | PID | | | COMMENTS | SAMPLER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5-29 | 0850 | 0 | 160 | 7.04 | 19.6 | | | | | GRAY-BROWN 10% Sand | MDS/EJD |
| • | 0854 | 5 | 100 | 5.90 | 20.1 | | | | | GRAY-BROWN 5% SAND | MDS/EJD |
| • | 0859 | 10 | 100 | 5.87 | 20.1 | | | | | BROWN - CLOUDY 0% SAND | MDS/EJD |
| • | 0903 | 15 | | | | | | | | N/A | MDS/EJD |
| • | 0907 | 20 | | | | | | | | N/A | MDS/EJD |
| • | 0911 | 25 | | | | | | | | N/A | MDS/EJD |
| • | 0915 | 30 | 110 | 5.80 | 19.4 | | | | | GRAY - Cloudy 0% Sand | MDS/EJD |
| • | | | | | | | | | | N/A | MDS/EJD |
| • | | | | | | | | | | | |
| • | | | | | | | | | | | |
| • | | | | | | | | | | | |
| FINAL READING | 1000 | 6* | 100 | 5.89 | 20.3 | 307.20 | 0.0 | | | BROWN - yellow 0% Sand | MDS/EJD |

NOTES: 1.5 g/min * Purge Rate [due to large amounts of sand in well]

TURBIDITY: 108, 157.6

[illegible] yellow tint to Dissolved Solution AFTER FILTRATION

# GROUNDWATER SAMPLING LOG

## FORT STORY

PAGE ___ OF ___

CLIENT USACE
SITE 3
WELL NUMBER MW 202
JOB NUMBER 1868.0411

TOTAL WELL DEPTH 12.0
WELL DIAMETER 2"
BOREHOLE DIAMETER 8 3/4"

MIN NUMBER WELL VOL TO BE PURGED 3
VOL PER VERTICAL FT CASING (GAL) .95
VOL PER FT BOREHOLE (LESS CASING)(GAL) ___

STATIC WATER LEVEL (FT) 2.5
STANDING WATER COLUMN (FT) 9.5

AMT ONE WELL VOL (GAL) 9.1
TOTAL GAL TO BE PURGED 27.3

PURGING SYSTEM TEFLON BAILER
SAMPLING SYSTEM TEFLON BAILER

| DATE | TIME | AMOUNT PURGED (GAL) | FIELD PARAMETERS MEASURED | | | | | | | COMMENTS | SAMPLER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | EC | pH | TEMP | TURBIDITY | PID | | | | |
| 5-29-96 | 0640 | 0 | 90 | 6.20 | 17.0 | / | / | | | Murky - Brown 0 - Sed | MDS/EJD |
| " | 0643 | 5 | 80 | 6.13 | 15.6 | / | / | | | Murky - Brown 0 - Sed | MDS/EJD |
| " | 0645 | 10 | 80 | 6.13 | 17.0 | / | / | | | Murky - Brown 0 - Sed | MDS/EJD |
| " | 0647 | 15 | / | / | / | / | / | | | N/A | MDS/EJD |
| " | 0649 | 20 | / | / | / | / | / | | | N/A | MDS/EJD |
| " | 0652 | 25 | / | / | / | / | / | | | N/A | MDS/EJD |
| " | 0655 | 30 | 75 | 6.11 | 17.5 | / | / | | | Brown - Tan 0% Sed | MDS/EJD |
| " | / | / | / | / | / | / | / | | | N/A | MDS/EJD |
| " | | | | | | | | | | | |
| " | | | | | | | | | | | |
| " | | | | | | | | | | | |
| FINAL READING | 0711 | 6* | 80 | 6.10 | 17.6 | 361.2 | 0.0 | | | Brown Tan 0 - Sed | MDS/EJD |

NOTES: Purge Rate 2.6 g/min

TURBIDITY: 50 x 50 x 45.2 x 50 = 361.2

EMW 07

# GROUNDWATER SAMPLING LOG

## FORT STORY



CLIENT USACE
SITE 3
WELL NUMBER ~~EMW 07~~ ~~NU~~ LF-1 MK
JOB NUMBER 1868.0401

TOTAL WELL DEPTH 16.0
WELL DIAMETER 2"
BOREHOLE DIAMETER 8 3/4"

MIN NUMBER WELL VOL TO BE PURGED 3
VOL PER VERTICAL FT CASING (GAL) ~~.16~~ 1.88
VOL PER FT BOREHOLE (LESS CASING)(GAL)

STATIC WATER LEVEL (FT) 9.3
STANDING WATER COLUMN (FT) 6.7

AMT ONE WELL VOL (GAL) 12.6
TOTAL GAL TO BE PURGED 37.8

PURGING SYSTEM TEFLON BAILER
SAMPLING SYSTEM TEFLON BAILER

| DATE | TIME | AMOUNT PURGED (GAL) | FIELD PARAMETERS MEASURED: EC | pH | TEMP | TURBIDITY | PID | | | COMMENTS | SAMPLER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6-6 | 0701 | 0 | 130 | 5.37 | 14.4 | | | | | milky Brown 0% Sed | MDS/EJD |
| · | 0703 | 5 | 120 | 5.25 | 14.5 | | | | | milky Brown 0% Sed | MDS/EJD |
| · | 0705 | 10 | 125 | 5.33 | 14.1 | | | | | milky Brown 0% Sed | MDS/EJD |
| · | 0707 | 15 | 140 | 5.35 | 14.3 | | | | | milky Brown 0% Sed | MDS/EJD |
| · | 0710 | 20 | | | | | | | | N/A | MDS/EJD |
| · | 0713 | 25 | | | | | | | | N/A | MDS/EJD |
| · | 0715 | 30 | 130 | 5.37 | 14.2 | | | | | milky Brown 0% Sed | MDS/EJD |
| · | 0718 | 40 | | | | | | | | N/A | MDS/EJD |
| · | | | | | | | | | | | |
| · | | | | | | | | | | | |
| · | | | | | | | | | | | |
| FINAL READING | 0730 | 6* | 130 | 5.37 | 14.1 | 792.8 | 0.0 | | | milky Brown 0% Sed | MDS/EJD |

NOTES: Purge Rate: 2.58/min

TURBIDITY: 50 x 50 x 50 x 99.1

EMW 0

# GROUNDWATER SAMPLING LOG
## FORT STORY



CLIENT USACE
SITE 3
WELL NUMBER ~~EMW 8~~ MW LF-2 M.K.
JOB NUMBER 1868.0401

TOTAL WELL DEPTH 17.0
WELL DIAMETER 2"
BOREHOLE DIAMETER 8 3/4"

MIN NUMBER WELL VOL TO BE PURGED 3
VOL PER VERTICAL FT CASING (GAL) 1.88
VOL PER FT BOREHOLE (LESS CASING)(GAL) ___

STATIC WATER LEVEL (FT) 9.8
STANDING WATER COLUMN (FT) 7.2

AMT ONE WELL VOL (GAL) 13.6
TOTAL GAL TO BE PURGED 40.8

PURGING SYSTEM TEFLON BAILER
SAMPLING SYSTEM TEFLON BAILER

| DATE | TIME | AMOUNT PURGED (GAL) | FIELD PARAMETERS MEASURED | | | | | | | COMMENTS | SAMPLER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | EC | pH | TEMP | TURBIDITY | PID | | | | |
| 6-6 | 1401 | 0 | 430 | 6.62 | 19.1 | | | | | Brown 0% Sed | MDS/EJD |
| • | 1403 | 5 | 360 | 6.24 | 18.5 | | | | | Brown 0% Sed | MDS/EJD |
| • | 1406 | 10 | 350 | 6.19 | 16.8 | | | | | Brown 0% Sed | MDS/EJD |
| • | 1412 | 20 | | | | | | | | N/A | MDS/EJD |
| • | 1419 | 30 | | | | | | | | N/A | MDS/EJD |
| • | 1425 | 40 | 360 | 6.15 | 16.9 | | | | | Brown 5% Sand | MDS/EJD |
| • | 1428 | 45 | | | | | | | | N/A | MDS/EJD |
| • | | | | | | | | | | N/A | MDS/EJD |
| • | | | | | | | | | | | |
| • | | | | | | | | | | | |
| • | | | | | | | | | | | |
| FINAL READING | 1448 | 6* | 350 | 6.14 | 17.0 | 683.2 | 0.0 | | | Brown 1% Sand | MDS/EJD |

NOTES: Purge Rate = 2.5 g/min

TURBIDITY: 50% x 50% x 170.8

EMW 09

# GROUNDWATER SAMPLING LOG
## FORT STORY



CLIENT USACE
SITE 3
WELL NUMBER ~~EMW-9~~ MW LF-3 M.C.
JOB NUMBER 1868.0401

TOTAL WELL DEPTH 16.0
WELL DIAMETER 2"
BOREHOLE DIAMETER 8 3/4"

MIN NUMBER WELL VOL TO BE PURGED 3
VOL PER VERTICAL FT CASING (GAL) ~~.35~~ 1.88
VOL PER FT BOREHOLE (LESS CASING)(GAL) ____

STATIC WATER LEVEL (FT) 6.8
STANDING WATER COLUMN (FT) 9.2

AMT ONE WELL VOL (GAL) 17.3
TOTAL GAL TO BE PURGED 51.9

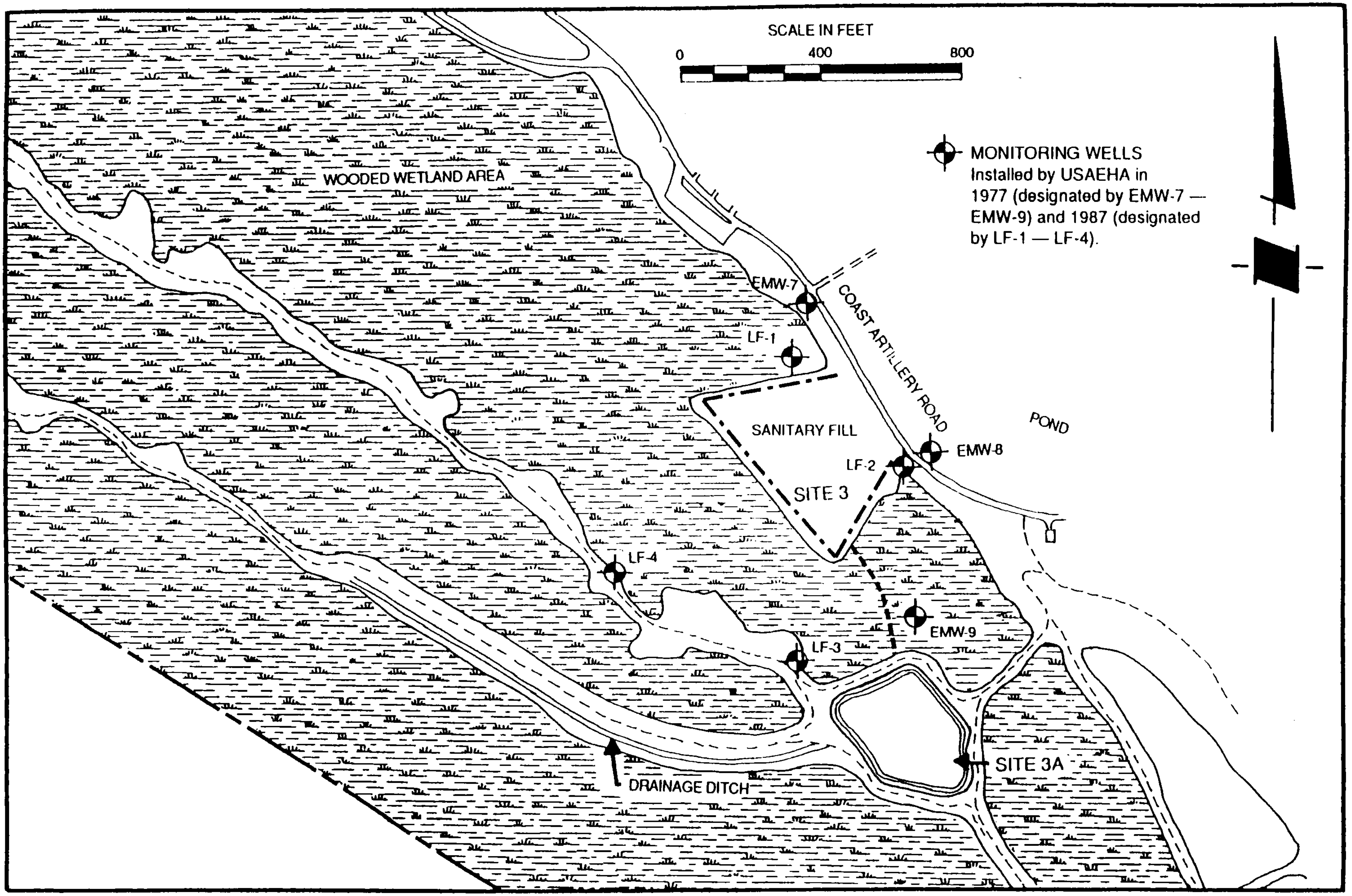
PURGING SYSTEM TEFLON BAILER
SAMPLING SYSTEM TEFLON BAILER

| DATE | TIME | AMOUNT PURGED (GAL) | FIELD PARAMETERS MEASURED: EC | pH | TEMP | TURBIDITY | PID | | | COMMENTS | SAMPLER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6-6-90 | 1513 | 0 | 110 | 5.24 | 19.1 | / | / | | | Brown – Grey 0% Sed | MDS/EJD |
| • | 1515 | 5 | 100 | 5.38 | 18.5 | / | / | | | Brown – Grey 0% Sed | MDS/EJD |
| • | 1518 | 10 | 100 | 5.37 | 17.9 | / | / | | | Brown 0% Sed | MDS/EJD |
| • | 1524 | 20 | / | / | / | / | / | | | N/A | MDS/EJD |
| • | 1531 | 30 | / | / | / | / | / | | | N/A | MDS/EJD |
| • | 1538 | 40 | 100 | 5.38 | 18.3 | / | / | | | Brown 0% Sed | MDS/EJD |
| • | 1547 | 50 | / | / | / | / | / | | | N/A | MDS/EJD |
| • | 1550 | 55 | 110 | 5.39 | 17.9 | / | / | | | Brown 0% Sed | MDS/EJD |
| • | | | | | | | | | | | |
| • | | | | | | | | | | | |
| • | | | | | | | | | | | |
| FINAL READING | 1630 | 6* | 100 | 5.37 | 17.9 | 120.4 | 0.0 | | | Brown 0% Sed | MDS/EJD |

NOTES:
P.R. 1.4 g/m

TURBIDITY: 80% × 50% × 105.1

# Appendix B




Site 3, Landfill 3, and Site 3A, Pond Adjacent to Landfill 3
Ft. Story, VA

Sources: USAEHA, 1977 and 1987.

Figure B-1

## TABLE B-1

## CONCENTRATION OF COMPOUNDS DETECTED IN GROUNDWATER SAMPLES COLLECTED AT SITE 3, LANDFILL 3[(a)]

| Parameter | Analytical Results | | | Maximum Contaminant Level[(b)] |
|---|---|---|---|---|
| | Well 7 | Well 8 | Well 9 | |
| pH (Std. units) | 6.5 | 6.3 | 6.0 | 6.5 - 8.5 |
| Conductivity (μmhos/cm) | 260 | 632 | 93 | — |
| Turbidity (NTU) | 90 | 165 | 185 | — |
| Total Solids (mg/L) | 348 | 648 | 377 | — |
| Total Dissolved Solids (mg/L) | 207 | 370 | 103 | 500.0 |
| Hardness (mg/L as $CaCo_3$) | 105 | 162 | 44 | — |
| Total Organic Carbon (mg-C/L) | 123 | 83 | 235 | — |
| Total Phosphate (mg/L) | 0.20 | 0.29 | 0.24 | — |
| Ammonia (mg-N/L) | 1.2 | 11.0 | 0.7 | — |
| Nitrate + Nitrate (mg-N/L) | 0.17 | 0.26 | 0.26 | 10.0 |
| Chloride (mg/L) | 25.7 | 48.2 | 14.4 | 250.0 |
| Chemical Oxygen Demand (mg/L) | 197 | 167 | 386 | — |
| Arsenic (mg/L) | 0.037 | 0.048 | 0.058 | 0.05 |
| Cadmium (mg/L) | 0.009 | 0.009 | 0.009 | 0.01 |
| Chromium (mg/L) | 0.025 | 0.026 | 0.066 | 0.05 |
| Copper (mg/L) | ND[(c)] | ND | ND | 1.0 |
| Mercury (mg/L) | ND | ND | ND | 0.002 |
| Zinc (mg/L) | 0.046 | 0.026 | 0.057 | 5.0 |
| Lead (mg/L) | 0.036 | 0.047 | 0.055 | 0.05 |
| Iron (mg/L) | 13.8 | 30.3 | 15.2 | 0.3 |

(a) Source: USAEHA, 1977 cited in ESE, 1987.
(b) EPA, 1986.
(c) Not detected.

**TABLE B-2**

**CONCENTRATIONS OF METALS DETECTED IN GROUNDWATER SAMPLES COLLECTED AT SITE 3, LANDFILL 3[a]**

| Parameter | Detection Limit (mg/l) | Analytical Results[b] LF-1 (mg/l) | LF-2 (mg/l) | LF-3 (mg/l) | LF-4 (mg/l) |
|---|---|---|---|---|---|
| Silver | 0.020 | ND[c] | ND | ND | ND |
| Arsenic | 0.001 | 0.005 | 0.006 | 0.075[d,e] | 0.009 |
| Barium | 0.05 | 0.210 | 0.349 | 0.226 | 0.234 |
| Cadmium | 0.001 | ND | ND | 0.002[d,f] | ND |
| Chromium | 0.020 | ND | ND | 0.248[d,e] | ND |
| Copper | 0.001 | 0.003 | 0.003 | 0.044 | 0.004 |
| Iron | 0.1 | 9.77[d,e] | 2.53[d,e] | 67.6[d,e] | 2.35[d,e] |
| Mercury | 0.005 | ND | ND | ND | ND |
| Manganese | 0.030 | 0.568[d,e] | 0.418[d,e] | 0.346[d,e] | 0.110[d,e] |
| Sodium | 1.0 | 27.8 | 15.7 | 23.1 | 22.4 |
| Lead | 0.001 | 0.005 | 0.012 | 0.062[d,e] | 0.011 |
| Selenium | 0.001 | ND | ND | 0.004 | ND |
| Zinc | 0.015 | 0.244[d,f] | 0.261[d,f] | 0.220[d,f] | 0.126[d,f] |

(a) Source: USAEHA, 1987.
(b) LF-1, LF-2 and LF-4 are dissolved metals results. LF-3 is total metals.
(c) Not detected.
(d) Concentration exceeded state water quality standard.
(e) Concentration exceeded federal drinking water standard/criteria.
(f) Concentration did not exceed proposed state water quality standard.

## TABLE B-3

## CONCENTRATIONS OF INORGANICS DETECTED IN GROUNDWATER SAMPLES COLLECTED AT SITE 3, LANDFILL 3[a]

| Parameter | Detection Limit | Analytical Results | | | |
|---|---|---|---|---|---|
| | | LF-1 | LF-2 | LF-3 | LF-4 |
| Cl (mg/L) | 1.0 | 60[b] | 17 | 41 | 48 |
| Conductivity (μmhos/cm) | 1.0 | 380 | 310 | 210 | 250 |
| F (mg/L) | 0.10 | ND[c] | 0.12 | ND | ND |
| $NO_2/NO_3$ (mg/L N) | 0.01 | 0.11 | 0.07 | 0.05 | 1.1 |
| pH | — | 5.2[b,d] | 6.6 | 5.4[b,d] | 5.7[b,d] |
| $SO_4$ (mg/L) | 1.0 | 62[b] | 20 | 0.89 | 23 |

(a) Source: USAEHA, 1987.
(b) Concentration exceeded state water quality criteria.
(c) Not detected.
(d) Concentration exceeded federal drinking water standard/criteria.

## TABLE B-4

## CONCENTRATION OF COMPOUNDS DETECTED IN WATER SAMPLES COLLECTED AT SITE 3A, POND ADJACENT TO LANDFILL 3[a]

| Parameter | Analytical Results | | | Ambient Water Quality Criteria[b] |
|---|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 3 | |
| pH (Std. units) | 6.70 | 6.70 | 6.70 | 6.5 - 9.0 |
| Dissolved oxygen (mg/L) | | | | |
| Top | 8.4 | 7.7 | 9.0 | 5.0 (minimum) |
| Bottom | 6.8 | 7.8 | 7.6 | 5.0 (minimum) |
| Conductivity (μmho/cm) | 179 | 178 | 179 | — |
| Turbidity (NTU)[c] | 8 | 8 | 9 | — |
| Total Solids (mg/L) | 158 | 148 | 151 | — |
| Dissolved Solids (mg/L) | 140 | 147 | 141 | — |
| Hardness (mg/L as $CaCo_3$) | 21 | 21 | 21 | — |
| Total Organic Carbon (mg-C/L) | 16.7 | 15.6 | 15.9 | — |
| Total Phosphate (mg-P/L) | 0.16 | 0.05 | 0.04 | — |
| Ammonia (mg-N/L) | 0.08 | 0.07 | 0.08 | 5.0 |
| Nitrate + Nitrate (mg-N/L) | 0.13 | <0.04 | 0.04 | 10.0 |
| Arsenic (mg/L) | ND[d] | ND | ND | 0.440 |
| Cadmium (mg/L) | ND | ND | ND | 0.0006 |
| Chromium (mg/L) | ND | ND | ND | 0.865 |
| Copper (mg/L) | ND | ND | ND | 0.005 |
| Iron (mg/L) | 2.87 | 3.15 | 3.11 | 1.0 |
| Lead (mg/L) | 0.007 | 0.006 | 0.007 | 0.025 |
| Mercury (mg/L) | 0.0002 | ND | ND | 0.004 |
| Manganese (mg/L) | 0.044 | 0.036 | 0.036 | — |
| Zinc (mg/L) | 0.198 | 0.093 | 0.307 | 0.088 |

(a) Source: USAEHA, 1977 cited in ESE, 1987.
(b) Criteria for cadmium, chromium, copper, lead, and zinc are logarithmic functions of total hardness of the water. Water quality data for the pond indicates an average total hardness of 21 mg/L as $CaCO_3$; therefore, the aquatic life criteria shown are based on a total hardness of 21 mg/L as $CaCO_3$.
(c) Nephelometric turbidity units.
(d) Not detected.

TABLE B-5

CONCENTRATION OF COMPOUNDS DETECTED IN SEDIMENT SAMPLES COLLECTED AT SITE 3A, POND ADJACENT TO LANDFILL 3[a]

| Parameter | Analytical Results | | |
|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 3 |
| Arsenic (μg/g) | 5.4 | 10.9 | 11.4 |
| Cadmium (μg/g) | ND[b] | 0.75 | 0.93 |
| Chromium (μg/g) | 5.8 | 10.6 | 15.7 |
| Copper (μg/g) | 19.8 | 16.5 | 23.0 |
| Iron (μg/g) | 7,900 | 14,200 | 17,800 |
| Lead (μg/g) | 27 | 48 | 50 |
| Zinc (μg/g) | 36 | 78 | 110 |
| Mercury (μg/g) | ND | ND | ND |
| Manganese (μg/g) | 52 | 127 | 143 |
| Aldrin (μg/g) | ND | ND | ND |
| Chlordane (μg/g) | ND | ND | ND |
| P,P-DDD (μg/g) | 0.19 | 0.095 | 0.27 |
| O,P-DDD (μg/g) | 0.029 | 0.035 | ND |
| P,P-DDE (μg/g) | 0.034 | 0.056 | 0.054 |
| O,P-DDE (μg/g) | ND | ND | ND |
| P,P-DDT (μg/g) | ND | ND | ND |
| O,P-DDT (μg/g) | ND | ND | ND |
| Dieldrin (μg/g) | ND | ND | ND |
| Endrin (μg/g) | ND | ND | ND |
| Heptachlor (μg/g) | ND | ND | ND |
| Heptachlor epoxide (μg/g) | ND | ND | ND |
| Kepone (μg/g) | ND | ND | ND |
| Lindane (μg/g) | ND | ND | ND |
| Methoxychlor (μg/g) | ND | ND | ND |
| Mirex (μg/g) | ND | ND | ND |
| Toxaphene (μg/g) | ND | ND | ND |
| Chlorpyrifos (μg/g) | ND | ND | ND |
| Ronnel (μg/g) | ND | ND | ND |
| Diazinon (μg/g) | ND | ND | ND |
| Malathion (μg/g) | ND | ND | ND |
| Methyl parathion (μg/g) | ND | ND | ND |
| Parathion (μg/g) | ND | ND | ND |
| Cis-chlordane (μg/g) | ND | ND | ND |
| Trans-chlordane (μg/g) | ND | ND | ND |
| Oxychlordane (μg/g) | ND | ND | ND |
| 2,4-D (μg/g) | ND | ND | ND |
| 2,4,5-T (μg/g) | ND | ND | ND |
| Silvex (μg/g) | ND | ND | ND |
| PCBs (Arochlor 1260) (μg/g) | ND | ND | ND |

(a) Source: USAEHA, 1977 cited in ESE, 1987.
(b) Not detected.

# Appendix C

# APPENDIX C - PART I

# TOXICOLOGICAL PROFILES

# CHROMIUM

The principal use for pure chromium (Cr) is in the metal plating industry. Many household appliances and other manufactured items, including automobiles, are chrome plated. It is used for alloying with several other metals and is used in radiological medicine.

Chromium is reported in ranges from 35 to 200 mg/kg in the earth's crust and occurs in the ocean at a level of 0.0005 mg/l. A USGS survey showed a general range of surface water concentrations of 0.006 to 0.05 mg/L of hexavalent chromium (Cr[VI]); trivalent chromium (Cr[III]) salts are insoluble. The U.S. EPA drinking water standard for chromium in drinking water supplies is 0.1 mg/l.

Chromium is an essential nutrient for animals, being required along with insulin for the metabolism of carbohydrates. The average daily dose is around 1 mg per day. Excess chromium is rapidly excreted by the body and therefore, not accumulated in the body.

Chromium occurs in oxidation states ranging from Cr (II) to Cr (VI), but only Cr (III) and Cr (VI) are of biological importance. There is only equivocal evidence that trivalent chromium will form in biological systems, but hexavalent chromium readily crosses cell membranes and is reduced intracellularly to the trivalent form of chromium.

Known adverse health effects have been attributed to the hexavalent form. Acute systemic toxicity may result from accidental exposure during historical therapeutic uses or suicide attempts. The major effect from ingestion of Cr (VI) is acute renal (kidney) tubular necrosis.

Chromium (VI) is corrosive and causes chronic ulceration and perforation of the nasal septum and other skin surfaces. Cr (III) is considerably less toxic and is neither irritating or corrosive.

## PHARMACOKINETICS

Chromium (III) compounds are not readily absorbed relative to Cr (VI) salts by either inhalation or oral routes of exposure. In the gastrointestinal tract, about 0.4% Cr (III) and 10% Cr (VI) is absorbed (U.S. EPA, 1984a). Chromium is bound by constituents in the gastric juices, which reduce intestinal uptake. Absorption also occurs through the skin. Factors influencing dermal absorption include the chromium salt employed, the valence state (III or VI), anionic form, concentration and pH (U.S. EPA, 1984a).

Once absorbed, chromium (III) is transported by binding to proteins in the blood. Chromium (VI), however, crosses the red blood cell membrane where it can bind to cellular compounds or undergo reduction to chromium (III). Chromium (III) is cleared rapidly from the blood and slowly from tissues, while chromium (VI) is distributed to the liver, spleen, bone marrow, lung and kidney. There is some indication that accumulation may also occur in the testes, brain and heart.

Excretion primarily occurs through the urine (about 50-60%) with some fecal elimination (about 8%) (U.S. EPA, 1984c). The remainder is deposited in various tissue compartments and has a long biological half-life. Chromium (VI) is eliminated much faster than Cr (III). Adipose and muscle tissue retain Cr (VI) for about 2 weeks while liver and spleen tissue retain Cr (III) for about 1 year.

## SYSTEMIC EFFECTS OF CHROMIUM III

Chromium (III) compounds generally do not produce increased mutation rates in microbial test systems. In one study, chromium (III) was weakly mutagenic in Bacillus subtilin (U.S. EPA, 1984a). Several mammalian cell assays have indicated chromosomal alterations due to chromium (III), however, contradictions have been reported (U.S. EPA, 1984a).

A no-observed-adverse-effect-level (NOAEL) of 1468 mg/kg/day was observed in a study when rats were fed Cr (III) oxide for over two years (Ivankovic and Pressmann, 1975). This study was used to support a reference dose (RfD) of 1 mg/kg/day.

## SYSTEMIC EFFECTS OF CHROMIUM VI

Chromium (VI) is more toxic than Cr (III) following both acute and chronic exposures. Chromium (VI) compounds are very strong skin irritants and sensitizers. These compounds have been demonstrated to produce nasal irritation, skin ulceration, irritant dermatitis and allergic contact dermatitis in humans. Nasal irritation in workers has been observed at airborne (soluble) Cr (VI) concentrations of 0.068 $mg/m^3$. At higher concentrations, perforations of the nasal septum have been observed. Chrome skin ulcers are deep round holes that develop at sites where Cr (VI) compounds redeposited on broken skin. Favored sites for ulcer development include nail root areas, knuckles and finger webs, and on the back of hands and forearms. The ulcer heals slowly and may persist for months. Allergic dermatitis may result after one or more exposures to Cr (VI). Subsequent exposures resulting in dermatitis are of varying severity. Allergic eczematous dermatitis due to Cr (VI) has been described in a variety of people, including those without occupational exposure. Skin patch tests indicate that 8 to 15 percent of all patients suffering from eczematous dermatitis react positively with chromium. In some individuals, chromium (chromate) sensitization has resulted in asthmatic attacks upon subsequent reexposure (U.S.EPA, 1984b).

In occupational settings, Cr (VI) exposure has resulted in local lung effects such as pneumoconiosis and acute upper respiratory disease. There have been reports of kidney damage in workers where Cr (VI) was absorbed through damaged skin (which can be sustained due to the irritant effects of Cr (VI), as described previously. In adults, ingestion of 1 to 2 grams of chromate has resulted in kidney and liver damage that appears 1 to 4 days following ingestion. Ingestion of about 5 grams of chromate results in the appearance of liver and kidney damage within 12 hours of the intake. Gastrointestinal bleeding and massive fluid loss may also occur after this exposure (U.S EPA, 1984b).

The EPA reports an oral RfD for ingestion of chromium (VI) of 0.005 mg/kg/day (IRIS). The estimate is based on information from a study conducted by MacKenzie and others (1958) which identified a NOAEL of 25 mg/L (2.4 mg Cr (VI)/kg/day).

An inhalation reference concentration (RfC) of $2 \times 10^{-6}$ $mg/m^3$ is reported in HEAST (1991), while IRIS currently reports that the assessment is under review. The RfD is based on a study by Lindberg and Hedenstiernan (1983). The study reported a lowest-observed-adverse effects level (LOAEL) of 0.002 mg Cr $(VI)/m^3$ from production of degeneration and atrophy of the nasal mucosa in humans.

No studies on possible teratogenic effects resulting from ingestion of chromium are available (IRIS, 1988).

## CARCINOGENIC EFFECTS OF CHROMIUM VI

EPA classifies Cr (VI) as a Group 'A', human carcinogen by inhalation. There are no studies indicating that chromium (VI) is carcinogenic following ingestion exposure (IRIS, 1991). Studies have found in vivo conversion of Cr (VI) to Cr (III), and some evidence of the reverse. Therefore, exposure to one form may involve exposure to both. However, Cr (III) is classified as a Group 'D' carcinogen.

Hexavalent chromium compounds have produced excess tumors in several animal bioassays, although chromium (VI) has not produced lung tumors following inhalation exposures (IRIS).

A review of the histologic classification of lung cancer cases in chromate workers attributed the greatest risk of cancer due to acid-soluble, water-insoluble Cr (VI) rather than trivalent compounds. Other studies have supported this hypothesis.

Mancuso (1975) divided a 332-member cohort into three groups of workers who began work between 1931 and 1932, between 1933 and 1934, and between 1935 and 1937. Of all the cancer deaths in the cohort up until 1974, 63.6 percent were attributed to lung cancer in the first group, 62.5 percent were attributed to lung cancer in the second group, and 58.3 percent were attributed to lung cancer in the third group. Workers were exposed to both chromium (III) and chromium (VI), and therefore, the risk estimation for chromium (VI) is actually based on exposure to total chromium.

Epidemiological studies of chromate production facilities in the United States, Great Britain, Norway, Japan, and West Germany have established an association between chromium exposure and lung cancer. Most of these studies did not establish whether Cr (III) or Cr (VI) was the causative agent. Three studies of workers in the chrome pigment industry also found an association between occupational chromium (predominantly hexavalent) exposure, and lung cancer (IRIS).

A slight increase in cancer of the gastrointestinal tract has been reported in other studies, but each involved only a small group of workers. Animal studies support the human data that Cr (VI) is the carcinogenic chromium compound. Trivalent compounds have little to no mutagenic activity in bacterial systems.

On the basis of the epidemiology study by Manuso, an inhalation slope factor of 41 $(mg/kg/day)^{-1}$ has been estimated by EPA's Cancer Assessment Group for Cr (VI).

# COPPER

Copper is an essential nutrient for humans and is necessary for the proper functioning of many important enzyme systems. Copper deficiency results in reduced hemoglobin formation by causing decreased iron absorption , reduced elastin formation, teratogenesis, and abnormal oxidase activity (NAS, 1977).

## SYSTEMIC HEALTH EFFECTS OF COPPER

Various effects from acute/subchronic exposures of humans to ingested copper/copper sulfate have been reported and are as follows: nausea, vomiting, epigastric pain, headache, dizziness, and abdominal cramps (Chuttani, et al., 1965; Semple, et al., 1960; Wyllie, 1957). Dermal exposure to relatively high doses of copper salts may produce skin irritation and eczema. The inhalation of dusts and mists of copper salts through occupational exposure may result in irritation of the mucous membranes and pharynx and ulceraton and perforation of the nasal septum. No adverse effects via the occupational exposure of copper welders to copper fumes were reported at concentrations up to 0.4 mg-Cu/m$^3$.

In humans, Wilson's disease is the most studied form of chronic copper toxicity. Wilson's disease is an inherited autosomal recessive disorder of copper metabolism. This ailment reportedly results in increased copper deposition in the liver, brain, and cornea (Schroeder, et al., 1966). The high levels of accumulated copper may result in damage to erythrocytes, kidneys, corneas, and the central nervous system (Scheinbert and Sternlieb, 1969). These effects occur at otherwise normal exposures and are brought about by a reduced ability to metabolize copper. Chronic exposure to $CuSO_4$(3 to 15 years) by vineyard sprayers is reported to have resulted in copper-containing benign granulomas in the lungs. Metal fume fever in the occupational polishing of metal plates was reported in air samples containing 0.12 to 0.30 mg Cu/m$^3$ (NAS, 1977).

No reports of teratogenic effects in humans associated with oral or inhalation exposure to copper are available in the literature.

Data regarding the carcinogenicity of copper to humans is not available in the literature.

# LEAD

Lead is a naturally occurring metal found in the earth's crust. The gray-blue metal is found in air, soil, water, and plants. Lead is used for a variety of purposes. Its primary use is for the manufacture of batteries. Other uses include use as an additive in gasoline, ammunition, and in other metal products (ATSDR, 1989).

## ACUTE EFFECTS

Many neurotoxic effects are associated with lead intoxication. In children, acute encephalopathy can result from blood lead levels greater than 80 µg/dl. It is initially characterized by irritability, loss of memory, and inability to concentrate. It can progress to delirium, convulsions, coma, and death (U.S. EPA, 1986a).

At high lead exposure, the gastrointestinal system is one of the earliest to show symptoms of acute lead intoxication. Colic (acute abdominal pain) is a consistent early symptom of lead poisoning. It is most often seen in cases of occupational lead exposure, and has been observed in workers with blood lead levels exceeding 40 µg/dl (ATSDR, 1989).

## SYSTEMIC HEALTH EFFECTS

Inorganic lead is primarily absorbed through the gastrointestinal tract and the lungs. Absorption through the skin appears to be limited. The absorption of lead in the gastrointestinal tract is dependent upon numerous factors including: the age and nutritional status (e.g., iron, zinc, and calcium stores) of the individual ingesting the lead, how recently the individual has eaten, and the form of the lead (e.g., solubility and particle size). It has been estimated that, on the average, 6-15 percent of normal adult dietary lead (including beverages) is absorbed (EPA, 1986c).

Toxic effects resulting from lead exposure are well documented, and many effects have been associated with a specific range of blood-lead (PbB) levels. Children have been found to develop symptoms at lower PbB levels than do adults. Dose related toxic effects are observed in heme synthesis and hematological (blood system) effects, the neurological system, the kidney, in reproduction and development, and in the cardiovascular system.

### Central Nervous System Effects

In general, lead can cause adverse neurological effects, with children being more susceptible than adults. Encephalopathy has been observed in adults as a result of blood lead levels as low as 100 µg/dl (Kehoe 1961 a,b; Smith and others, 1938). Similar results in children have been found to result from blood lead levels as low as 80 µg/dl (NAS, 1972). The high lead levels in children have also been observed to result in lasting cognitive impairment (USEPA, 1986a). Similarly, blood lead levels of 50-70 µg/dl in children have been associated with a 5 point decrease in IQ (ATSDR, 1989).

Less severe neurotoxic effects have been observed at lower blood lead levels. For example, decreased nerve conduction velocities, indicative of peripheral nerve dysfunction, have been noted in children and adults at blood levels of 30 to 40 µg/dl. Altered auditory and electrophysiological responses have been observed in children with blood lead levels of 15 µg/dl. Neurobehavioral deficits have also been observed in infants and young children with blood lead levels of 10-15 µg/dl, although these may be reversible in later years if exposure ceases (ATSDR, 1989).

### Hemolytic Effects

Blood lead can have many diverse effects due to its interference with the synthesis of heme, a compound that functions in many tissues including blood, kidney, liver and nerves. Lead interference with heme synthesis, as indicated by elevated levels of erythrocyte protoporphyrin (EP), has been associated with blood lead levels of 25-30 µg/dl in adults and 15 µg/dl in children. Changes in heme synthesis enzyme activity levels have been observed at blood lead levels as low as 10 µg/dl, although it is not clear whether this has any physiological effects. In the blood, heme is a critical component of hemoglobin, the protein that transports oxygen throughout the body. Anemia, a functional and potentially serious deficit in the amount of hemoglobin in the body, is characteristic of more severe cases of lead poisoning and has been observed at 80 µg/dl blood lead in adults and 70 µg/dl blood lead in children. In the kidney, reduced heme content results in reduced vitamin D metabolism, which in turn, interferes with several hormonally regulated effects. In the liver, reduced heme synthesis may result in the impairment of detoxification of toxic organic compounds and drugs by the cytochrome P-450 enzymes, as the P-450 metabolism enzymes require heme as a cofactor (ATSDR, 1989).

Hematologic effects appears to be among the most sensitive indicators of lead absorption. Lead interference with heme synthesis has been noted in humans and other mammalian species at levels below 10-15 µg/100 ml. The step most sensitive to lead in the heme synthetic pathway is that mediated by the enzyme 7-aminolevulinic acid dehydratase (7-ALAD), although the health significance of 7-ALAD inhibition at low blood-lead levels is unclear.

### Nephrotoxicity

Renal (kidney) toxicity has been observed in victims of lead intoxication. Reversible proximal tubule damage has been observed primarily in cases of short exposure. Reduced glomerular function has been associated with chronic exposures and blood lead levels ranging from 40 to more than 100 µg/dl (U.S. EPA, 1986a).

### Cardiovascular Effects

Cardiovascular effects, including increased blood pressure and hypertension, have been associated with lead exposure to adults. The EPA considers that sufficient evidence exists from four large-scale general population studies, as well as smaller studies, to make the conclusion that there exists a slight positive association between blood lead levels and increased blood pressure (ATSDR, 1989).

## CARCINOGENIC EFFECTS

### Inhalation

The EPA has concluded that inorganic lead is a probable human carcinogen, with a weight of evidence classification of B2. Although human evidence is inadequate, several animal bioassays have shown statistically significant increases in renal tumors following dietary and drinking water exposure to lead acetate or lead subacetate, two soluble lead salts. No quantitative cancer potency factor has been derived for lead because of the large uncertainties involved in the derivation, including the effect of age, health, nutritional status, and body burden. Lead has been associated with several mutagenic and other genotoxic effects under certain conditions.

No studies regarding exposure to lead report quantified exposure concentrations, and they are further limited due to smoking and exposure to other metals by the subjects. Two studies found no association between exposure to lead and cancer mortality (Dingwall-Fordyce and Lane, 1963; Nelson and others, 1982); one found a slight association (Selevan and others, 1985); and one found a significant excess of total cancer mortality (Cooper and Goffey, 1975; Cooper 1985 update).

### Ingestion

The animal evidence is considered sufficient to classify it as a probable human carcinogen. Statistically significant increases of renal tumors associated with oral exposure to lead have been reported in 10 bioassays in rats and one in mice. Results have been reproduced in several laboratories in several strains of rats with evidence of multiple tumor sites (IRIS).

Two two-year feeding studies in rats were conducted by Azar and others (1973). Exposure concentrations ranged from 10 to 2000 ppm of lead acetate. Male rats in exposure groups of 500 ppm and above exhibited an increased incidence of renal tumors. No tumors were observed in rats of either sex at 10 to 100 ppm or in control groups. The study is limited however by lack of experimental detail.

Koller and others (1986) also reported an increased incidence of renal tumors in male rats at a dietary exposure concentration of 2600 ppm of lead in lead acetate. Eighty-one percent of the rats in the treatment groups had renal tumors after 76 weeks of exposure. Male rats were fed 8500 ppm for 79 weeks in a study by Kasprzak and others (1985). Approximately 45 percent of surviving treatment group rats had renal tumors.

One study (Van Esch and Kroes, 1969) reported a low incidence of renal tumors in a treatment group of 1.0 percent lead acetate. The investigator felt that the low incidence of renal tumors was due to early mortality. No significant increase of renal tumors was observed in hamsters at 0.5 percent and 1 percent dietary concentrations.

## TERATOGENICITY, EMBRYOTOXICITY, AND REPRODUCTIVE EFFECTS

Several occupational studies have suggested a relationship between lead exposure and adverse reproductive effects in both women and men. However, the data were all obtained at moderate to high lead exposure levels, and the number of individuals was small. These studies are not considered definitive. Animal studies, primarily in rodents, also indicate there are adverse reproductive, but not teratogenic, effects following chronic exposure to lead in food and/or drinking water (EPA, 1986c). Delays in neurobehavioral development have been described. Other developmental effects that have been associated with lead exposure include low birth weight and decreased gestational age, which occurs at maternal blood lead levels above 12-14 µg/dl, and reductions in childhood growth (ATSDR, 1989).

An approach to determining hazard-associated levels of lead in soil is the determination of lead soil levels that are not associated with elevated blood lead levels in children. According to the report "The Nature and Extent of Lead Poisoning in Children in the United States: A Report to Congress" (ATSDR, 1988), lead in soil and dust appears to be responsible for blood lead levels in children increasing above background levels when the concentration in the soil or dust exceeds 500-1000 ppm.

## SYSTEMIC HEALTH EFFECTS

As the zinc ion is too poorly absorbed to induce systemic intoxication, zinc compounds are relatively non-toxic by oral exposure. Zinc is an essential component of numerous enzyme systems of diverse activities in the body. Zinc is a nutritionally essential metal and deficiency results in several health consequences. Excessive exposure to zinc is relatively uncommon and requires very heavy exposure. Zinc also exerts protective effects in many disease states (Klaasson, 1986).

In brass foundry workers, zinc oxide was found to produce zinc fume fevers due to inhalation of fumes during manufacturing processes. Clinical recovery is usually complete in 24 to 48 hours. Chronic exposure to fumes has not been shown to cause adverse effects (NIOSH, 1976).

Fine salts of strong mineral acids can be corrosive to the skin and irritating to the gastrointestinal tract. However, the use of zinc oxide in many topical dermatologic preparations has demonstrated a low potential for skin irritation. An occupational dermatitis "Oxidepox" was reported by Mogelivskaya in workers. The author concluded that zinc oxide particulates and lack of personal hygiene contributed to the minor eruptions. These were reversible with the institution of good hygiene practices (Clayton, 1981).

Gastrointestinal disturbances with peptic ulcer-like symptoms have been shown in workers employed for years in brass foundries (Clayton, 1981).

Clinically latent liver dysfunction has been reported in workers exposed to high levels of zinc oxide. Evidence of peptic ulcers was felt to be indicative of gastrointestinal tract damage (NIOSH,1976).

# APPENDIX C - PART II

# SAMPLE EXPOSURE CALCULATIONS

# APPENDIX C

## EXPOSURE ASSESSMENT MODELS

This appendix contains the mathematical models and calculations used to estimate exposure to contaminants of potential concern through potential current and future exposure pathways at Fort Story. Calculations for ground-water ingestion, fish ingestion, and recreational exposure to soil and surface water are presented.

## C.1 GROUND-WATER INGESTION

**Ingestion.** The dose received from ingestion of water from a hypothetical well as estimated by the following equation:

$$\text{Dose} = \frac{C_W \times V \times Y/70}{W} \times \frac{1\ \text{mg}}{1000\ \mu\text{g}} \qquad \text{C-1}$$

where:
- Dose = Lifetime average daily intake (mg/kg/day),
- $C_W$ = Contaminant concentration in ground water (µg/L),
- V = Volume of water ingested per day (L/day),
- Y = Number of years living in one house (exposure duration), and
- W = Body weight (kg).

Inputs for Equation C-1 are shown in Table C-1.

## C.2 FISH INGESTION

The data for contaminants in Site 3A sediments were used to represent levels in fish tissue since no analysis of fish tissue had been perfomed. The fish ingestion scenario includes the following assumptions:

- Levels of contaminants in tissue are equal or less than levels found in sediments.
- Assume fish is consumed 48 days per year (EPA, 1989b).
- A quantity of 0.054 kg of fish is consumed each day that fish is eaten (EPA, 1989a).
- Distribution of contaminants to various organs within the fish is not taken into account.

The dose received from ingestion of fish tissue was estimated by the following equation:

$$\text{Average Daily Fish Ingestion Dose (mg/kg/day)} = \frac{\text{Quantity Ingested (mg/day)} \times \text{Frequency of Ingestion (days/365 days)} \times \text{Fraction Ingested}}{\text{Average Body Weight (70 kg adult)}} \qquad \text{C-2}$$

## TABLE C-1

## GROUNDWATER INGESTION EXPOSURE PARAMETERS

| Variable | | Value Used | Rationale |
|---|---|---|---|
| Cw - | Contaminant concentration in groundwater (μg/l) | See Table 7-8 | Calculated by averaging results from existing wells. |
| V - | Volume of Water Ingested, (L/day). | 2 | Maximum adult ingestion rate from range of 1.4 to 2.0 L/day (EPA, 1989a). |
| W - | Body Weight, (kg) | 70 | Average adult body weight (EPA, 1989a) |
| Y - | Years Living in One House (exposure duration) | 30 | 90th percentile of length of time spent at one residence (EPA, 1989a). |

After substituting the parameters listed above the equation becomes:

$$\frac{0.054 \text{ kg/day} \times \frac{48 \text{ days}}{365 \text{ days}} \times 1}{70 \text{ kg}} = 1.02 \text{ E-4 mg/kg/day of contaminated fish tissue}$$

Inputs for equation C-2 are shown in Table C-2.

## C.3 RECREATIONAL VISITOR EXPOSURE TO SEDIMENT

This present scenario includes three aspects: incidental ingestion of soil and/or sediment, incidental ingestion of surface water and dermal absorption from soil and/or sediment. The recreational visitor exposure scenario includes the following assumptions:

- All ingested water, sediment, and dermally contacted contaminants are conservatively assumed to be 100 percent bioavailable.
- Visitor is exposed by ingestion of sediment and/or soil at a level of 100 mg/day for adults provided in EPA 1991.
- Visitor is exposed by incidental ingestion of water at the level 50 mg/day the equivalent to 1 hour of swimming (EPA, 1989b).
- Visitor is exposed by dermal contact with sediment through wading in the Pond 3A. Surface area exposed was 4030 $cm^2$ based on mean dermal surface area for hands (0.084 $m^2$), feet (0.112 $m^2$) and lower legs (0.207 $m^2$) for an adult male (USEPA 1989a).
- Assume site visit during 10 months of each year.
- Assume a site visit 2 days during each month.
- Inhalation exposure is not quantified.

The resulting equation for oral exposure to soils and sediments is therefore:

$$\text{Average Soil Ingestion Rate (mg/kg/day)} = \frac{\text{Amount of Soil Ingested (mg/day)} \times \text{Fraction Contaminated} \times \text{Number of Days Exposed Yearly (days/365 days)}}{\text{Average Body Weight (70 kg adult)}} \qquad \text{C-3}$$

Inputs to equation C-3 are shown in Table C-3. After substituting the parameters listed above the equation becomes:

$$\frac{\frac{100 \text{ mg}}{\text{day}} \times 1.0 \times \frac{20 \text{ days}}{365 \text{ days}}}{70 \text{ kg}} = 0.078 \text{ mg/kg/day of contaminated soil}$$

TABLE C-2

FISH TISSUE INGESTION EXPOSURE PARAMETERS

| Variable | | Value Used | Rationale |
|---|---|---|---|
| CF- | Contaminant concentration in fish tissue (mg/kg) | See Table 7-19 | Calculated by averaging results from sediments and assuming this to be equal to concentrations in fish tissue. |
| IR - | Quantity of Tissue Ingested, (kg/day) | 0.054 | Average consumption rate for recreational fishing (EPA, 1991a). |
| W - | Body Weight, (kg) | 70 | Average adult body weight (EPA, 1989b) |
| Y - | Years Living in One House (exposure duration) | 30 | 90th percentile of length of time spent at one residence (EPA, 1989b). |
| EF - | Exposure Frequency (days/year) | 48 | Average per capita for fish and shellfish (EPA Tolerance Assessment System in EPA 1989b). |

TABLE C-3

INCIDENTAL SOIL/SEDIMENT INGESTION EXPOSURE PARAMETERS

| Variable | | Value Used | Rationale |
|---|---|---|---|
| $C_S$ - | Contaminant concentration in soil/sediment (mg/kg) | See Table 7-18 | Calculated by averaging results from sediments. |
| IR - | Quantity of Sediment Ingested, (mg/day) | 100 | Adult incidental ingestion rate - 100 mg/day (EPA, 1991a). |
| W - | Body Weight, (kg) | 70 | Average adult body weight (EPA, 1989b) |
| Y - | Years Living in One House (exposure duration) | 30 | 90th percentile of length of time spent at one residence (EPA, 1989b). |
| D - | Desorption Factor (unitless) | 1 | Complete description of chemical from soil matrix (EPA, 1989b). |
| EF - | Exposure Frequency (days/year) | 20 | Best professional judgment based on two recreational visits to site, per month for ten months of each year. |

The dermal absorption equation is:

$$\text{Average Dermal Absorption Rate (mg/kg/day)} = \frac{\text{Fraction Contaminated} \times \text{Surface Area (cm}^2) \quad \text{Adherence Factor (mg/cm}^2) \quad \text{Number of Days Exposed Yearly (days/365 days)}}{\text{Average Body Weight (70 kg/adult}} \qquad \text{C-4}$$

Inputs to equation C-4 are shown in Table C-4. After substituting the parameters listed above the equation becomes:

$$\frac{1 \times 4030\ \text{cm}^2\text{/day} \times 2.77\ \text{mg/cm}^2 \times \frac{20\ \text{days}}{365\ \text{days}}}{70\ \text{kg}} = \text{8.74 mg/kg/day of dermal absorption}$$

## C.4 RECREATIONAL VISITOR EXPOSURE TO SURFACE WATER

The equation for oral exposure to surface water is:

$$\text{Average Water Ingestion Rate (mg/kg/day)} = \frac{\text{Amount of Water Ingested (L/day)} \times \text{Number of Days Exposed Yearly (days/365 days)}}{\text{Average Body Weight (70 kg adult)}} \qquad \text{C-5}$$

Inputs to equation C-5 are shown in Table C-5. After substituting the parameters listed above the equation becomes:

$$\frac{\frac{0.05\ \text{l}}{\text{day}} \times \frac{20\ \text{days}}{365\ \text{days}}}{70\ \text{kg}} = \text{3.91 E-5 mg/kg/day of contaminated water}$$

TABLE C-4

DERMAL EXPOSURE PATHWAYS

| Variable | | Value Used | Rationale |
|---|---|---|---|
| FS - | Weight fraction of chemical in sediment, (unitless) | See Table 7-18 | Calculated by averaging results from pond sediment samples. |
| SA - | Skin surface area available for contact, ($cm^2$/event) | 4030 | Adult male, mean surface area ($m^2$): feet - 0.112, lower legs - 0.207, hands - 0.084 (EPA, 1989b). |
| BW - | Body Weight, (kg) | 70 | Average adult body weight (EPA, 1989b) |
| Y - | Years Living in One House (exposure duration) | 30 | 90th percentile of length of time spent at one residence (EPA, 1989b). |
| DF - | Desorption Factor (unitless) | 1 | Desorption of contaminant from the sediment matrix (EPA, 1989b). |
| AF - | Soil to skin adherence factor ($mg/cm^2$) | 2.77 | Value for kaolin clay (1988d). |
| EF - | Exposure Frequency (days/year) | 20 | Best professional judgment based on two recreational visits to site, per month for ten months of each year. |

TABLE C-5

INCIDENTAL SURFACE WATER INGESTION EXPOSURE PARAMETERS

| Variable | | Value Used | Rationale |
|---|---|---|---|
| Cw - | Contaminant concentration in surface water (µg/l) | See Table 7-17 | Calculated by averaging results from Site 3A water. |
| IR - | Ingestion Rate (l/day) | 0.05 | Volume ingested during 1 hour of swimmping (EPA, 1989b). |
| BW - | Body Weight, (kg) | 70 | Average adult body weight (EPA, 1989b) |
| Y - | Years Living in One House (exposure duration) | 30 | 90th percentile of length of time spent at one residence (EPA, 1989b). |
| EF - | Exposure Frequency (days/year) | 20 | Best professional judgment based on two recreational visits to site per month for ten months of each year. |

# Appendix D

# APPENDIX D

# REFERENCES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# PERSONAL COMMUNICATION

September 9, 1991. James N. DiClementi, JMM, with Alex Barron, Commonwealth of Virginia State Water Control Board, regarding Virginia Water Quality Criteria applications.

September 10, 1991. James N. DiClementi, JMM, with Bekir Krishnan, Commonwealth of Virginia Department of Waste Management, regarding Virginia Groundwater Protection Levels applications.