March 15, 2006

Ms. Ginny Lombardo
U.S. Environmental Protection Agency
1 Congress Street
Suite 1100 (Mailcode HBT)
Boston, MA 02114-2023

Ms. Lynne Welsh
Massachusetts Department of Environmental Protection
627 Main Street
Worcester, MA 01605

Dear Ms. Lombardo and Ms. Welsh:

Re: Data Gaps Analysis Report, Shepley's Hill Landfill, Devens, Massachusetts
Contract No. GS-10F-0230J, Delivery Order W912WJ-05-F-0037

On behalf of the Army BRAC Office at Devens and the US Army Corps of Engineers (USACE), AMEC Earth & Environmental (AMEC) is pleased to provide the attached draft final Data Gaps Analysis Report for the Shepley's Hill Landfill. The stakeholder draft of this document was submitted on October 31, 2005, comments were received from the Environmental Protection Agency (EPA) on December 15 and Massachusetts Department of Environmental Protection (MassDEP) on December 22, 2005, and a draft Response to Comments Letter (RCL) was submitted on February 5, 2006. Follow-up comment letters and the final RCL (containing all original comments) have been appended to the Data Gaps Analysis Report.

The enclosed document is characterized as a "draft final" document. However, it is our intent that this submittal comprise the final report. In accordance with the FFA and as described in the Project Management Plan, the draft final version of a primary document will become the final primary document either forty-five days after issuance, if dispute resolution is not invoked, or as modified by decision of the dispute resolution process.

In response to follow-up comments from the Agencies the Army notes that the majority of Comment Responses are accepted and the outstanding technical issues are to be addressed in the Comprehensive Site Assessment (CSA) Scope of Work. Those issues include:

1. Adequacy of the existing monitoring well network,
2. Proposed revisions to the current groundwater model,
3. The need for an upgradient bedrock well, and
4. The details of proposed geophysical investigations.

The follow-up comments largely reiterate the Agencies' positions with regard to the need for detailed site characterization and provide a number of recommendations. The Army concurs that a thorough review of historical information and interpretation of monitoring data in three dimensions (maps and cross-sections) will be needed as part of the CSA and may contribute to the understanding of the arsenic source. The Army also accepts that it will be difficult to prove

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that arsenic-bearing wastes are absent, and therefore it would be prudent to "conservatively assume that arsenic-bearing wastes in the landfill are contributing to elevated As in groundwater" within the remedial decision-making process. However, it should be noted that this assumption would obviate the need for detailed intrusive investigations to locate that portion of the waste that may be arsenic-bearing.

With regard to the use of electrical leak detection surveys, the Army believes the current proposed approach involving test pit inspection targeted at potential high stress locations is a reasonable and appropriate first step, and that it would be prudent to consider this or other more advanced techniques only if (1) test pit surveys reveal evidence the PVC geomembrane is not functioning correctly or was improperly installed and (2) the quality and utility of the data from advanced investigation techniques would warrant the expense.

With regard to the impact of floc in Red Cove, the Army agrees that there remain significant unknowns and notes the Data Gaps Analysis Report identifies this issue as a data gap. The comment response has been revised accordingly.

Finally, with regard to alternative remedial actions to be considered in the Corrective Actions Alternatives Analysis (CAAA), the Army has invested substantial resources in the Agency-approved contingency remedy and associated monitoring plan. Part of the CAAA will be to determine the effectiveness of this system. While full startup has not been achieved (but is imminent), data collected during pilot operations suggests the system does in fact intercept significant arsenic mass. Only if this system (under full operating conditions) is determined to be ineffective at mitigating off-site migration and associated unacceptable risks, if any, will remedies which supplant it be considered.

We look forward to proceeding with the CSA Scope of Work. Please contact Kate Sellers of AMEC if there are any questions.

Sincerely,

Kathleen Sellers, P.E.
Associate Environmental Engineer

Christopher Abate, Ph.D.
Senior Hydrogeologist

Attachment 1: Data Gaps Analysis Report, Shepley's Hill Landfill, Devens, Massachusetts

CC: Devens BRAC Distribution List (attached)

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Data Gaps Analysis Report

Shepley's Hill Landfill

Devens, Massachusetts

MARCH 2006

Prepared for:

U.S. Army Corps of Engineers
New England District
Concord, Massachusetts

Prepared by:

AMEC Earth & Environmental, Inc
Westford, Massachusetts
Contract No.: GS-10F-0230J
Delivery Order: W912WJ-05-F-0037

SHL-0066

NOTICE

The United States Department of Defense, Department of the Army, funded wholly or in part the preparation of this document and work described herein under Contract No. GS-10F-0230J and Delivery Order W912WJ-05-F-0037. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

DATA GAPS ANALYSIS REPORT

Shepley's Hill Landfill

Devens, Massachusetts

March 2006

Prepared for:

U.S. Army Corps of Engineers
New England District
Concord, Massachusetts

Prepared by:

AMEC Earth & Environmental, Inc.
Westford, Massachusetts

Data Gaps Analysis Report

Devens, Massachusetts

March 2006

CERTIFICATION:

I hereby certify that the enclosed Report, shown and marked in this submittal, is that proposed to be incorporated with Contract Number GS-10F-0230J. This Document has been prepared in accordance with USACE Scope of Work and is hereby submitted for Government approval.

Reviewed by:

AMEC Task Manager   Date

AMEC Project Manager   Date

Received by:

USACE Project Manager   Date

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

ACL	Alternate Concentration Limit
Ag	Silver
Al	Aluminum
AMEC	AMEC Earth and Environmental, Inc.
ARAR	Applicable or Relevant and Appropriate Requirements
As	Arsenic
ASTM	American Society of Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registrys
Ba	Barium
bgs	below ground surface
BOD	biological oxygen demand
Ca	Calcium
CAA Analysis	This is used interchangeably with CAAA
CAAA	Corrective Action Alternatives Analysis
CaCO3	Calcium Carbonate
Cd	Cadmium
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Cl	Chloride
CMR	Code of Massachusetts Regulations
COD	chemical oxygen demand
CQA	Construction Quality Assurance
Cr	Chromium
CSA	Comprehensive Site Assessment
CSM	conceptual site model
Cu	Copper
cy	cubic yards
DGA	Data Gaps Analysis
DO	dissolved oxygen
DQO	data quality objective
EM	electromagnetic
EPA	Environmental Protection Agency
ERA	Ecological Risk Assessment
Fe	Iron
FFA	Federal Facilities Agreement
FS	Feasibility Study
gal/day	gallons per day
GPR	Ground Penetrating Radar
GW-#	MADEP water supply zone designation
HERA	human and ecological risk assessment
Hg	Mercury
HHRA	Human Health Risk Assessment
ID	identification
IWPA	Interim Wellhead Protection Area
MassDEP	Massachusetts Department of Environmental Protection

ABBREVIATIONS, ACRONYMS, AND SYMBOLS CONT.

MCL	Maximum Contaminant Level
MCP	Massachusetts Contingency Plan
Mg	Magnesium
mg/kg	milligram per kilogram
mg/L	milligram per liter
µg/L	microgram per liter
MMCL	Massachusetts Maximum Contaminant Level
umhos/cm	micro Mhos per centimeter
Mn	Manganese
Mo	Molybdenum
MSGRP	Multiple Source Groundwater Response Plan
mV	millivolt
Na	Sodium
NAS	National Academy of Science
NCSS	statistical software company
Ni	Nickel
NPL	National Priorities List
O&M	Operation and Maintenance
ORD	Office of Research and Development
ORP	oxidation-reduction potential
OU	Operable Unit
Pb	Lead
pH	potential of Hydrogen
PVC	polyvinyl chloride
RAB	Restoration Advisory Board
RAM	Release Abatement Measure
RI	remedial investigation
ROD	Record of Decision
SGI	Supplemental Groundwater Investigation
SHL	Shepley's Hill Landfill
Si	Silicon
TDS	total dissolved solids
TKN	Total Kjeldahl Nitrogen
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers
USACE-NAE	U.S. Army Corps of Engineers – New England District
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOC	volatile organic compound
WP	Work Plan
Zn	Zinc

EXECUTIVE SUMMARY

Shepley's Hill Landfill encompasses approximately 84 acres in the northeast corner of the main post of the former Fort Devens, Massachusetts (Figure ES-1). The landfill is bordered to the northeast by Plow Shop Pond, to the north by Nonacoicus Brook (which drains the pond), to the west by Shepley's Hill, to the south by recent commercial development, and to the east by the site of a former railroad roundhouse.

The landfill was reportedly operating by the early 1940s, and evidence from test pits within the landfill suggests earlier usage, possibly as early as the mid-nineteenth century. The landfill contains a variety of waste materials, including incinerator ash, demolition debris, asbestos, sanitary wastes, spent shell casings, glass, and other wastes. The maximum depth of the refuse occurs in the central portion of the landfill and is estimated to be about 40 feet. The volume of waste in the landfill has been estimated at over 1.3×10^6 cubic yards (cy), of which approximately 25 percent is below the water table.

The landfill was closed in five phases between 1987 and 1992-93 in accordance with Massachusetts regulations at 310 CMR 19.000. The Massachusetts Department of Environmental Protection (MADEP) approved the closure plan in 1985. Closure consisted of installing a 30-mil polyvinyl chloride (PVC) membrane cap, covered with soil and vegetation and incorporating gas vents. Closure also included installation of wells to monitor groundwater quality around the landfill, and construction of a storm drainage system to control surface water runoff. MADEP issued a Landfill Capping Compliance Letter approving the closure in February 1996.

The Environmental Protection Agency (EPA) placed the Site on the National Priorities List (NPL) in July 1989 due to contamination of groundwater with arsenic (As), cadmium (Cd), chromium (Cr), lead (Pb), and mercury (Hg). The EPA and Army signed a Federal Facilities Agreement (FFA) on May 13, 1991 as amended March 26, 1996.

Remedial investigations (RIs) under CERCLA evaluated soil, sediment, surface water, and groundwater conditions at and in the immediate vicinity of the landfill. The results confirmed the presence of various contaminants, particularly volatile organic compounds (VOCs) and certain inorganics, in groundwater, sediments and surface water at or adjacent to Shepley's Hill Landfill. A Feasibility Study (FS) and Record of Decision (ROD) resulted in a remedy that required long term monitoring and maintenance of the existing landfill cap and groundwater monitoring.

The ROD outlined the remediation objectives for the site (USEPA, 1995). It requires the Army to monitor groundwater, maintain the landfill, and prepare annual reports. It also requires that the Army review the effectiveness of the remedy every five years. The goal of that remedy, which relied heavily on the previously installed landfill cap, was to attain groundwater clean-up goals by 2008 thereby reducing exposure risks. In addition, the ROD states that if the landfill cap were found not to meet the prescribed risk-reduction performance criteria, the Army was to implement a contingency remedy consisting of groundwater extraction and treatment. Due to continued elevated contaminant concentrations, the Army recently installed and started operating a groundwater extraction and treatment system to address groundwater contamination emanating from the northern portion of the landfill.

The ROD also states that Massachusetts solid waste laws and regulations are Applicable or Relevant and Appropriate Requirements (ARARs) for Shepley's Hill Landfill. Citing those requirements, the MassDEP requested that the Army perform a Comprehensive Site Assessment (CSA) and Corrective Action Alternatives Analysis (CAAA) (Welsh, 2005). The *Landfill Technical Guidance Manual* (MassDEP, 1997) provides guidelines for performing those studies.

This Data Gaps Analysis (DGA) Report serves as the first step to complete the CSA and CAAA. The CSA will be completed in accordance with the requirements of MassDEP regulation 310 CMR 19.150. Major components of the CSA are anticipated to include off-site groundwater plume investigation, quantitative Human Health Risk Assessment (HHRA), qualitative Ecological Risk Assessment (ERA), and a landfill cap assessment. The HHRA and ERA shall evaluate known and anticipated exposures related to releases from the landfill and shall be performed in accordance with CERCLA risk assessment guidance. The CAA Analysis will be completed in accordance with the requirements of MassDEP regulation 310 CMR 19.150 and CERCLA requirements for a FS. The CAA Analysis will review all prior FS alternatives, revise and/or validate these alternatives based on new data and develop any new alternatives as necessary. The CAAA will include a recommendation for a final corrective action alternative.

The purpose of this DGA Report is to assess existing site characterization data, identify major data gaps and outline the corresponding additional data needs, and define data quality objectives (DQOs) necessary to support completion of the CSA and CAAA. For this DGA, available data was reviewed to develop and confirm the conceptual site model and to identify data gaps with respect to stakeholder's principal general objectives, MA requirements for a CSA and CAAA, and USEPA requirements for risk assessments and feasibility studies.

AMEC concludes that the following constitute the key data gaps for the Shepley's Hill Landfill:

- Extent of arsenic plume north and northwest of landfill
- Potential impact of landfill contaminants to McPherson Well
- Magnitude of impact from landfill contaminants on Red Cove
- Existence of completed exposure pathways and magnitude of current and future risk to human health and environment from landfill-derived contaminants.
- Integrity and effectiveness of existing landfill cap, including unvegetated areas on southeastern portion of landfill cover.

The detailed data gaps identified during the data review are summarized on Table ES-1. Table ES-1 includes preliminary actions proposed to acquire appropriate and sufficient information to close the data gaps. Closure of the data gaps as described will provide necessary data to complete delineation of contaminants, complete human and ecological risk assessments, prepare the CSA report, and evaluate previously identified and potentially new remedial alternatives in the CAAA report.

Table ES-1
Summary of Data Gaps Closure Strategy
Data Gaps Analysis Report
Shepley's Hill Landfill

ISSUE	EXISTING DATA	DATA GAP(S)	DATA GAP "NEEDS"	PURPOSE	OUTCOME
1. Evaluate magnitude of plume impact to Nonacoicus Brook and wetlands, if any	• Existing wells, GW sample results from existing proximal wells • GW head data from wells	• Downgradient extent of plume undefined. • GW/SW interaction unclear. • Is stream/wetland a hydraulic barrier? • Are contaminants reaching wetlands, and if so, at what concentrations?	• Install wells and piezometers and collect key GW, SW and sediment samples. • Determine key SW and GW elevations. • Gauge upgradient/downgradient streamflows.	• Delineate plume at all critical margins, especially toward the wetlands. • Determine contaminant concentrations in the GW and SW at wetlands. • Support concept that stream/wetland is a hydraulic barrier. • Make appropriate GW model adjustments • Provide input for risk assessments.	Achieve adequate delineation of plume boundary and contaminant concentrations in wetlands attributable to Shepley's Hill Landfill to be used to complete the human health and ecological risk assessment for the CSA.
2. Evaluate potential for impact to McPherson water supply well.	• GW head data from existing wells in vicinity of currently defined plume. • Historic pumping rates of well. • Location of mapped Zone IIs	• Undefined plume boundary on NW side of plume. • Effectiveness of Willow Brook as hydraulic barrier. • Likelihood of plume reaching Zone II of well in future.	• Selected elements from #1 above. • Review/confirm derivation of Zone IIs. • Use refined groundwater model to determine if (and at what concentrations) contaminants could reach the well.	• Determine western plume boundary downgradient of SHL • Develop relevant information to confirm potential for contaminants to reach well.	Decision whether GW contamination is currently or could in the future impact McPherson Well and potential extent, if any, to complete the human health risk assessment for the CSA.
3. Evaluate landfill cap integrity and effectiveness at minimizing surface/groundwater intrusion and leachate generation.	• As-built and annual cap condition reports • Existing topo surveys • Site inspection reports.	• Accurate geographic extent of cap • Detailed inspection of cover and PVC condition • Cap tie-in to bedrock	• Test pits for direct liner-cover inspection, cap edge inspection and evidence of potential underflow. • Geophysical surveys for guiding test pit location, depth to bedrock, and potentially waste thickness.	• Determine if cap function is compromised due to subsidence. • Improved representation of cap and underflow process in GW model	Confirm significance of cap infiltration to GW and identify recommendations for mitigating any significant deficiencies.
4. Assess Red Cove as an area of historic and possibly current leachate discharge	• GW sample results from existing wells • GW head data	• Vertical hydraulic gradients • GW-to-SW flow. • Contaminant flux to Red Cove	• Compliment planned EPA studies at Red Cove • Analysis of hydraulic data from nested piezometers • Collect sediment core samples to estimate vertical hydraulic conductivity, gradients, and groundwater flow	GW discharge rate will be used to estimate the present contaminant flux to Red Cove and calibrate model representation of this process.	Determine Shepley's Hill Landfill contribution to historic (pre-capping), current, and future surface water and sediment contribution to complete the ecological risk assessment for the CSA.
5. Assess landfill gas issues and the non-vegetated cap areas along the southeast portion of the Landfill.	• Annual landfill gas sampling results. • Annual inspection reports.	• Results of proposed gas probe sampling along the northern edge. • Cause of lack of vegetation.	• Data from proposed gas probe sampling will be thoroughly reviewed relative to cap integrity or risk assessment. • Non-vegetated cap areas will be specifically inspected, and their significance relative to cap integrity will be assessed.	• Define potential for significant gas migration toward potential receptors. • To evaluate the integrity of the Shepley's Hill Landfill cap.	Confirm that gas migration is not a significant concern.
6. Human and Ecological Risk Assessment	• GW-1 and Zone II delineations • GW and SW sample results • Evaluate predicted GW fluxes from USEPA results due in January 2006	• Demonstration of complete exposure pathways for evaluating potential effects to people and to ecological receptors. • Improved confidence in GW model	• Elements of all preceding issues • Evaluate USEPA results due in January 2006 and decide whether to collect additional GW, SW, or sediment samples to fill new data gaps, if any. • As speciation. • Presence of domestic wells.	• Quantification of risk levels under present site conditions for human and ecological receptors	• Determination of acceptable/ unacceptable risk levels under present site conditions for human and ecological receptors • Recommendation for mitigating unacceptable risks
7. Complete CSA and CAAA Reports.	All of the above	All of the above	• Collect, evaluate and complete the site investigation; assess the landfill cap; and assess potential effects on human health and ecological receptors. • Collect pertinent geologic and hydraulic data to evaluate engineering feasibility of select alternatives.	• Define project objectives, decisions and data requirements. • Establish data quality objectives and analyze data gaps.	A protectiveness determination of the remedy for SHL was deferred in the 2005 Five Year Review until further information is obtained through the completion of the CSA and CAAA. The CSA and CAAA reports will meet a critical milestone obligation set forth in the 2005 Five Year Review.

Abbreviations: SHL = Shepley's Hill Landfill, GW = groundwater, SW = surface water

1.0 INTRODUCTION

This Data Gaps Analysis (DGA) Report serves as the first step to complete a Comprehensive Site Assessment (CSA) and Corrective Action Alternatives Analysis (CAAA) for Shepley's Hill Landfill in Ayer, Massachusetts. Subsequent steps include development and execution of a work plan for collection of information required to "close" the identified data gaps, completion of a comprehensive site assessment report which describes relevant site and contaminant conditions and identifies and quantifies potential risks to human health and the environment by site-derived contaminants, and performance of a CAAA. The CAAA is the process by which remedial alternatives are identified and evaluated to eliminate or mitigate unacceptable adverse impacts caused by conditions resulting from the landfill. The CAAA will focus on identifying alternatives with a high probability of success and screening out lower probability alternatives based on data compiled in the CSA.

This DGA Report was prepared under contract Number GS-10F-0230J, Delivery Order Number W912WJ-05-F-0037, for the US Army Corps of Engineers, New England District (USACE-NAE).

1.1 Site History and Background

Shepley's Hill Landfill encompasses approximately 84 acres in the northeast corner of the main post of the former Fort Devens (Figure 1-1). The landfill is bordered to the northeast by Plow Shop Pond, to the north by Nonacoicus Brook (which drains the pond), to the west by Shepley's Hill, to the south by recent commercial development, and to the east by land formerly containing a railroad roundhouse.

The landfill was reportedly operating by the early 1940s, and evidence from test pits within the landfill suggests earlier usage, possibly as early as the mid-nineteenth century. The landfill contains a variety of waste materials, including incinerator ash, demolition debris, asbestos, sanitary wastes, spent shell casings, glass, and other wastes.

Based on boring logs, the maximum depth of the refuse occurs in the central portion of the landfill and is estimated to be about 40 feet below ground surface (bgs). The volume of waste in the landfill has been estimated at over 1.3×10^6 cubic yards (cy), of which approximately 3.2×10^5 cy (25%) is below the water table.

The landfill was closed in five phases between 1987 and 1992-93 in accordance with Massachusetts regulations at 310 CMR 19.000. The Massachusetts Department of Environmental Protection (MADEP) approved the closure plan in 1985. Closure consisted of installing a 30-mil polyvinyl chloride (PVC) membrane cap, covered with soil and vegetation and incorporating gas vents. Closure also included installation of wells to monitor groundwater quality around the landfill, and construction of drainage swales to control surface water runoff. MADEP issued a Landfill Capping Compliance Letter approving the closure in February 1996.

Subsequent to closure, remedial investigations (RIs) under CERCLA evaluated soil, sediment, surface water, and groundwater conditions at and in the immediate vicinity of the landfill. The results confirmed the presence of various contaminants, particularly certain inorganics and volatile organic compounds (VOCs), in groundwater, sediments and surface water at or adjacent to Shepley's Hill Landfill. A Feasibility Study (FS) and Record of Decision (ROD) resulted in a remedy that required long term monitoring and maintenance of the existing landfill cap and groundwater monitoring. The ROD included a contingency provision, which required that a pump and treat system be installed if groundwater contaminant concentrations (primarily arsenic) did not meet risk-based performance standards over time. Due to continued elevated contaminant concentrations, the Army recently installed and started operating a groundwater extraction and treatment system to address groundwater contamination emanating from the northern portion of the landfill.

Past investigation and monitoring work has produced a wealth of characterization data. AMEC will maximize the use of these data in the CSA/CAAA process.

1.2 Objectives

The Performance Objectives for this project are to:

1. Complete a CSA of Shepley's Hill Landfill in accordance with the requirements of MADEP regulation 310 CMR 19.150. This CSA shall include, but may not be limited to:
    a. Offsite groundwater plume investigation
    b. Quantitative Human Health Risk Assessment (HHRA)
    c. Quantitative Ecological Risk Assessment (ERA), and
    d. Landfill cap assessment

   The HHRA and ERA shall evaluate known and anticipated exposures related to releases from the landfill and shall be performed in accordance with CERCLA risk assessment guidance.

2. Complete a CAAA in accordance with the requirements of MADEP regulation 310 CMR 19.150 and CERCLA requirements for a Feasibility Study. This CAA Analysis shall review all prior Feasibility Study alternatives, revise and/or validate these alternatives based on new data and develop any new alternatives as necessary. The CAA Analysis shall recommend the final corrective action alternative.

The purpose of this DGA Report is to: assess existing site characterization data, identify major data gaps and define the corresponding additional data needs, and define data quality objectives (DQOs) necessary to support completion of the CSA and CAAA. These DQOs represent a conceptualization of how the data will be used in the context of the regulatory requirements for evaluation of risk in the CSA and potential actions to mitigate unacceptable risk in the CAAA.

1.2.1 Regulatory Context

The Site was placed on the National Priorities List (NPL) in July 1989 due to contamination of groundwater with arsenic (As), cadmium (Cd), chromium (Cr), lead (Pb), and mercury (Hg). The Environmental Protection Agency (EPA) placed the installation on the NPL in November 1989.

The EPA and Army signed a Federal Facilities Agreement (FFA) on May 13, 1991 (amended March 26, 1996).

The ROD outlined the remediation objectives for the site (USEPA, 1995). It requires the Army to monitor groundwater, maintain the landfill, and prepare annual reports. It also requires that the Army review the effectiveness of the remedy every five years. The goal of that remedy, which relied heavily on the previously installed landfill cap, was to attain groundwater cleanup goals by 2008 thereby reducing exposure risks. In addition, the ROD states that if the landfill cap was found not to meet the prescribed risk reduction performance criteria, the Army was to use a contingency remedy that consisted of groundwater extraction and treatment. That remedy has been constructed and started up in September 2005.

The table below summarizes clean-up levels for Shepley's Hill Landfill Operable Unit groundwater, as defined in the ROD.

Clean-Up Levels for Groundwater

Chemical of Concern	Cleanup Level (µg/L)	Selection Basis
Arsenic	50	MCL
Chromium	100	MCL
1,2-Dichlorobenzene	600	MCL
1,4-Dichlorobenzene	5	MMCL
1,2-Dichloroethane	5	MCL
Lead	15	Action level
Manganese	291	Background
Nickel	100	MCL
Sodium	20,000	Health Advisory
Aluminum	6,870	Background
Iron	9,100	Background

MCL – Maximum Contaminant Level; MMCL – Massachusetts MCL

The ROD put these goals into the following context:

> The Army proposes to use reduction of risk rather than reduction of concentration as a measure of progress toward attainment of cleanup levels because this approach focuses on the cleanup of arsenic, which is the primary contributor to risk in the Group 2 wells. This approach prevents a situation in which failure to attain a concentration reduction goal for a minor contributor to risk (e.g. 1,2-dichloroethane where reduction of 2.5 ppb represents a 50 percent reduction in concentration exceeding the cleanup level) overshadows the achievement of 50 percent or greater reduction in the concentration of arsenic. In the Group 2 wells, a 50 percent reduction in the concentration of arsenic approximates to a 50 percent reduction in groundwater risk, while a 50 percent reduction in the concentration of 1,2-dichloroethane represents less than 1 percent reduction in groundwater risk. Alternative

SHL-2 will be considered effective with regard to these wells if five-year reviews show an ongoing reduction of potential human health risk at Group 2 wells and the ultimate attainment of cleanup levels by January 2008.

The specific criteria for evaluating effectiveness of Alternative SHL-2 are stated below. The criteria for both groups of wells must be met for the alternative to be considered effective.

Group 1 Wells. For Group 1 wells where analyte concentrations have historically attained cleanup levels, Alternative SHL-2 will be considered effective if concentrations of individual chemical within individual well do not show statistically significant cleanup level exceedences. To determine statistical significance the Army will apply methods consistent with the regulations at 40 CFR 264.97, 40 CFR 258.53, 310 CMR 30.663.

Group 2 Wells. For Group 2 wells where chemical concentrations have exceeded cleanup levels in the past, Alternative SHL-2 will be considered effective if 50 percent reduction in the increment of risk between cleanup levels and baseline concentrations for chemical of concern within individual wells is achieved by January 1998, if an additional 25 percent (75 percent cumulative) is achieved by January 2003, and if cleanup levels are attained by January 2008.

Well Group 1 consists of wells, primarily at the north end of the landfill, where cleanup levels have been attained historically. Well Group 2 consists of wells where historically cleanup levels have not been attained.

The ROD also states that Massachusetts solid waste laws and regulations are Applicable or Relevant and Appropriate Requirements (ARARs) for Shepley's Hill Landfill. Citing those requirements, the MADEP requested that the Army perform a CSA and CAAA (Welsh, 2005). The *Landfill Technical Guidance Manual* (MADEP, 1997) provides guidelines for performing those studies.

Massachusetts regulations at 310 CMR 19.150 describe the requirements for landfill assessment. However, they do not describe specific requirements for monitoring groundwater during a CSA. At 310 CMR 19.118(2), Solid Waste Management regulations specify requirements for "any person conducting landfill activities" to monitor groundwater, including both performance requirements and design standards. The regulations provide more details on environmental monitoring requirements at 310 CMR 19.132(1). These requirements pertain to landfill monitoring in toto. At the Shepley's Hill Landfill, the Army monitors environmental conditions under a long term monitoring program which will be supplemented by the CSA.

1.2.2 Technical Objectives

The technical objectives of the Army and other project stakeholders include:

1. Evaluation of the plume to determine whether the plume is impacting the wetlands and the potential magnitude of that impact, if any.
2. Determination of any impact to the McPherson water supply well and the magnitude of such impact, if any.

3. Evaluation of landfill cap integrity and its effectiveness at minimizing surface/groundwater intrusion and leachate generation.
4. Assessment of Red Cove as an area of historic and possibly current leachate discharge.
5. Assessment of landfill gas issues and the non-vegetated cap areas along the southeast portion of the Landfill.

Each of these issues is specifically addressed in this report.

This DGA Report evaluates available data and identifies additional data required to complete a CSA in accordance with requirements of MADEP regulation 310 CMR 19.150. In general, these requirements relate primarily to identification and delineation of site-derived contaminants (e.g., "nature and extent, fate and transport"), and identification and quantification of current and future potential risks to human health and the environment (risk assessments). Development of a reliable risk assessment is considered a key component of a CSA, because risk clearly is a significant driver in identifying contaminants of concern and their distribution (at concentrations of concern), and potential remedial approaches for mitigating the risks. The human health and ecological risk assessments will evaluate known and anticipated exposures related to releases from the landfill and will be performed in accordance with CERCLA risk assessment guidance.

AMEC will also evaluate available data and identify additional data required to complete a CAAA in accordance with the requirements of MADEP regulation 310 CMR 19.150 and CERCLA requirements for a Feasibility Study. This CAAA will review all prior Feasibility Study alternatives, revise and/or validate these alternatives based on new data and develop any new alternatives as necessary. The CAAA will recommend a final corrective action alternative.

The DGA Report is organized as follows:

- Section 2 provides a brief summary of existing data, including a preliminary plume delineation and statistical analysis of geochemical data,
- Section 3 is an identification of the major data gaps, organized consistent with the five stakeholder objectives listed above, and
- Section 4 is a summary of the data to be collected.

It should be noted that this report describes data gaps identified on the basis of information available to AMEC as of the report submittal date. AMEC understands that data acquisition is an ongoing activity at the landfill. New data may change the conceptual site model (CSM), or our confidence in the CSM. New data may result in identification of new data gaps.

This DGA Report provides general discussions of the means and methods for acquiring the requisite data. Specific details regarding the methods for collecting data will be presented in a subsequent CSA Work Plan. The CSA Work Plan will be prepared after agreement has been reached with the stakeholders on the data gaps and resultant scope of the CSA investigation.

1.3 Work by Others

This DGA Report was prepared as work continued on and around the landfill. Table 1-1 summarizes ongoing and proposed work.

Table 1-1 shows that ongoing work by others will continue to amass data. This DGA Report therefore represents a "snapshot" of the landfill and surrounding area which will be refined as work progresses. It will be used as a basis for planning and executing the CSA and CAAA. Data generated by others will be utilized to address data gaps and will be incorporated into the CSA Report and CAAA as appropriate after this DGA Report is finalized.

1.4 Technical Approach

The concerns at the Shepley's Hill Landfill relate to the movement of water: potential infiltration of water through the cap, groundwater flow through the waste material and downgradient, groundwater discharge to surface water and ecological receptors, and, potentially, groundwater migration toward drinking water wells. The DGA focused on this flow of water.

The existing CSM and numerical groundwater model provide a good technical basis for the proposed work. The DGA tested key aspects of this basis where they are not strongly substantiated by site data and could significantly influence the need for and type of remediation. In particular, we examined and will continue to explore:

- Groundwater inflow into the landfill;
- Hydraulic integrity of the cap;
- Groundwater / surface water interaction; and
- Potentially complete human and ecological exposure pathways

The project will also examine the risk assessment as required for the CSA and as appropriate to determine the need for additional remedial actions. The ROD laid the groundwork for assessing clean-up progress thoughtfully. We will hone the previous analyses of the need for cleanup by considering:

- Background levels and speciation of arsenic;
- The potential for other releases to have affected environmental conditions;
- Potential risks to probable receptors; and
- ROD requirements.

In other words, a strategy based on a realistic assessment of the context for the site (background, receptors) will be explored to bound the need for additional remediation. The feasibility of Alternate Concentration Limits (ACLs) and deed restrictions will be further evaluated.

Throughout the CSA, conclusions will be based on an approach considering multiple lines of evidence. For most questions, no single datum can provide an absolute, conclusive answer.

Instead, conclusions will be drawn from several types of data to close the data gaps identified in the report and achieve validation of key elements of the CSM.

Alternative engineering solutions through the Landfill Cover Assessment and CAAA will be assessed and developed, as appropriate. Those solutions will focus on water flow through the cap and through the landfill, and toward downgradient receptors. That focus will aid in defining cost-effective solutions. For example, if the flow through the landfill cap is minimal, then it would make little sense to expend substantial monies upgrading the cap beyond the maintenance already planned.

With respect to groundwater remediation, this focus will incorporate the following considerations:

- The mass of waste in the landfill represents a long-term influence on groundwater conditions.
- As long as water flows through the landfill, generating reducing conditions and mobilizing arsenic, the Army will need to pump and treat water unless a risk-based solution is effective.
- An alternative approach may be to limit the water flowing through the landfill by routing water around the landfill. This will minimize the influence of the landfill on downgradient groundwater.
- If the HERA identifies unacceptable risks which the existing remedy does not address, then alternative remedial actions will be considered.

Table 1-2 provides an overview of the technical approach and issues that are addressed in this DGA Report.

2.0 REVIEW OF EXISTING DATA

AMEC reviewed various forms of data as the first step of the data gap analysis. These data include:

- Geologic/geographic data including lithologic and hydraulic head information, distribution of arsenic in regional groundwater and bedrock, location and extent of wetlands, etc.;
- Chemical analytical data for groundwater, surface water, landfill gas, and sediment samples;
- Engineering data for the landfill structure (cap extent, thickness, design details, etc.); and
- Cultural and regulatory data such as State-classified wellhead protection areas, non-potential drinking water source areas, and Areas of Critical Environmental Concern, etc.

In addition to the References section of this report, a listing of documents that have been provided to AMEC to date is compiled in Appendix A.

Following is a brief description of the information reviewed for the data gap analysis. Although an attempt has been made to acquire all data available for and relevant to the site, there may be existing data that were not available for the review. Data provided after the publication of this report will be incorporated into subsequent work plans and reports.

2.1 Geologic/Geographic Data

Surface-location data for borings and monitoring wells appear to be relatively complete, as more than 130 sets of northing-easting coordinates have been compiled from various data files. Where such data may be missing, it will likely be possible to estimate surface locations with sufficient accuracy from maps in existing reports.

Data on well/boring location, surface elevation, screen depth, and other aspects of construction have been reviewed and are being compiled into a database. AMEC understands that the results of a comprehensive elevation survey of new and existing wells are forthcoming. Electronic data provided to AMEC include historic static-water-level data for 18 monitoring wells. These data are adequate to: 1) provide control for AMEC's refinements to the groundwater model, and 2) indicate potential groundwater gradients toward Plow Shop Pond and Nonacoicus Brook, when used in conjunction with additional data to be acquired.

2.2 Chemical Data

Since 1991, groundwater and other data have been gathered under several programs, by several parties, and for various purposes; and have been preserved in various electronic and paper formats. Groundwater, sediment, and other data were reviewed for the data gaps analysis.

2.2.1 Groundwater

More than 40 electronic files containing data from 1991 through 2005 have been reviewed and assembled into a preliminary database. This entailed unit conversions, sampling-point and analyte respellings, date corrections, and other changes where necessary. These data have been used to develop a working arsenic plume map and to perform a preliminary statistical analysis as discussed below.

This effort supplements related monitoring work. With respect to trends in arsenic concentrations, according to the draft 2005 Five Year Site Review (USACE 2005c) the most recent long term monitoring data indicate no significant changes relative to historic arsenic values over the last five years.

2.2.2 Soil, Surface Water, and Sediment

Data on concentrations of contaminants in soil are few in comparison to other data. Contaminants in soil are not a driver for monitoring or response actions in relation to Shepley's Hill Landfill and therefore do not represent a critical data gap; however, these data will be examined in the CSA for their potential bearing upon the extent of groundwater- and sediment-borne contamination.

Surface water and sediment samples have been collected as part of several field programs and by various entities:

1. In 1993, 27 co-located surface water and sediment samples were taken in Plow Shop Pond (ABB, 1995).
2. In 2001, 14 co-located surface water and sediment samples (SHW-01-x series) were collected in Nonacoicus Brook and its unnamed tributary, which flows away from the central business district of Ayer and joins Nonacoicus Brook below Plow Shop Pond (Harding ESE, 2002). Three sets of samples were taken in the unnamed tributary above the confluence, and may or may not represent local brook conditions unaffected by Shepley's Hill Landfill. The remaining 11 colocated samples in lower Nonacoicus Brook are inevitably subject to influence by drainage from Plow Shop Pond, and at least some may be subject to influence by groundwater leaving the landfill area as well.
3. EPA studies were undertaken in and on the margins of Plow Shop Pond during the winter of 2004-2005, and the below-listed data sets were acquired.
   - Six surface-water and sediment samples for toxicity testing;
   - More than 20 samples of pore water from sub-bottom sediment;
   - 19 sediment samples for metals analysis; and
   - More than 30 additional sediment samples focused in Red Cove, including some sub-bottom sediment profiles to 5-foot depth.
4. Earlier EPA field studies were conducted of Plow Shop Pond during the period 1992-2002, focusing on samples of surface water, sediment, and biological tissues and populations. These data are not yet available for review.

The EPA's report on the Plow Shop Pond data is expected in January 2006. When the historic and recently acquired EPA data become available in that report, all surface water and sediment data will be reviewed to determine whether any data gaps remain.

2.2.3 Landfill Gas

Data collected annually in the fall as part of landfill monitoring have been summarized in the most recent 5-year and Annual reports (USACE, 2005c and 2005). The gas vents reveal highly varying concentrations of methane and carbon dioxide. The perimeter gas monitoring points do not indicate detectable concentrations of methane.

3.0 IDENTIFICATION OF MAJOR DATA GAPS

The following section defines major data gaps related to the five major stakeholder issues, as shown in Table 3-1, as well as the overall quantification of risk based on an understanding of arsenic geochemistry and completed exposure pathways.

For each data gap, the project team considered the Data Quality Objectives (DQO) process. The DQO process produces qualitative and quantitative statements that define the type, quality, and quantity of data necessary to support defensible technical decisions. The DQOs identify when and where to collect monitoring samples, the number of samples to be collected, how the samples should be analyzed, the analytical performance criteria to be met, how the results should be interpreted relative to the monitoring objectives, the practical constraints for collecting the samples, and the level of uncertainty that is acceptable to the decision makers using the data. This DGA Report contains the first steps in the DQO process. For each technical issue, it identifies the objectives, hypotheses, and decision rules that provide a framework for data collection (USEPA, 2004). It also specifies, in a general sense, the data to be collected. Details regarding the precise data collection methods and quality control/ quality assurance measures will be specified in the CSA Work Plan.

3.1 Conceptual Site Model and Overview of Areas Identified for Refinement

The major elements of the existing CSM (Harding ESE, 2002) are the starting point for the CSA/CAAA. However, the DGA and CSA will test key aspects of this model where they are not strongly substantiated by site data and could significantly influence the feasible remedial alternatives. To provide the context for the DGA, this section of the report summarizes the current CSM, identifies elements that are less well supported by site data, and suggests where alternate concepts may offer improved opportunity to minimize contaminant generation and/or migration.

3.1.1 Existing CSM

The CSM for Shepley's Hill Landfill describes the pathways through which human and ecological receptors might be exposed to landfill-related compounds. A complete exposure pathway comprises geochemical and hydrogeologic elements (contaminant source, release, and transport mechanisms) as well as exposure elements (points and routes of exposure for receptor populations).

The major elements of the existing CSM are as follows:

1. The primary contaminant relating to SHL and presenting human and ecological risk is arsenic.
2. In the Shepley's Hill area, the original primary source of dissolved arsenic in groundwater is probably the metasedimentary bedrock of Silurian age (USGS, 2003). This bedrock is known to contain elevated concentrations of arsenic, has been mapped at the surface adjacent to Shepley's Hill Landfill, and may occur directly beneath the landfill.

3. In other places where groundwater is oxygenated, dissolved iron and manganese that migrate through an oxygenated aquifer typically precipitate as oxides, and these minerals serve as sorption sites for arsenic. Therefore, in an oxygenated aquifer, all three metals typically become stored within the solid phase of the aquifer, rather than migrating with groundwater.
4. By contrast, Shepley's Hill Landfill (in common with many landfills) creates anoxic (reducing) conditions in the groundwater that passes beneath, as a result of the bacteria that consume the organic matter placed in the landfill. Reducing conditions liberate the arsenic (possibly also the iron and manganese), which again migrates with groundwater. The existence of organic waste below the local water table especially promotes the establishment of reducing conditions.
5. Downgradient within the aquifer or beyond its discharge to surface water, wherever oxygenated conditions are again established, iron, manganese, and arsenic will again be deposited in solid phase.
6. With respect to the unconfined aquifer beneath the landfill, negligible inflow (vertical recharge) occurs through the landfill cap, lateral inflow occurs from topographic Shepley's Hill to the west and upgradient areas to the south, major lateral outflow occurs in the vicinity of the landfill toe to the north, and minor outflow occurs toward Plow Shop Pond to the east.

The conceptual statements regarding hydrogeochemistry (elements #2, 3, 4, and 5) are sufficiently grounded either by site-specific data, or by well established inference from regional and/or theoretical studies.

3.1.2 DGA Focus with Respect to Risk Characterization

The statement regarding human and ecological risk (Element #1) is correct in a general sense. However, the following factors must be considered:

- Earlier risk characterizations viewed the site conservatively and defined risks based on exposure pathways that may not occur under the current and expected future use of the site.
- Background levels of arsenic, known to be high in central Massachusetts, must be accounted for in the risk assessment. Further, the bioavailability of arsenic depends on its chemical speciation.

Considering these factors in the CSM will allow for a more realistic, scientifically-defensible risk characterization as the basis for remedial actions.

3.1.3 DGA Focus with Respect to Groundwater Flow and Surface Water Interactions

Several additional, specific questions persist in terms of groundwater interactions with surface water and quantification of directions and rates of flow (Element #6). The CSM will be refined in the CSA as needed to satisfy regulatory requirements and move the site toward completion and closure of all CERCLA related investigations and reporting for the site.

The approximate magnitudes of several flow components (run-under from Shepley's Hill beneath the landfill, groundwater discharge to Plow Shop Pond, etc.) are important for two reasons:

1. The discharge rates of arsenic-bearing waters strongly affect arsenic concentrations in the receiving waters (groundwater or surface water) and associated sediments to which potential receptors may be exposed.
2. The flow-related attributes of hydrogeologic units – especially their geometry and hydraulic conductivity – determine the remedial alternatives that may be applicable and feasible.

The existing data offer relatively loose characterization of the magnitudes of key attributes of the local hydrogeologic system. Accordingly, data acquisition will be focused to establish:

- The rate of groundwater discharge to Nonacoicus Brook within the reach that may receive flow that passes from the toe of the landfill.
- The relative potentiometric level ("head") of shallow groundwater on either side of Nonacoicus Brook downgradient of the plume, which will indicate whether or not there is potential for groundwater underflow that bypasses the Brook.
- The geometry (width, thickness, and relative vertical position) of the gap between the western edge of the landfill cap and the top of the east-sloping bedrock surface.
- The vertical hydraulic conductivity of the saturated unconsolidated sediments present near the western edge of Plow Shop Pond, and the vertical hydraulic gradient(s) in that area.

3.2 Arsenic Geochemistry

As groundwater flows through the waste in the landfill and migrates beyond the site, discharging in places to surface water, the concentrations of arsenic in the groundwater vary depending on several factors. These factors may include contributions from background conditions in soil and rock; contributions from waste in the landfill and, possibly, other off-site sources. The levels of oxygen, as well as the presence of other compounds in the groundwater (e.g., iron, manganese, hydrogen ion) will also affect the type of arsenic and therefore its mobility downgradient of the landfill.

The current CSM incorporates two critical aspects of arsenic geochemistry. First, the subsurface geochemistry of arsenic is complex. Anaerobic, reducing environments will always favor the solubilization and mobilization of iron and manganese oxides. Because arsenic geochemistry is controlled by coprecipitation reactions with oxides, it may be present as a natural trace contaminant of iron and manganese and therefore be released upon reduction (and dissolution) of these oxides. Second, some of groundwater plume may be in contact with minerals within the bedrock (e.g., pyrite-bearing bedrock within the "Worcester band") that may have naturally elevated concentrations of arsenic. Also of interest is the fact that natural lenses of peat underlie some regions of the landfill, which may contribute to reducing conditions. The possibility therefore exists that tannins may be leaching arsenic from the natural bedrock substrate. Finally, it is important to investigate the possibility that arsenic is being mobilized by the bacterial methylation of inorganic arsenic, which may be present as a result of contaminated fill material (e.g., lead arsenates).

This section of the DGA Report begins with general information about arsenic geochemistry to provide context for the DGA. It proceeds to discuss a preliminary statistical evaluation of geochemical data from Shepley's Hill Landfill, then describes apparent data gaps on that basis.

3.2.1 Perspective on Arsenic in Groundwater

Data from the landfill area must be evaluated in light of arsenic levels in central Massachusetts; mechanisms which control the speciation and mobility of arsenic; and conditions found adjacent to other landfills. The information provided below is not intended to be a comprehensive treatise on arsenic, but simply to provide the context for subsequent discussions.

3.2.1.1 Arsenic in Central Massachusetts

Various papers describe the presence of arsenic in the bedrock underlying central Massachusetts. The US Geological Survey (USGS) found that arsenic in private wells is widespread in eastern New England. They have linked the presence of arsenic in private drinking wells to a defined "arsenic belt" that runs from central Maine through northeastern and central Massachusetts, to as far as Connecticut. Within Massachusetts the "arsenic belt" is generally bounded on the west by the towns of Ashburnham, West Brookfield, and Douglas and on the east by Northbridge, Westborough, Stow, and Maynard (USGS, 2003). The Shepley's Hill Landfill is situated within this belt.

Arsenic is a common trace element in groundwater and can range, on the high end, from 10 micrograms per liter (µg/L) to 50 µg/L in New England (USGS, 2003). More and more evidence shows the arsenic in groundwater originates in minerals in the rocks of the region. The bedrock running through the central region of Massachusetts is classified as metamorphosed marine sediments described as "variably calcareous" (5% - 50% calcite) or derived from calcareous protoliths (USGS, 2003). A USGS study showed that water from bedrock wells in the calcareous metasedimentary rock had high arsenic concentrations, with 46% of the wells returning arsenic concentrations over 5 µg/L and 29% of the wells over 10 µg/L. An investigation of the bedrock itself showed arsenic present in the sulfide mineralization (pyrite and pyrrhotite with accessory chalcopyrite) portion of the rock, notably in the thin layers of calcite in the overall rock and on the water-bearing fractures. Analytical results of bulk rock and water from the water-bearing fractures returned an average concentration of 15 milligrams per kilogram (mg/kg) and a range of 0.74 – 6.1 µg/L, respectively (USGS, 2003).

3.2.1.2 Arsenic Mobility

The more mobile of the forms of arsenic (commonly As(V) and As(III)) is As(III). As(V) is capable of binding to soil because of its charge, and is thereby removed from the dissolved phase. Higher pH and reducing conditions favor the formation of As(III).

Many of the binding sites for arsenic are metal oxides, such as iron, aluminum, and manganese. These "matrix" metals occur naturally as part of the chemical structure of soils and rocks (some at percent levels). When these metals are subjected to reducing conditions, they may be released to the groundwater. As a consequence, arsenic may be released to the groundwater. If sulfide is present in the water, however, arsenic may bind to the free sulfide ion and precipitate out of solution.

The presence of reducing bacteria can mobilize arsenic via several mechanisms. The reducing bacteria may directly reduce the As(V) to As(III). Alternatively, native bacteria can reduce iron, releasing it to the groundwater and thereby mobilizing arsenic. The level of organic carbon is also an important variable, and can be particularly important at landfills. The organic carbon may act as a nutrient for the bacteria, allowing the microbial population to flourish and grow, which, in turn, may foster a reducing environment. Microbial activity within the landfill has the potential to convert inorganic arsenic into an organic form, such as mono-, di- or trimethylarsinic acid (or methylarsines). These organic forms of arsenic are not only mobile in ground and surface water, but they are volatile and can be relatively toxic. Alternatively, bacteria in the presence of oxygen may oxidize sulfides, converting the sulfide to sulfate, which is soluble in water. The sulfate will then release the arsenic to groundwater, making it mobile.

There is also some evidence that naturally occurring [dissolved] organic matter, such as tannins or lignans, may affect the subsurface transport of arsenic in groundwater (possibly by inhibiting complexation to iron or manganese oxides). Various measurements to determine the concentration of dissolved organic matter in groundwater (e.g. TOC, DOC, tannins) will therefore be included as a way to ensure that previous data gaps are eliminated. (See Section 3.2.4.)

3.2.1.3 Arsenic at Other Landfills in New England

Several landfill sites in New England have faced problems with arsenic in groundwater. The research on these landfills provides valuable insight into the issues at the Shepley's Hill Landfill and is therefore summarized below.

A recent study examined conditions at landfills located along the Massachusetts and New Hampshire border (Mayo, 2003). These landfills, which had observed elevated arsenic concentrations in groundwater that were not necessarily related to disposal materials, are located in the "arsenic belt" (with historically elevated arsenic concentrations in the substrate soils). The arsenic concentrations in groundwater ranged from 5.4 µg/L upgradient of the landfills to over 4,200 µg/L downgradient of the leachate plume.

The study showed poor correlation between arsenic levels and sodium and chloride concentrations, suggesting the arsenic was contributed from sources were outside the landfills. Increasing concentrations of arsenic correlated well with increasing alkalinity and decreasing sulfate concentrations, indicating a reducing environment downgradient of the landfills. These findings supported the theory that arsenic impacts were caused by a natural occurrence of arsenic in the bedrock and optimal reducing conditions to mobilize this arsenic (Mayo, 2003).

Groundwater at a landfill in Saco, Maine has shown concentrations of arsenic in the leachate plume as high as 700 µg/L. The USGS conducted studies at the landfill and determined that the source of arsenic was not the contents of the landfill, but the sediments that the leachate plume was moving through. Tests conducted on the plume showed a high dissolved organic carbon content and an anaerobic environment, leading to the conclusion that a reducing environment existed and the arsenic was mobilizing from the sediment to the leachate plume (Colman et al., 2002).

3.2.2 Reduction of Existing Data

The current data set for Shepley's Hill Landfill includes a host of geochemical parameters that, for most investigative studies, are subsequently used to determine whether there is a "cause and effect" relationship between a particular chemical of concern and a key environmental variable (or set of variables). At the Shepley Hill Landfill, hundreds of measurements have been taken on at least ten key parameters that affect the fate and transport of metals in subsurface environments, including:

- Oxidation/reduction ("redox") potential (ORP)
- Biological/chemical oxygen demand (BOD, COD)
- Anionic/cationic electrolytes
- Dissolved/suspended solids (TDS, TSS)
- Hardness/alkalinity
- Conventional water quality parameters (temperature, dissolved oxygen [DO], pH, specific conductivity)

With the exception of calculated averages, there were no descriptive or multivariate statistics run on any of these key variables to identify interrelationships between metals (e.g., arsenic, manganese, iron) and a key variable that may be affecting their mobility. Therefore, to the extent practicable, the following preliminary statistical evaluations were run on the available data in order to focus additional data collection efforts:

- Descriptive statistics of normal and log-transformed data; and
- Pearson's correlation runs on metals vs. variables that may affect their mobility.

Note that these analyses simply show correlations between the data; they do not define cause-and-effect relationships.

Available electronic data files were assembled into a common spreadsheet. Following selected queries, a careful examination of each analyte or parameter showed that many types of data were qualified, i.e., 20% or more of the data for any one sampling event were qualified as "U" (less than the instrument detection limit) or "B" (above the instrument detection limit but less than the reporting limit). Additionally, some measurements, like pH or Chemical Oxygen Demand (COD), were found to be either fairly homogeneous across all well samples, or measured at levels below the sensitivity range of the instrument. Because robust statistical analyses cannot be performed on certain qualified data, the following metals were not included in the analysis: cadmium, chromium, copper, lead, mercury, nickel, selenium and silver. It is also important to note that, where detected, these metals were found at relatively low concentrations in groundwater (<10 µg/L). Some "General Chemistry" variables, including pH, BOD, COD, cyanide, nitrate (as nitrogen), total suspended solids, total organic carbon and dissolved oxygen also were excluded from the preliminary statistical analysis because of censored data, low variability (defined as maximum historical changes less than a factor of 2), or they are not considered key variables in terms of explaining the fate and transport of contaminants in the Shepley's Hill landfill., It was also discovered that there were some errors in transcription, possibly due to the incompatibility of electronic file formats while transferring data. Additionally, some of the older sampling rounds of monitoring wells only sampled for one parameter (e.g., arsenic) while excluding other metals or measurements that typically control arsenic mobility in subsurface environments (e.g., iron, manganese, ORP, alkalinity).

Given the above discrepancies in the data file, the decision was made to analyze the most complete data set that would also be representative of current conditions. The data set used was therefore the results from the May 2004 sampling round. This data set represents a good "surrogate" for many of the older data because it includes many parameters that had complete data for every well location. The following metals and general chemistry parameters were processed using both the Microsoft Excel Data Analysis statistical functions and the NCSS Statistical Software (Version 6.0; NCSS, 1995):

- Arsenic (As, µg/L)
- Barium (Ba, µg/L)
- Chloride (Cl, µg/L)
- Iron (Fe, µg/L)
- Manganese (Mn, µg/L)
- Sodium (Na, µg/L)
- Zinc (Zn, µg/L)
- Alkalinity (mg/L as $CaCO_3$)
- Oxidation-Reduction Potential (ORP, mV)
- Specific Conductivity (µmhos/cm)
- Sulfate (SO_4, µg/L)
- Total Dissolved Solids (TDS, µg/L)

A total of 16 wells had available data and therefore the total number of variables for each of the above parameters was N = 16.

3.2.3 Preliminary Statistical Analysis

After importing data into the NCSS Statistical Software, the "Descriptive Statistics" routine was run all of the above variables to examine the frequency distributions of each variable. The output of this run is presented in Appendix B, Descriptive Statistics Report. Sodium, chloride, TDS and, to a lesser extent, specific conductivity met the requirements of most of the statistical functions that test for "normality". The remaining parameters were all log-normally distributed, which is typical of most metals data that are obtained from groundwater investigations (i.e., a few elevated values found at individual locations, but the majority of values being an order of magnitude below these values).

It was therefore deemed acceptable to transform the log-normally distributed data before analysis because most parametric statistical functions assume the data set will be normally distributed. This transformation was done by taking the log base 10 of each data set. Once the data were transformed, relationships could be identified between key variables by running a Pearson's correlation of each variable against all of the others. A correlation coefficient of 1.0 represents a perfect, positive linear relationship between two variables while a coefficient of -1.0

represents a perfect negative linear relationship. This correlation analysis for the 2004 data is presented in Table 3-2. It is important to note that this is a "screening" step in identifying relationships between different parameters because Pearson's correlations only measure linear relationships. Therefore, if two variables correlate in a sigmoid or some other type of non-linear function, the relationship may be missed.

It can be seen from Table 3-2 (shaded boxes = $|r| > 0.70$) that arsenic correlates well with iron, manganese, sodium, oxidation-reduction potential (ORP) and, to a lesser extent, barium, alkalinity and specific conductivity. Iron and manganese also show a strong negative correlation with ORP. Concentrations of conservative "tracers" like sodium and chloride also correlate very well with measurements thereof, such as TDS and specific conductivity.

The relationship between arsenic and the main elements that control its solubility in subsurface environments can be seen in Figure 3-1 (arsenic vs. ORP), Figure 3-2, (arsenic vs. manganese) and Figure 3-3 (arsenic vs. iron). Elevated levels of arsenic in groundwater are clearly associated with elevated levels of iron and manganese, and reducing conditions, in turn, favor this association. The concentrations of other trace metals typically found in groundwater beneath landfills (e.g., Cd, Cr, Cu, Hg, Ag, etc.) are relatively low, which may indicate that historical waste within the landfill may not be the "source" of the arsenic. This is because trace metals are generally found at elevated concentrations in groundwater samples taken from "hot" wells.

These graphs support the supposition made in previous Shepley's Hill reports (e.g., Harding ESE, 2002) that the concentration of arsenic generally increases as the reduction potential (ORP) of the subsurface groundwater increases (negative ORP meaning an increase in reduction potential, see Figure 3-1). The most likely mechanism is that the positively charged oxides of manganese (Figure 3-2) and iron (Figure 3-3) act as ligands which coprecipitate the negatively charged anions of arsenic. When reducing conditions prevail, all three metals are subsequently solubilized and are therefore free to migrate with the natural flow of the groundwater.

Another important feature of the relationship between arsenic, iron and manganese is that the concentrations increase with decreasing ORP but then appear to "level off" in an asymptotic fashion. In other words, it appears that there may be a solubility limit for all three metals at the most severely reducing conditions within the landfill. The hypothesis for the mechanism for this solubility limit is as follows: if arsenic is mobilized in concert with iron and manganese from natural till or bedrock, then arsenic will stay in general proportion with these metals. In other words, an upper limit for iron or manganese, imposed by ambient subsurface physicochemical conditions (pH, ORP), also infers an upper limit for arsenic since all three elements are derived from the same parent material. If this is true, it would mean that arsenic levels cannot go any higher than approximately 4 or 5 mg/L. Consequently, knowing that arsenic cannot go higher than a predicted level (based on solubility) may be very important information for future clean-up strategies.

One aspect of arsenic geochemistry that is important from the standpoint of fate and transport is the fact that certain types of facultative soil bacteria are able to further reduce arsenic through a process known a biomethylation. These bacteria turn arsenic from an inorganic compound (e.g., As(III) or As(V)) to an organic compound (e.g., mono-, di- or trimethyl arsenic species). It is impossible to determine from the current data set whether the forms or "species" of arsenic in groundwater below the landfill are organic or inorganic.

These organic forms of arsenic are not only mobile in ground and surface water, but if converted to monomethylarsine or dimethylarsine gas they are volatile and can thus be mobilized under certain types of remedial activities, such as air sparging. It is therefore important to understand whether these forms of arsenic may be present beneath the landfill. This can be accomplished by taking a low flow groundwater sample (preferably at one or more wells containing elevated arsenic concentrations) and having the various forms of arsenic speciated at an analytical laboratory. Some organoarsenicals, such as arsine gas, are also toxic, so if these compounds are present they may affect the results of the risk assessment process. This issue will be addressed in the next section.

3.2.4 Additional Geochemical Data Needs

The preliminary statistical analysis above focused on the subsurface mechanism(s) that may be responsible for a "cause and effect" relationship between arsenic mobility in groundwater and other metals and/or geochemical parameters that affect them. The following items address additional geochemical data needs that may further clarify whether arsenic is being mobilized within the landfill waste or from the natural bedrock or till matrix that supports it:

- In general, the following analytes and/or parameters should be evaluated to provide consistency with measurement of fate and transport analytes/parameters being performed in Plow Shop Pond (USEPA, 2005b): matrix metals (Ba, Ca, K, Fe, Mg, Mn, Mo, Na, Si) and trace metals (As, Cr, Zn). Other routine analyses and/or parameters that would enhance the knowledge of geochemical conditions in groundwater include: alkalinity, chemical oxygen demand, sulfur species (sulfate and sulfide), nitrogen species (TKN, ammonia, nitrate, nitrite), carbon species (total organic carbon, dissolved organic carbon, total inorganic carbon), chloride, hardness, total dissolved solids, total suspended solids, dissolved oxygen (DO), oxidation-reduction potential (ORP), pH and specific conductivity. DO and ORP characterize the redox state of groundwater; at some sites, the concentrations of oxidized and reduced metals iron and manganese are used to supplement that characterization. Some parameters that were routinely negative in past samples should be eliminated: cyanide, BOD, Al, Cd, Cr, Cu, Hg, Ni, Ag.
- In some cases, principally at wells exhibiting strong reducing potential and/or elevated levels of As, Fe and Mn, the relationship between these three metals will be performed (e.g. assessment of molar ratios of electrolytes vs. reducing potential/ORP). These relationships may become more important if reducing conditions predominate in the wetlands to the north of the Shepley's Hill Landfill.
- There is a limited amount of data from up-gradient wells. AMEC proposes sampling both up-gradient and down-gradient wells (only one sampling event needed), and that they be analyzed for selected metals and general chemistry parameters. Detailed information on analytical methods and general chemistry protocols and their respective limits of detection/measurement will be provided in the CSA Work Plan.
- Some wells that had historically elevated arsenic concentrations have not been sampled for a long period. Data from these wells would support whether arsenic is truly elevated in

reducing environments (ORP < zero) and/or inhibited from mobilization under oxidizing conditions (ORP > zero).

- In addition to measurements of total arsenic in groundwater samples, the speciation of organic forms of arsenic should be performed. This requirement only needs to be fulfilled at a few selected wells that contain both low ORP values and elevated levels of arsenic. If the amount of methylated arsenic species in each sample does not exceed 10% of the total amount of arsenic, then it can be concluded that biomethylation processes within the landfill are not significant to mobilize a substantial portion of the waste.
- The role of organic acids (e.g., tannins, humic acids) that may be leaching from buried peat lenses is not known. Selected groundwater samples should be analyzed for the presence/absence of tannins in order to eliminate the possibility that peat-derived organic acids may be mobilizing arsenic from naturally-occurring subsurface material.

3.2.5 Summary of Arsenic Geochemistry Assessment

Table 3-3 summarizes the data gaps analysis relative to arsenic speciation.

3.3 Plume Assessment

Assessment of hydrogeologic data gaps began with a preliminary interpretation of the plume. None of the available reports contained graphical illustrations of the plume; therefore, the plume was preliminarily mapped as the basis for the DGA. The plume assessment continued with an examination of groundwater models to date. It then focused on the extent of the off-site plume, with particular focus on potential receptors.

3.3.1 Preliminary Plume Interpretation

Previous investigations have identified arsenic as the primary contaminant of concern in groundwater. Most of the wells represented by recent groundwater hydrochemical samples are located on Figure 3-4, which is reprinted from Figure 1 of the Performance Monitoring Plan of August 2005 (CH2MHill). Figure 3-5 shows the extent of arsenic in groundwater based on currently available data. It is an interpretive, conceptual map which draws upon groundwater arsenic-concentration data gathered since 1992. Groundwater contours on this map illustrate the highest arsenic concentrations observed at a given location, except where data have been obtained within the past year, in which case the current concentrations are used. At certain locations where multiple wells are located in proximity, only the maximum concentration is used, irrespective of subsurface depth: for example, for the three wells SHM-99-31a, b, and c, only the concentration from well "c" is used. Sites and relative arsenic concentration ranges of surface-water and sediment samples are also shown on this map, but are not used in contouring.

On Figure 3-5, the contour lines are colored bold red in areas where historic data suggest a increasing trend, and bold blue where there appears to be a decreasing trend. In general, most areas appear to have arsenic concentrations that fluctuate within a relatively narrow range, but there are limited areas of overall (though fluctuating) increase below the toe of the landfill and near Red Cove. The Increase/Decrease indications based on past time trends are for general illustration only, are not statistically rigorous, and do not necessarily represent predictions of future trends.

Historic and current data establish that arsenic is present in groundwater at elevated and locally high concentrations immediately beneath the landfill, and is carried eastward and northward in a continuous plume. Immediately south of the landfill, elevated arsenic was historically detected in some upgradient wells and not others. However, the upgradient data lack simultaneous field measurements of Oxidation-Reduction Potential, and therefore it is difficult to substantiate that the upgradient arsenic contribution to groundwater is insignificant. Even so, all of the highest arsenic concentrations detected in groundwater occur directly beneath or immediately downgradient of the landfill, and most likely originate directly beneath the landfill. Some arsenic may also enter the sub-landfill area along its western side. Downgradient, the plume nears upper Nonacoicus Brook just below the Brook's origin at Plow Shop Pond, and crosses Molumco Road and West Main Street to the north.

The plume is incompletely delineated in the following critical geographic locations:

1. Along its eastern edge, the plume approaches and may contribute to Plow Shop Pond in the Red Cove area. Data recently acquired by EPA may bear upon this question, and will be reviewed when available.
2. At its leading edge to the north, the plume approaches and may reach lower Nonacoicus Brook, and is undelineated along the western part of its leading edge west of Molumco Road.

Additional borings, wells, and surface-water and sediment samples are planned in these two geographic locations, as discussed in later sections of this report.

Though data are also sparse that delineate the plume along its upgradient western margin, this aspect is of lesser concern because the potentiometric gradient prevents westerly plume migration in that area. Additional western-edge data are desired mainly in respect to controlling the rate and volume of possible groundwater inflow to the landfill and to evaluate background concentrations of arsenic in groundwater.

3.3.2 Groundwater Flow Modeling

Groundwater modeling provides an important tool to evaluate site-scale flow patterns and velocities. AMEC has reviewed the groundwater model variant entitled "RUN200" (as provided by CH2MHill) which was originally developed by Harding ESE. The model is a reasonably well-constructed groundwater flow simulation that has been used to date to understand flow patterns, explore a limited range of active remediation alternatives, and provide the basis for the current pump and treat system design.

The current model indicates the following components of the water budget through the landfill:

- More than 90% of discharge (82,500 gal/day) from the landfill footprint is through the extreme northern end (where the unconsolidated aquifer is thickest) between Shepley's Hill and Plow Shop Pond,
- The model predicts that only 5 to 10% of discharge is directed toward Plow Shop Pond in the Red Cove area, yet the downgradient end of the pond is a significant source of groundwater recharge to the northern portion of the landfill footprint,

- Recharge from the unconsolidated sediments upgradient (to the south) is approximately 25% (22,500 gal/day) of total inflow, and
- More than 50% of recharge (45,000 gal/day) occurs as upwelling from the underlying bedrock layer.

By combining these results with groundwater and surface water sampling and analysis, AMEC intends to provide a quantitative assessment of the flux of arsenic to the Red Cove area of Plow Shop Pond and Nonacoicus Brook. This information will, in turn, be fed into the risk assessments.

In addition, a preliminary analysis of the potential for impacts to the McPherson well was conducted. Figure 3-6 presents the results of a reverse particle track simulation using the unmodified RUN200 model. In this simulation particles were started at the supply well location and tracked backward through the flow system to their point of origin. As Figure 3-6 shows, groundwater captured by the supply well originates from the west flank of Shepley's Hill and migrates northward to the well location. While a rigorous validation of the model has not been completed, this preliminary result suggests there is no potential for contamination originating from the landfill on the east flank of Shepley's Hill to reach the well.

3.3.3 Off-Site Plume Extent

Though the existence of the plume beneath off-site public and private property has been established, there are important data gaps in plume delineation. Additional delineation will be required to accurately assess the risks to human and ecological receptors, and to support the CAAA.

Specific data gaps include:

1. The leading (downgradient) edge of the plume closely approaches Nonacoicus Brook, and it is likely that arsenic-bearing groundwater discharges to the brook. However, no data exist to show whether some contaminated groundwater passes under to the north side of the brook.

   An additional gap in regard to leading-edge delineation occurs at the northeast corner of the plume as shown in Figure 3-5. At this location (in SHX-01-6X), arsenic was found in groundwater at 148 µg/L. This observation raises the possibility that the surface-water and sediment samples collected near that location were affected by the groundwater plume or another source, and possibly should not be considered "reference samples" as indicated in the SGI report.

2. Near the leading edge, the plume is undelineated along its western side. An arsenic concentration of 1170 µg/L in groundwater from soil boring SB-01 (since succeeded by an additional sample with an arsenic concentration of 299 µg/L from well SHM-05-39B)) was reported from a location along Scully Road, and there are no samples further west to bound this area of high-arsenic groundwater.

3. Although the plume is also undelineated along most of its western side between the landfill and Shepley's Hill, the gradient from the hill toward the landfill prevents groundwater beneath the landfill from moving farther westward here. The data collection that is proposed along the western side of the landfill is for the purposes of engineering design and

groundwater-model constraint, rather than plume delineation and to evaluate background As contribution.

One possible way of identifying the migration of the plume is through the use of "tracer" substances that are unique to the chemistry of the dissolved constituents within the plume itself. These substances tend to be small molecules, such as chloride, that are easily measured and have little tendency to bind to subsurface materials (e.g., soils, organic matter, debris). As described in Section 3.2.3, the concentrations of many trace metals typically found in groundwater beneath landfills are relatively low. The potential to use other tracers will be explored in the CSA Work Plan. Table 3-2 indicates which of the potential tracers correlated well with elevated arsenic concentrations in the preliminary statistical evaluation.

3.3.4 Potential Receptors

Specific exposure points – known and potential - are discussed further below with respect to hydrogeologic and hydrologic conditions. Section 3.5 discusses these exposure points from a risk assessment perspective.

3.3.4.1 Nonacoicus Brook and Adjacent Wetlands

One of the key data gaps is the understanding of the plume's interactions with Nonacoicus Brook and its adjacent wetlands. This interaction is significant for two primary reasons: 1) the downgradient (northern) extent of the As plume is undefined, and 2) the nature and rate of groundwater-surface water interactions are not quantified. Specifically, data will be needed to:

- Establish the stream/wetland is a discharge zone for groundwater both north and south and therefore can be considered a hydraulic barrier to plume migration beyond, and
- Determine if contaminants are reaching wetlands, and if so, at what concentrations.

As discussed in later sections of this report, AMEC proposes an integrated assessment combining piezometer installation, hydraulic monitoring of the stream and groundwater levels, sampling of surface water, groundwater, and sediments, and stream gauging. The techniques to be used to investigate the area will be limited by the conditions in the area; for example, a drill rig cannot be used to install permanent monitoring wells in the relatively large areas of submerged wetland. A holistic evaluation of the data will be used to strengthen the CSM, estimate contaminant flux to the stream, and thereby inform the risk assessment with respect to the stream and potential ecological receptors.

No borings or wells are proposed to reach bedrock in the Nonacoicus Brook or wetlands areas. In part this is a limitation established by the impracticality of locating a drilling rig there, as mentioned above. Moreover, data from a bedrock well constructed near the brook would be of relatively small additional value for three reasons:

1) Regionally, the brook/wetlands area – as part of the Nashua River valley -- is highly likely to be a discharge zone for groundwater moving in the bedrock. This is true because bedrock lies at higher elevations, and therefore contains groundwater at higher head, in all areas bordering Nonacoicus Brook except westerly toward the Nashua River. Figure 3-6 in the Supplemental Groundwater Investigation (Harding ESE, 2002) illustrates this situation. To cross the brook/wetlands area, groundwater moving northerly

in bedrock from the landfill would probably have to flow upgradient. Therefore this probably does not occur.

2) If a bedrock zone existed that could transmit landfill-influenced groundwater northward beyond the brook/wetlands area, such a zone would have to be open to a relatively distant downstream reach of the Nashua River – since this river establishes the local surface-water as well as groundwater base level. Regional geologic control admits little possibility of such a zone, unless it were a narrow, strike-crossing fracture. A narrow fracture or zone is unlikely to be encountered by any given well.
3) Using data from the planned shallow-depth piezometers and stream gauging, it is likely to be demonstrable that stream gain below the landfill can account for substantially all groundwater flow that leaves the landfill.

Field programs to address the data gaps cited in this report will be designed in general adherence to the framework described in *Guidance for Monitoring Hazardous Waste Sites* (OSWER Directive No. 9355.4-28, January 2004) (USEPA, 2004). Among other reasons, following the Objectives-Hypothesis-Decision Rule framework described there is valuable in helping to avoid attempts to "prove the negative". Multiple lines of evidence (such as flow, head, and conductivity measurements and regional potentiometric relationships, as well as hydrochemical sampling) will be used to demonstrate, test, and/or further detail the dominant fate and transport modes of arsenic as described in the current CSM.

The data quality objectives for this effort are to:

1. Delineate the plume at all critical margins, especially toward the wetlands,
2. Determine contaminant concentrations in the wetlands,
3. Determine if the stream/wetland is a hydraulic barrier, and
4. Provide input for groundwater model and risk assessments.

The result of this investigation effort will be to achieve adequate delineation of plume boundary and contaminant concentrations in wetlands attributable to Shepley's Hill Landfill to be used to complete the human health and ecological risk assessment for the CSA.

3.3.4.2 McPherson Well

The McPherson Well is located several thousand feet west of the landfill and, as discussed above, preliminary assessment of the existing groundwater model suggests the recharge area for this supply well is actually the western flank of Shepley's Hill. However, the potential for impacts due to off-site plume migration to the northwest cannot currently be ruled out as the plume is not bounded in this direction. Thus, the critical information needed to complete this assessment is primarily groundwater data to bound the plume. In addition, existing and new data from a range of proposed investigations will be used to improve confidence in the representativeness of the groundwater model and thereby confirm the preliminary analysis discussed above.

3.3.4.3 Red Cove/Plow Shop Pond

A second key data gap is the quantification of groundwater discharge and arsenic flux to Plow Shop Pond, principally in the Red Cove area. Red Cove is a specific area of concern of EPA, which has recently completed (but not yet issued) a report on an initial study of As flux and is currently undertaking a comprehensive research investigation as described in the *Arsenic Study Work Plan* (USEPA, 2005b) prepared by USEPA National Risk Management Research Laboratory. This study proposes to collect a wealth of hydraulic and geochemical data from sampling of pond sediments, surface water, groundwater seepage, and adjacent groundwater. These data are to be collected beginning September 2005 through summer 2006 and may therefore be available for AMEC's review and incorporation into the CSA. Thus, AMEC proposes to utilize this data and collect additional information only as necessary to complement the ongoing studies. Specifically, data will be required to quantify vertical hydraulic gradients and estimate permeability of the aquifer and pond bed sediments in this area. These data will then be used to calculate groundwater discharge rates and, along with analytical data, calculate contaminant flux to Red Cove.

The result of this investigation effort will be to establish the Shepley's Hill Landfill contribution to the Red Cove area of Plow Shop Pond under historic (pre-capping), current, and future conditions (along with surface water and sediment contributions) to complete the ecological risk assessment for the CSA.

3.3.5 Summary of Plume Assessment

Table 3-4 summarizes the data gaps analysis relative to the plume delineation.

3.4 Landfill Cover Assessment

A landfill cover controls the flow of water into the waste, diverting surface water runoff and preventing rainwater and snow melt from seeping into the waste. Visible damage to a landfill cover may cause immediate concern during a site inspection but the subsurface components of a cover, which cannot be directly observed, can be more important to preserving the cover's function. The observable conditions at Shepley's Hill Landfill include erosion rills, animal burrows, subsidence, non-vegetated areas, and vehicle ruts. These surface conditions are presently slated for repair in the Fall of 2005. The greater concern and the most prominent unknowns relate to the adequacy of the 30 and 40 mil PVC liner, the compacted waste support beneath, and the vegetative, drainage and erosion capabilities of the 18 inch thick soil cover. Of considerable concern related to the runoff and groundwater contribution to leachate production, is the unknown permeability of the PVC liner and its protective soil layers. These items are considered to be major data gaps.

Data gaps have been identified by an initial review of existing and available site closure construction documents, reports of follow-up inspections, a preliminary reconnaissance and a review of the MADEP (1997) *Landfill Guidance Technical Manual*. Both major and minor data gaps have been identified for this report. An example of a major data gap is the integrity of the buried PVC geomembrane (i.e., permeability, tears in welded seams). An example of a minor gap would be the occasional occurrence of animal burrows. For purposes of completeness, both major and minor data gaps are identified in this section.

Several factors that influence the data gap analysis and follow-on tasks prior to the field investigation program are as follows:

1. A thorough review of existing and available Construction Quality Assurance (CQA) documentation will provide a high or low confidence level relative to the integrity of the existing landfill cover.
2. It is understood that Nobis Engineering will be performing landfill surface repair work (filling subsidence areas) on behalf of USACE during the Fall of 2005. Such work will eliminate or modify some of the less critical data gaps.
3. Long term subsidence (rate and horizontal and vertical extent) is unknown. The impact of long term subsidence can seriously compromise the PVC geomembrane. Although the subsidence areas are to be filled soon, subsidence may continue or even increase after filling. Therefore, field investigations and monitoring will be an important factor for long term maintenance and remediation.

The specific significant data gaps identified and their data quality objectives are described below. The project team will obtain as much information as possible from CQA documents, including as-built drawings and a detailed engineering reconnaissance to develop an elevated level of confidence in the structural integrity of the landfill cover, and to identify important data gaps. Those data gaps will be addressed by field investigations, and material testing to modify, expand and refine the phased field program.

The focus of this assessment will be to:

- Concentrate on the competence of the low-permeability (PVC) layer rather than relatively minor surface conditions,
- Integrate the study with repair work already planned for Fall 2005,
- Use a two-phase approach consisting of inspection, followed by testing as necessary, and to
- Minimize intrusive testing to preserve the integrity of the PVC.

Data to be collected to fill these data gaps are as follows:

- Survey and compare contours to historical plans to assess subsidence,
- Excavate test pits to examine PVC,
- Physical testing of soil, and
- Limited testing of PVC, only if absolutely needed.

3.4.1 Structural Integrity of the Existing Buried PVC Geomembrane

A major objective of the cover investigation phase is to determine if the PVC geomembrane is performing as designed, approved, maintained and installed. Ideally, there should be no leaks, no split seams, no undue lateral stress, no decomposition of the PVC, and no stone or metal penetrations or impressions. The first major step, other than observing any PVC exposures, is to obtain and review available CQA data to determine the quality of landfill cover construction. A comparison of old and new manufacturers' technical specifications and subsequent field testing at the time of installation, are significant in determining if specifications have changed due to advances in PVC fabrication.

Test pits will be carefully excavated at selected locations to expose the PVC geomembrane and soil cover for visual observation of its integrity. If necessary, samples of the liner may be collected for physical testing. Any such areas would be carefully patched and sealed.

3.4.2 Differential Surface Subsidence

Subsidence is observable on the landfill surface in certain areas. Such occurrences usually reflect differential settlement due to poor waste compaction or waste decomposition beneath the landfill cover. Field testing methods, other than elevation monitoring, are typically impractical. The proposed filling of these areas scheduled for the Fall of 2005 will provide an opportunity for short and long term surface elevation monitoring.

3.4.3 Cover Soil Quality and Permeability

Although the PVC is the primary barrier to rainfall/snowmelt infiltration, soils placed immediately beneath as a cushion and its protective layers above also play an important role in restricting infiltration and preventing frost damage. An initial review of the 1996 *Close-Out Report* does not provide sufficient information on thickness on actual in-place soil gradation, layering and permeability to assess the cover soil quality and permeability. The planned field investigation program will provide the necessary information.

3.4.4 Uniform Grading, Drainage Features and Erosion Control

Observable subsidence features, erosion gullies and rills and ponding are all indicators of the need for site surface repairs. Planned repair work by Nobis Engineering may address all of the grading and erosion issues. However, a comparison of original and current finish grades and erosion control features and the current planned earthwork will provide an indicator of the probability of future drainage problems. Uniform sloping, with careful control of surface runoff minimizes rainfall penetration to the geomembrane. AMEC plans to determine if current and planned grades conform to the MADEP landfill closure technical standards by comparing typical existing grades to those standards.

3.4.5 Non-Vegetated Surface Soils

A worst case scenario condition leading to non-vegetated surface areas would be landfill gas or leachate leakage to the surface soil. However, it may be a simple case of the lack of topsoil or loam with seed. For this situation, a field investigation program will be performed. Hand dug test pits with soil observations, and sampling and testing for agricultural and landfill gas parameters will address the data gap.

3.4.6 Perimeter Anchoring of PVC Geomembrane

Information regarding the precise physical relationship between the perimeter end of the PVC and the impermeable soil or bedrock with the anchoring mechanism appears to be minimal. The relationship between impermeable PVC and soil and bedrock is important. The potential for runoff to penetrate the porous soil between the PVC and bedrock exists to create leachate. The objective in identifying the perimeter conditions is to determine how much water infiltration is entering the refuse. Non-destructive geophysical methods will be used to obtain this information to prevent inadvertent destruction of the existing anchoring system.

3.4.7 Landfill Gas Migration

A review of available landfill gas information indicates that the off-site potential for gas migration is relatively low. The most recent *Draft 2004 Annual Report* (USACE, 2005) reports increases in landfill gas components in the landfill gas vents within the site, but reports no increases in the perimeter gas monitoring wells. Sampling frequency may need to be increased to account for possible climate and seasonal factors. However, during the investigation phases of the project, it is planned to review on-going landfill gas monitoring data (gathered by others) and analyze for trends.

The potential adverse impacts of landfill gas migration have four components requiring field investigations. These components are as follows:

- <u>Non-vegetated soil cover in certain locations</u>. Investigations will involve soil cover evaluation (thickness, soil type, agricultural parameter testing, presence of loam, presence of combustible gas) and PVC geomembrane inspection (test pits and welded seam inspection)
- <u>Gas vent and subsurface piping integrity</u>. If subsurface piping connected to the gas vents became distorted in the subsidence areas, it is possible that the flow of gas to the vent may be blocked. Since the piping is buried beneath the PVC geomembrane, access to inspect is impractical. By evaluating existing gas vent emissions and by obtaining additional measurements, it may be appropriate to add additional gas vents in those subsidence areas as a final closure remedial action rather than destroying a significant amount of geomembrane to locate the possible blocked vent pipes.
- <u>Gas vent number and placement</u>. An evaluation of existing historical data as to the primary zones of recent solid waste, ash, incinerator residue, and demolition waste will provide the locations where a higher number of gas vents are needed as a final closure remedial action. The goal would be to minimize the potential for horizontal landfill gas migration.
- <u>Landfill gas migration to nearby/adjacent buildings</u>. The existing four gas monitoring vents between the landfill and the nearest residence do not indicate any landfill gas migration. Additional soil gas probing at locations between the landfill perimeter and building may be appropriate only after field geophysical investigations to determine the spatial relationship between impermeable bedrock and the anchored PVC geomembrane indicate it is appropriate to do so.

3.4.8 Summary of Landfill Cover Assessment

Table 3-5 summarizes the data gaps analysis relative to the landfill cover assessment.

3.5 Risk Assessment

The human and ecological risk assessment (HERA) is required to complete the CSA. More important than simply fulfilling regulatory requirements, however, is the strategic role of the

HERA in determining the need for and extent of, remedial actions. Closing data gaps related to exposure pathways and putting the site-related data into the context of background conditions are critical to defining the extent of remedial actions.

Data gaps for both the human health and ecological risk assessments consist of uncertainties about where impacts from the landfill exist and in what environmental media, the presence of complete exposure pathways to the impacted media, and the potential toxicity of these impacts. In many cases, data collected for other tasks (e.g., groundwater plume delineation and flux) will be used to address these data gaps. Other data gaps will be addressed with specific sampling and analytical efforts (e.g., upstream surface water concentrations in Nonacoicus Brook and arsenic speciation).

3.5.1 Data Gaps for the Human Health Risk Assessment

In order to complete the HHRA, information will be needed to make the determination as to whether two possible routes of human exposure are complete exposure pathways: exposures to impacted groundwater used as drinking water and exposures to impacted surface water by dermal contact with and/or ingestion during recreational use.

Human health risk assessments conducted at the site to date have relied on the assumption that there was a complete exposure pathway from groundwater, or in other words that people were drinking groundwater affected by the site. While such conservative assumptions are not uncommon, the assumption of potable use of impacted groundwater as a "potential exposure pathway" is a data gap. For the DGA, the project team evaluated whether the Shepley's Hill Landfill and/or downgradient areas impacted by the arsenic plume lie within a GW-1 area (i.e. a current or potential drinking water source area) under the Massachusetts Contingency Plan (MCP). If this condition does not exist under current or future conditions, then one can conclude that groundwater is not nor will be used as a source of drinking water and a quantitative risk characterization of this exposure pathway is not required under either state or federal guidance. Similarly, as discussed earlier, the determination of the impact to the McPherson water supply well and the magnitude of the impact, if any, will be used to address this data gap.

AMEC's preliminary review of available information regarding state and local designations of groundwater resources (Figure 3-7) indicates that the site and areas immediately downgradient of the landfill are likely not within any Zone II area or Interim Wellhead Protection Area (IWPA) and, although groundwater beneath and downgradient of the Landfill is situated within medium and/or high-yield aquifers, these areas are likely to be classified as non-potential drinking water source areas in accordance with MADEP policy (# WSC-97-701). Such designation, which considers both size and surrounding land use, would preclude the groundwater from being defined as a current or potential drinking water source area and, therefore would not be a designated GW-1 area in accordance with the MCP. Further, as discussed in Sections 3.3.2 and 3.3.4, an initial modeling effort indicates that the plume emanating from the landfill does not affect the water supply from the McPherson well.

If further analysis during the CSA changes this conclusion - that is, if it indicates that groundwater affected by Shepley's Hill Landfill could be situated within an MCP GW-1 area or discharge to the McPherson well - then exposure to groundwater would be considered a complete pathway. The groundwater exposure pathway would be evaluated by performing quantitative risk calculations in accordance with USEPA guidance which includes an evaluation of concentrations in groundwater relative to Massachusetts Maximum Contaminant Levels (MMCLs), which are applicable public health standards for groundwater classified as GW-1. (The current MMCL for arsenic is 50 µg/L; the proposed MMCL for arsenic is 10 µg/L, effective January 2006.) The groundwater arsenic data would also be compared to background levels for arsenic which, as noted in Section 3.2.1, are elevated in the Ayer area. The evaluation of background concentrations relative to site-related concentrations is important for determining the relative contribution of arsenic from the landfill, if any, to that from "natural" sources in groundwater and surface water.

The CSA will also examine the potential for discharge of site-related contamination in groundwater to surface water. If data demonstrate that the groundwater plume associated with impacts from landfill discharges to Nonacoicus Brook and associated wetlands and/or to Plow Shop Pond, then the HHRA would likely consider recreational use of these water bodies as complete exposure pathways. Media likely to be evaluated would include surface water, sediment and possibly biota (fish). The evaluations will take into account information regarding stream dynamics (stream volumes and flow rates), as well as previous risk or hazard evaluations of these water bodies as they relate to Shepley's Hill Landfill, including:

1. The Revised Draft Shepley's Hill Landfill Supplemental Groundwater Investigation (Harding ESE, Inc., 2002), which contained a risk evaluation of surface water and sediment of Nonacoicus Brook; and
2. The Agency for Toxic Substances and Disease Registry's (ATSDR) Health Consultation Evaluation of Health Concerns Associated with Grove Pond and Plow Shop Pond, Fort Devens, Ayer, Middlesex County, MA. Grove Pond is not located hydrologically down gradient of the Shepley's Hill Landfill and therefore will not be considered in the HHRA. The ATSDR evaluation of Plow Shop Pond concluded that, under the current conditions of catch and release fishing, risks from fishing and incidental dermal contact were potentially acceptable. This information will be utilized should an evaluation of this pathway become necessary.

For each complete exposure pathway, the potential adverse health effects will be quantified based on potential toxicity as it relates to the identified arsenic species in the relevant media.

3.5.2 Data Gaps for the Ecological Risk Assessment

The purpose of the ecological risk assessment (ERA) will be to determine whether site-related conditions pose unacceptable risks to potential ecological receptors at downgradient sites within Plow Shop Pond and Nonacoicus Brook and, if so, to identify the compounds contributing to excess risk. For the concentrations of chemicals in surface water and sediment to be significant to this project, those compounds must be present in the surface water body as a result of groundwater transport from Shepley's Hill Landfill.

3.5.2.1 Plow Shop Pond

Previous studies concluded that conditions in Plow Shop Pond relate at least in part to contamination migrating from the landfill. However, the potential risks to the Plow Shop Pond aquatic ecosystem estimated in the Final Remedial Investigation (ABB, 1993) were primarily from copper and silver in surface water. They did not result from exposure to arsenic in surface water, which is the constituent of concern primarily associated with Shepley's Hill Landfill. However, concentrations of arsenic, barium, iron, manganese, and nickel exceeded sediment quality benchmarks.

More recently, USEPA (2005a) has performed surface water and sediment toxicity studies in Plow Shop Pond, Grove Pond, and two reference locations. Sediment chemistry results focused on arsenic, chromium, and mercury source areas. The arsenic source area was identified as Shepley's Hill Landfill, while the chromium and mercury source was identified as Tannery Cove. None of the surface water samples showed toxicity to either of the two test organisms. Red Cove sediment toxicity testing showed growth effects to one of two test organisms (USEPA, 2005a). AMEC will evaluate these test results when the report is published (scheduled for January 2006). These data are anticipated to fill several data gaps. However, detailed data evaluation may show that additional sample collection efforts are necessary to address the remaining data gaps.

Both of the above studies evaluated direct sediment toxicity to benthic organisms. However, the concentrations of contaminants in the sediments is a function of not only current loadings, but also historical loadings from times when the landfill was capped and earlier prior to cap installation. The current contribution of the Shepley's Hill Landfill to concentrations of compounds in Red Cove sediments in Plow Shop Pond is a data gap. USEPA is currently conducting groundwater flux studies to evaluate the current contribution of Shepley's Hill Landfill to arsenic concentrations in Red Cove. This report is scheduled to be available in January 2006.

Another data gap is the potential effect of floc on aquatic organisms. Floc forms as an iron precipitate as groundwater containing an elevated level of dissolved iron enters oxygenated surface water. Arsenic will also co-precipitate with the iron and settle to the bottom of a surface water body. At a site visit on April 18, 2005, AMEC biologists noted that except for shallow area near shore, Red Cove was relatively clear so the floc was not remaining suspended in the water column. Also as discussed above, none of the most recently collected (USEPA, 2005a) surface water samples from Red Cove showed toxicity to either of the two test organisms. It should also be noted that Plow Shop Pond contains approximately 30 acres (USEPA, 2005a), that Red Cove is a small part (approximately 2%) of Plow Shop Pond (Figure 3-8), and that the sediments in Red Cove do not provide suitable habitat because of floc. In summary, the area of Red Cove where floc accumulates is relatively small compared to the ecosystem represented by Plow Shop Pond. Further, the floc tends to settle and therefore does not affect pelagic aquatic organisms. Therefore, based on the available information, the presence of floc is not of concern to aquatic organisms. The extent of floc will be visually observed and noted during surface water and sediment sampling programs in the CSA.

The contribution of groundwater concentrations of arsenic to Red Cove is also a data gap, but the USACE (2005) states that arsenic concentrations measured in the wells near Plow Shop Pond are the same or decreasing in all wells but one. AMEC's review of the groundwater data, summarized in Figure 3-5, also indicates steady, or decreasing concentrations in groundwater. Previous groundwater flow characterization (Harding ESE, 2002) showed that the groundwater flow prior to the installation of the landfill cap was more easterly. This work also showed that, with the cap, only a small portion of the landfill contributes groundwater to Plow Shop Pond. The USEPA (2005a) also indicated that contaminant flux analyses work was being done at Red Cove, but these results are not yet available. These results, when available, will be used to reduce this data gap.

USEPA is also currently undertaking a comprehensive research investigation as described in the Arsenic Study Work Plan (2005b) prepared by USEPA National Risk Management Research Laboratory. Samples are to be collected in September 2005, March 2006, May 2006, and August 2006. These results, as they become available, will be used to reduce this data gap.

3.5.2.2 Nonacoicus Brook

Previous studies have also inferred that elevated arsenic levels in Nonacoicus Brook originated with Shepley's Hill Landfill. However, those studies did not clearly demonstrate that the arsenic could have migrated to that area at that concentration from the landfill, either via direct groundwater discharge or by surface water flow from Plow Shop Pond to Nonacoicus Brook. Data from Plow Shop Pond show low concentrations of arsenic in surface water while sediment data obtained from an upstream reference location (Harding ESE, 2002) suggest that other sources of arsenic may contribute to conditions in the brook.

An additional gap in regard to the groundwater plume delineation and evaluation as a source to Nonacoicus Brook occurs at the northeast corner of the plume as shown in Figure 3-5. At this location (near SHX-01-6X), an arsenic concentration of 148 µg/L was found in groundwater. This observation raises the possibility that the surface-water and sediment samples collected near that location were affected by the groundwater plume or other source, and possibly should not be considered "reference samples" as indicated in the SGI report.

As discussed above, the magnitude of the groundwater contribution to sediment and surface water arsenic concentrations in Nonacoicus Brook have not been quantified and previous investigations have implicated upstream background contributions to Nonacoicus Brook arsenic concentrations. Groundwater and surface water data, to be collected in the CSA as described in Section 4, will be used to fill this data gap.

3.5.3 Summary of Data Gaps Analysis Related to Risk Assessment

The data gap analysis is focused on identifying complete exposure pathways for both human and ecological receptors to be evaluated in risk assessments. In order to evaluate whether complete pathways exist, determinations regarding the nature and extent of impacts from the Shepley's Hill Landfill are required. This includes evaluations of the landfill water balance dynamics, including evaluating the groundwater flow into, through, and from the landfill, characterizations of he arsenic plume, and the groundwater-surface water interactions. In addition, the groundwater use designation needs to be determined for the landfill and surrounding areas. If complete exposure pathways exist, potential risks and hazards for all complete exposure pathways must be quantified. Table 3-6 summarizes the data gaps analysis relative to the human health and ecological risk assessments.

3.6 CAAA Support

Based on currently-known information, the CAAA will focus on two points: Landfill cap assessment and groundwater remediation. Section 3.4 describes the DGA relevant to the Landfill Cap Evaluation. Our approach toward assessing corrective action alternatives for groundwater is described further below.

The CAAA begins with defining the objectives for remediation. Risk-based objectives will be developed considering:

- Background levels and speciation of arsenic;
- Potential risks to probable receptors, as determined during the HERA; and
- ROD requirements.

If the current remedy meets all objectives, then no further remedial action is necessary. Alternatively, once specific objectives are determined, the engineering team will identify technologies and alternatives that are potentially applicable to the site-specific conditions. Each remedial alternative may include one or more remedial technologies. The project team will then evaluate these technologies using regulatory criteria.

One possible option is to reduce the sources of inflow to waste materials. Specifically, the CAAA will likely evaluate the following option: a French drain installed along the landfill edge adjacent to Shepley's Hill, which would intercept and divert "run under". In order to limit the potential for landfill-impacted groundwater to flow into the drain (thereby requiring treatment) a barrier wall could be constructed along its eastern side. Water would be routed downslope (to the north) and merge with the drainage structure. Similarly, a barrier wall/drain combination could be designed for the upgradient extent of landfill (similar to the slurry wall proposed in the SGI) to divert flow toward Plow Shop Pond. Preliminary evaluation of the groundwater budget suggests this type of solution would reduce inflows to the landfill (and therefore outflows) by as much as 50%, and substantially more than the proposed approach of sealing the cap to an impervious anchor.

If necessary to address unacceptable risks, the CAAA will explore several aspects of this alternative, including hydraulics and constructability.

In order to fully assess alternative approaches in the CAAA, the project team must fill the following data gaps:

- Hydraulics – use existing data, supplemented as described in Section 3.1;
- Constructability - Review boring logs, and as-built drawings of 36-inch storm drain on the south side of the landfill, as described below;
- Arsenic distribution and speciation – Use existing data, supplemented as described in Section 3.2.4; and
- Performance of existing system - Review performance and costs of current extraction and treatment system, which will be operational when the CAAA is performed, as reported in O&M data and reports on the system.

An initial constructability review examined data showing the stratigraphy on the South and West sides of the landfill. Harding ESE (2002) developed an interpretative bedrock surface map for the Supplemental Groundwater Investigation Report using logs gathered from all the subsurface explorations conducted at Shepley's Hill Landfill. Figure 1-2, Pre-Landfill Topography of this report, shows that the ground surface along the landfill's western boundary is at an elevation between 270 ft and 275 ft in the vicinity of Shepley's Hill. At the landfill's southern boundary, the ground surface is at a high elevation of 260 ft at the southwestern corner and generally decreases to an elevation of 240 ft at the landfill's southeastern corner. Figure 3-6, Interpreted Bedrock Surface, indicates that bedrock is at an elevation of 250 ft or higher along the landfill's western boundary, in the vicinity of Shepley's Hill, placing the depth to bedrock between 20 ft to 25 ft below ground surface (bgs) or less. Along the southern boundary, bedrock is at a high elevation of 250 ft at the landfill's southwestern corner and generally decreases to an elevation of 170 ft, placing the maximum depth to bedrock at approximately 70 ft bgs. To confirm this conceptual understanding of depth to bedrock, select historical boring logs and geophysical results were also reviewed.

As part of the RI Addendum Report, a seismic refraction survey was conducted in the following manner:

> Seismic lines were obtained using two 200-ft, 12-channel seismic spread cables for a 400 ft seismic spread. Seismic spreads were placed end to end to produce continuous subsurface seismic profiles. Spacing between geophones along the spread cables was 20ft, although the last three geophones on each seismic spread cable were 10 ft apart to facilitate resolution of near surface seismic velocity variations.

Four seismic refraction lines were generated along the southern and eastern boundaries of the landfill. Of the four, only seismic line 1 extends along the southern boundary. The line is located approximately 215 ft from the landfill's southern edge of membrane and runs east to west as shown in Figure 2-3 of this report. The survey indicates that bedrock at line 1 is approximately 75 ft to 80 ft bgs. Near the western extent of the line, bedrock slopes closer to the surface. A review of select monitoring wells along the southern boundary shows four SHL monitoring wells were in place at the time of the RI. The wells are, from west to east: SH-15 (total depth 27 ft bgs), SH-25 (total depth 35 ft), SHL-12 (water table well), and SHL-17 (total depth 17 ft) and do not extend into bedrock. SHL-24, located approximately 400 ft beyond the southeastern edge of the landfill encountered bedrock at a depth of 95 ft bgs. At refraction line 1, approximately 170 ft northwest of SHL-24, depth to bedrock was measured at 90 ft bgs (surface elevation 240 ft/bedrock elevation 150 ft) at the projected location of SHL-24 (station 17+75) onto this line.

Along the western edge of the landfill, at the time of the RI, there were two monitoring wells installed: SH-1/BAR-1, and SH-23. SH-1/BAR-1 was located close to the midpoint of the western extent of the landfill, had a total depth of 28.7 ft bgs, encountered bedrock at 23.7 ft bgs, and was abandoned in 1991. SH-1/BAR-1 was replaced by a shallow water table well, SH-1, that is located approximately 710 ft north of SH-15 and 1,360 ft south of SH-23 near the assumed vicinity of SH-1/BAR-1. An additional piezometer, SHP-99-01C, was installed for the supplemental groundwater investigation report and is located in the vicinity of SH-1, approximately 700 ft north of SHL-15. At this location, bedrock was encountered at 9 ft bgs. SHL-23, located at the northwestern extent of the landfill, has a total depth of 35 ft bgs, ended in sand, and is the only monitoring well located northwest of the landfill. An examination of Figures 1-2 and 3-6 presented in the supplemental groundwater investigation report reflects this fact. At SHL-23, Figure 1-2 indicates a ground surface elevation of 240 ft and an approximate bedrock elevation of 230 ft placing depth to bedrock at only 10 ft bgs. Bedrock well SHL-22 located 400 ft northwest of SHL-23, encountered bedrock at a depth of 115 ft bgs. Bedrock appears to drop off at a steeper slope north of Shepley's Hill than is shown in Figure 3-6. Installing a boring to bedrock in the vicinity of SHL-23 may be necessary if a groundwater containment barrier needs to be constructed northwest of the edge of the landfill.

Table 3-7 summarizes the data gaps analysis relative to the CAAA. (See also Table 3-5 for related information on the landfill cover assessment.)

4.0 DATA COLLECTION

The CSA Work Plan will provide detailed information on the techniques to be used to fill the data gaps. This section of the DGA Report provides a brief overview of the data to be collected. Table 4-1 shows how the data collection activities relate to the project objectives.

4.1 Landfill Cover Reconnaissance and Test Pit Survey

The primary method for collecting data for evaluating the integrity of the PVC geomembrane and overlying soil cover is by performing a detailed engineering reconnaissance and a series of carefully constructed test pits at representative locations. The test pit and reconnaissance program will be supplemented by evaluating existing and available CQA information and a perimeter geophysical survey.

4.1.1 Engineering Reconnaissance

The existing and available Five Year Review dated August 1998 and the Findings of Inspection dated November 2004 identify numerous items and locations for minor or major repairs or maintenance. Recognizing the high level of effort previously conducted to identify these conditions, AMEC will perform a supplemental reconnaissance for verification purposes. The reconnaissance will provide engineers with an opportunity to finalize the field investigation program and develop site remediation concepts relative to final grading, drainage and leachate seepage. The reconnaissance will include but not be limited to the following:

- Verification of unfavorable conditions previously identified by others (i.e., non-vegetated areas, subsidence locations and ponding, erosion features, PVC exposures, leachate seepage),
- Identification of leachate outbreaks, if any, and collection of up to three samples for analysis. (This contingency may also apply to Level 1 and/or Level 2 investigations.)
- Development of grading concepts to attain proper surface drainage,
- Development of concepts to minimize leachate seepage to the edge of Plow Shop Pond, as it pertains to the landfill cover,
- Identification of appropriate techniques to remediate a variety of minor conditions, recognizing that planning exists to perform some of this on-site soils work outside of this contract, and
- Determine optimum and representative locations for field investigations.

4.1.2 Field Investigations (Level 1) and Evaluation

AMEC will design and prepare a detailed initial field investigation program and execute the program upon receipt of appropriate approvals. The program will consist of the following tasks:

- Perform up to 10 linear test pits at representative locations (i.e., toe of slope, apparent leachate breakouts adjacent to gas vents, subsidence areas, non-vented areas, with consideration given to the phases of cap construction). The test pits will be started with a small lightweight backhoe for the first foot in depth. The remaining six inches of soil will be dug by hand shovel, being careful not to penetrate the liner. The test pit may extend thirty feet in a linear direction with the goal of locating a field welded seam. The PVC will be cleaned and visually examined for excessive tension, holes, tears, stone depressions, stretching, and sponginess. The seams will be examined for tears, breaks and poor welding. The thickness of the overlying soils will be measured and the condition of the grass root mat noted. Bag samples of the soil layers will be obtained for lab examination. Photos will be obtained of each test pit. Each test pit will be examined by an AMEC engineer with experience in liner technology. Following completion of the test pit, the soil will be replaced in the order of which the material was removed. A detailed test pit log will be completed. Efforts will be made to intercept PVC seams as much as possible. Representative soil samples will be submitted to a geotechnical testing laboratory for grain size analyses. If topsoil is found at the non-vegetated areas, selected chemical analyses (i.e., arsenic, iron, manganese) will be performed to determine the cause for the lack of vegetative growth.

- A local surveyor will be engaged to obtain precise elevations and locations of subsidence areas using an established baseline system. This data will be used to compare to historical elevations, future surveys and design of a permanent final grading plan. The surveyor will also obtain the precise location of each test pit and show the location on the site map provided for the project.
- Upon completion of the test pits testing and surveying, AMEC will review and evaluate the field data in order to obtain a professional opinion of the condition of the existing final cover. Recognizing that subsidence and erosion issues will need to be addressed in the CSA and CAAA as design issues, the soil and PVC materials encountered will be evaluated. If all test pits indicate satisfactory soil cover thickness and type and the PVC liner appears to be in good condition, including seams, then AMEC proposes to perform up to five supplemental test pits to verify conditions, fill in any data gaps and gain a higher level of confidence. These supplemental test pits will be performed as "Field Investigations, Level 2A" and will be performed in a similar manner as previously described. If the evaluation reveals indicators of PVC degradation and structural damage, then AMEC will proceed to "Field Investigations, Level 2B". If the soil cover is found to be deficient in thickness and/or the type of soil is poor, then additional soil thickness and quality measurements will be made.

4.1.3 Field Investigation, Level 2A and 2B

As described previously, Level 2A investigations are supplementary to verify apparent good cover conditions, exclusive of surface subsidence and erosion issues. The Level 2B investigations are oriented to determine the extent to which the cover has been compromised by deterioration of the PVC liner or the soil cover, as described previously.

In this scenario, AMEC proposes to perform a more detailed field investigation program that utilizes one or more of the following methods and technologies:

- Perform up to ten linear test pits in the same manner as described previously, except that samples of PVC, up to one foot square will be extracted. A special effort will be made to extract samples from welded seams. The PVC samples will be immediately placed in black plastic bags and sealed to preserve moisture content. The hole in the PVC will be patched by placing an oversized piece of PVC or similar geomembrane over the hole, after cleaning the edges and applying an all-purpose plastic adhesive. After patching, a mound of bentonite pellets or granules will be placed over the patch, and previously excavated soil will be backfilled, compacted and re-seeded. Representative samples of PVC will be examined and submitted to a local geotechnical testing laboratory for analysis. The analyses performed will depend on the physical appearance of the sample. Such tests may include Water Adsorption (ASTM D570), PVC Thickness (ASTM D1593), Seam Strength (ASTM D751), Dimensional Change (ASTM D1204), and Permeability Under Load (ASTM D5493).

- If extracting PVC samples presents concerns regarding the introduction of PVC patches into the soil cover, a leak location survey will be performed using the applied potential electrical method, using a hand held dipole or single pole probe. The probe consists of two copper/copper sulfate standard half cells to measure the potential gradient or resistance contours on top of the cover layer at orthogonal grid nodes. Use of this technology is non-intrusive and requires the use of a specialty vendor, such as I-Corp International. This method represents the latest technology for determining buried liner integrity in a non-intrusive manner. The specialty vendor will be responsible for submitting a report of findings and professional opinions of PVC liner suitability.
- Additional soil samples (up to ten) may need to be obtained above the liner for cover soil permeability and for chemical testing for leachate constituents.

4.2 Borings, Profiles and Wells

The two key areas of incomplete delineation of the arsenic plume are its northern extent (toward Nonacoicus Brook) and its western extent along the north end of Shepley's Hill. To address the northern data gap, AMEC plans to install two shallow drivepoint piezometer transects across Nonacoicus Brook and the adjacent wetlands to measure hydraulic heads and collect groundwater samples. Drivepoints must be used because a drill rig cannot access inundated wetland areas.

To address the western edge data gap, AMEC plans to extend the two existing well transects that cross the plume's leading edge; to acquire a vertical profile of water samples in each boring; and to construct two monitoring wells near the sites of two of these borings per transect. As arsenic contamination is expected at intermediate depths in this area, AMEC may need to recommend modification of MADEP protocols described in the *Landfill Technical Guidance Manual* (MADEP, 1997) which only provide for shallow and deep monitoring well installations. Drilling, well construction, and sampling will follow established quality assurance protocols as will be described in the CSA Work Plan.

Subject to obtaining approvals from private property owners in these areas, planned locations of the downgradient soil-boring transects will be approximately: (1) Extending westward from current monitoring wells SHM-05-41a/b/c; and (2) Extending westward from current monitoring wells SHM-05-39a/b. Exact locations are to be determined. The intent of these transects will be to establish firm westward delineation of the leading edge of the plume. Monitoring well locations will be chosen based on the results of laboratory analysis of the vertical-profile samples.

Additional soil borings may be executed along the upgradient (western and/or southern) edges of the landfill, to define the soil profile and to assess the constructability of remedial alternatives.

4.3 Surface Water and Sediment Sampling

As part of the integrated study of groundwater interaction with Nonacoicus Brook, sampling of surface water and sediments within the channel and wetlands will be conducted. This work will be conducted using portable equipment suitable for manual transport into the wetland area. In conjunction with this sampling, AMEC proposes to gauge flow in the brook at upstream and down stream locations to determine the magnitude of baseflow gains along the channel segment potentially impacted by the plume.

As part of the Plow Shop Pond investigations, AMEC proposes to collect intact core samples of the bed sediments in at least three locations in the Red Cove area. These samples will be subjected to laboratory permeameter tests to estimate the hydraulic conductivity of the pond's bed sediment layer. Recent USEPA studies designed to localize and estimate the flux of groundwater and arsenic into Plow Shop Pond will be reviewed when results become available, and will be used to refine the design of the core sampling program.

4.4 Geophysical Studies

Geophysical studies will be undertaken primarily to address data gaps related to 1) Landfill cap condition and 2) The magnitude and rate of influx of shallow groundwater to the landfill ("underflow"). Data quality objectives will accordingly be set to satisfy these information requirements. As detailed below, Ground Penetrating Radar (GPR) data on shallow subsurface conditions will be acquired along the western landfill margin and elsewhere to establish the lateral extent of the cap, to identify cap areas more susceptible to downgoing leakage, and to map the thickness of waste and unconsolidated sediment above bedrock.

AMEC prefers to use minimally intrusive methods to physically examine the PVC liner. These methods will focus on performing linear backhoe and hand-dug test pits to examine the PVC. The locations for these subsurface explorations will be representative locations where the PVC has a greater probability of being compromised, such as subsidence areas.

In order to guide location selection, and to better understand the depth and positioning of the liner, AMEC will also conduct a non-intrusive GPR survey in selected areas of the landfill. Impulse GPR is generally employed as a technique that uses high-frequency electromagnetic (EM) waves to acquire subsurface information. GPR detects changes in EM properties that, in a natural setting, are a function of soil and rock material, water content, and bulk density. GPR is routinely used to locate objects such as pipes, drums, tanks, cables, and boulders, and mapping landfill and trench boundaries and top of bedrock. In this case the liner should provide a good EM contrast due to the abrupt change in permeability and moisture content above and below the liner. The survey will also be extended slightly outside of the inferred boundary of the liner, in order to more accurately identify the position and attitude of the edges of the liner. In addition to the moisture and permeability contrast, the edges of the liner would also be identifiable by the character change between disturbed and undisturbed soil.

While the primary purpose of this effort is to elucidate shallow subsurface conditions, depending on the composition of the subsurface material, GPR depth of penetration can range from a few feet below ground in clay rich soil to up to 100 feet in pure sand. Since bedrock is shallow on the west side of the landfill, there is a good chance of seeing at least some of the bedrock surface near the western side of the landfill. If so, this information will be important in understanding the geologic relationship between the top of bedrock and the edge of the membrane. The distance between them and the attitude of the top of bedrock will have a strong effect on the groundwater flow in and around the landfill.

GPR survey data are normally acquired using antennas that are pulled along the ground surface. A transmitting antenna radiates EM waves that propagate in the subsurface and reflect from boundaries at which there are EM property contrasts. The receiving GPR antenna records the reflected waves over a selectable time range. The depths to the reflecting interfaces are calculated from the arrival times in the GPR data if the EM propagation velocity in the subsurface can be estimated or measured.

As part of the geophysical investigation, AMEC will also survey selected areas using a GSSI GEM-300 multifrequency terrain conductivity EM profiler as a reconnaissance tool to help identify locations where the PVC liner may be compromised.

5.0 CONCLUSION

Shepley's Hill Landfill encompasses approximately 84 acres in the northeast corner of the main post of the former Fort Devens. The landfill contains a variety of waste materials, including incinerator ash, demolition debris, asbestos, sanitary wastes, spent shell casings, glass, and other wastes. The maximum depth of the refuse occurs in the central portion of the landfill and is estimated to be about 40 feet. The volume of waste in the landfill has been estimated at over 1.3×10^6 cy, of which approximately 25 percent is below the water table.

The landfill was closed in five phases between 1987 and 1992-93 in accordance with Massachusetts regulations at 310 CMR 19.000. Closure consisted of installing a 30-mil PVC membrane cap covered with soil and vegetation. Closure also included installation of gas vents. Closure also included installation of wells to monitor groundwater quality around the landfill, and construction of a storm drainage system to control surface water runoff.

Subsequent to closure, remedial investigations (RIs) under CERCLA evaluated soil, sediment, surface water, and groundwater conditions at and in the immediate vicinity of the landfill. The results confirmed the presence of various contaminants, particularly VOCs and certain inorganics, in groundwater, sediments and surface water at or adjacent to Shepley's Hill Landfill. An FS and ROD resulted in a remedy that required long term monitoring and maintenance of the existing landfill cap and groundwater monitoring. The ROD included a contingency provision, which required that a pump and treat system be installed if groundwater contaminant concentrations (primarily arsenic) did not meet certain risk-based performance standards over time. Due to continued elevated contaminant concentrations, the Army recently installed and started operating a groundwater extraction and treatment system to address groundwater contamination emanating from the northern portion of the landfill. In addition, the continued release of contaminants beyond the site boundaries triggered the requirement to complete a CSA and CAAA under Massachusetts regulations. This DGA is the first step toward completing the CSA and CAAA.

The general objectives of the Data Gaps Analysis Report are to assess existing site characterization data, identify major data gaps and define the corresponding additional data needs, and define DQOs necessary to support completion of the CSA and CAAA. These DQOs represent a conceptualization of how the data will be used in the context of the regulatory requirements for evaluation of risk in the CSA and potential actions to mitigate unacceptable risk in the CAAA.

AMEC reviewed available data to develop/confirm the site conceptual model and to identify data gaps with respect to stakeholder's principal general objectives (as specified in the project RFP), MA requirements for a CSA and CAAA, and USEPA requirements for risk assessments and feasibility studies.

AMEC concludes that the following constitute the key data gaps for the Shepley's Hill Landfill:

- Extent of arsenic plume N and NW of landfill
- Potential impact of landfill contaminants to McPherson Well
- Magnitude of impact from landfill contaminants on Red Cove
- Existence of completed exposure pathways and magnitude of current and future risk to human health and environment from landfill-derived contaminants.
- Integrity and effectiveness of existing LF cap, including unvegetated areas on southeastern portion of landfill cover.

The detailed data gaps identified during the data review are summarized on Table 5-1. Table 5-1 includes preliminary actions proposed to acquire appropriate and sufficient information to close the data gaps. Closure of the data gaps as described will provide necessary data to complete delineation of contaminants, complete human and ecological risk assessments, prepare the CSA, and, as appropriate to address risks, evaluate previously identified and new proposed remedial alternatives (CAAA).

AMEC reviewed a substantial quantity of site-related data during completion of the DGA. However, some existing data was not available for review in time for inclusion in this report. In addition, ongoing investigation activities at the site will yield additional data. Review of new data may result in identification of new data gaps or revisions to the CSM.

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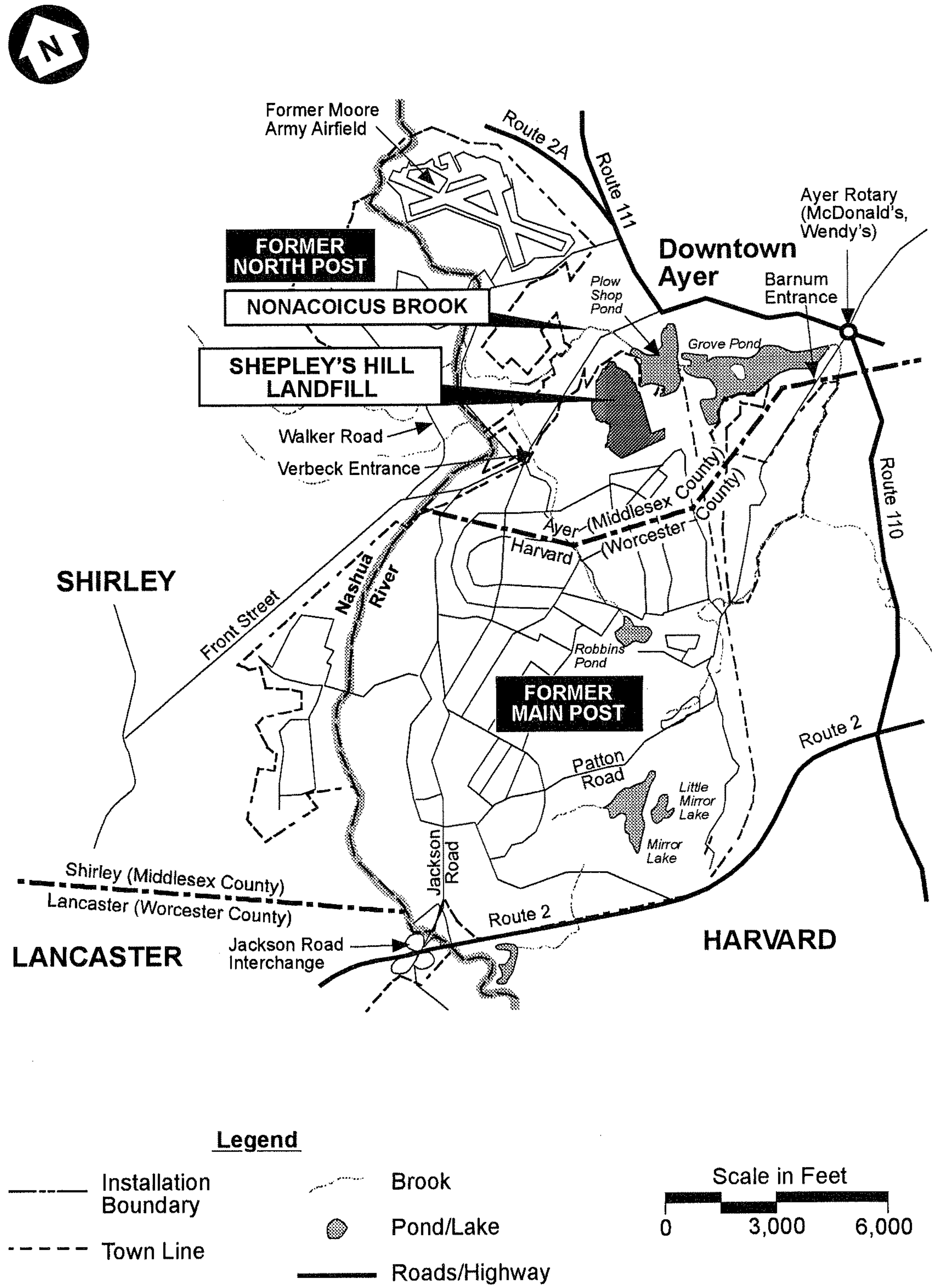


Harding ESE A MACTEC COMPANY	Location of Shepley's Hill Landfill Supplemental Groundwater Investigation Devens Reserve Forces Training Area Devens, Massachusetts	FIGURE 1-1

DRAWN:	JOB NUMBER:	FILE NUMBER:	APPROVED:	DATE:	REVISED DATE:
BGF	45227-993802	W2001097(d)		6/99	2/12/2

Figure 3-1
Correlation of Arsenic vs. ORP
Data Gaps Analysis Report
Shepley's Hill Landfill

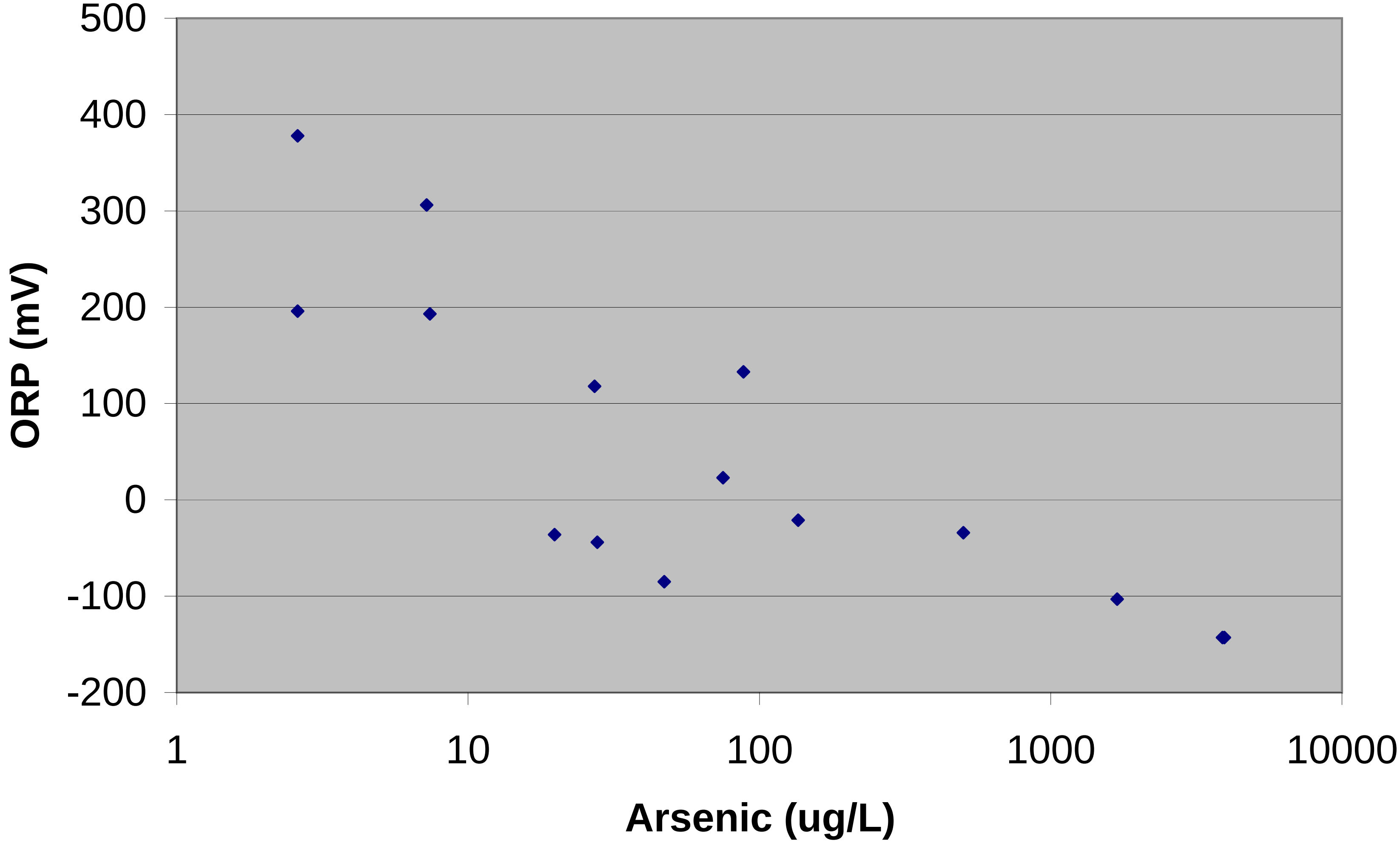


Figure 3-2
Correlation of Arsenic vs. Manganese
Data Gaps Analysis Report
Shepley's Hill Landfill

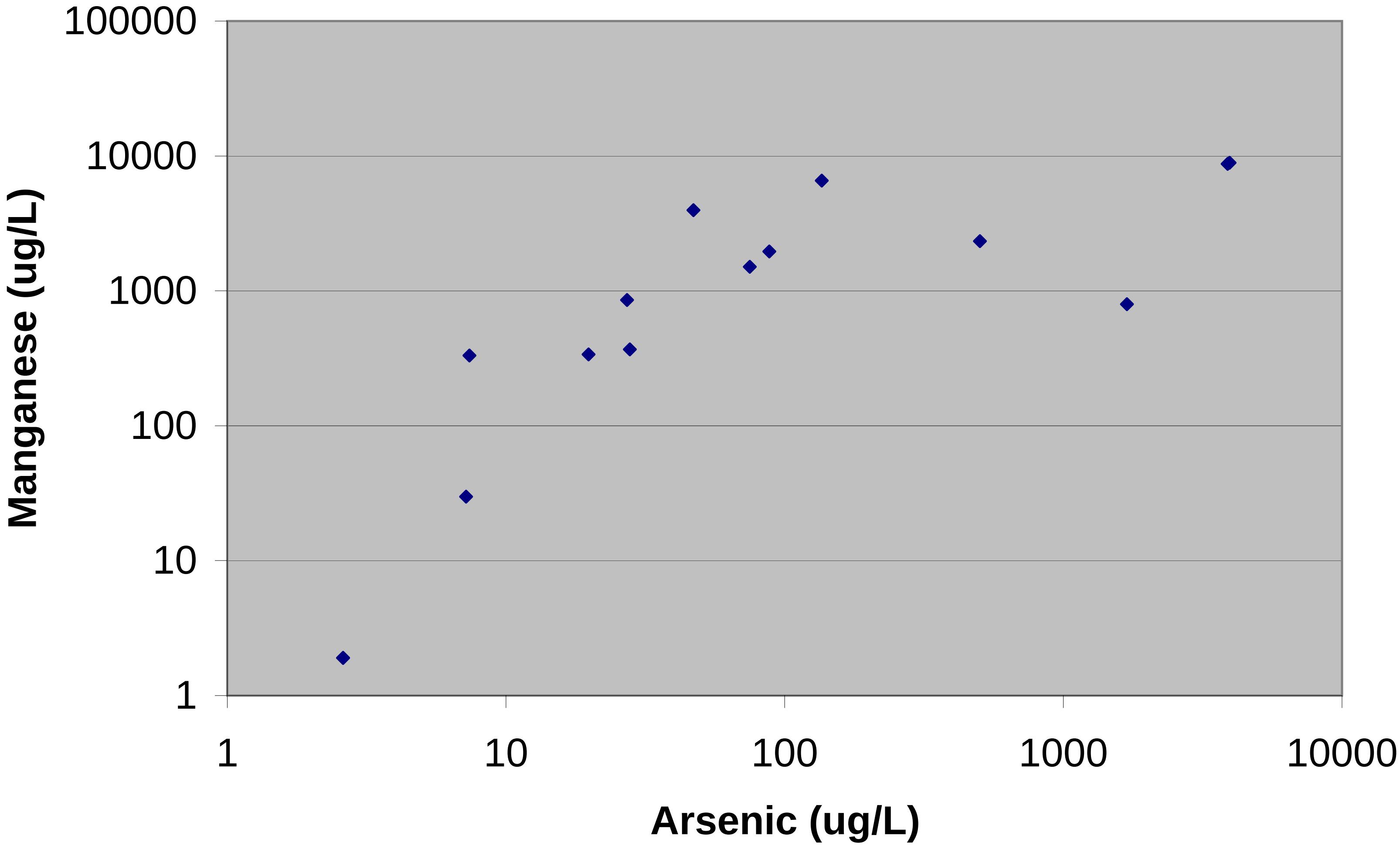
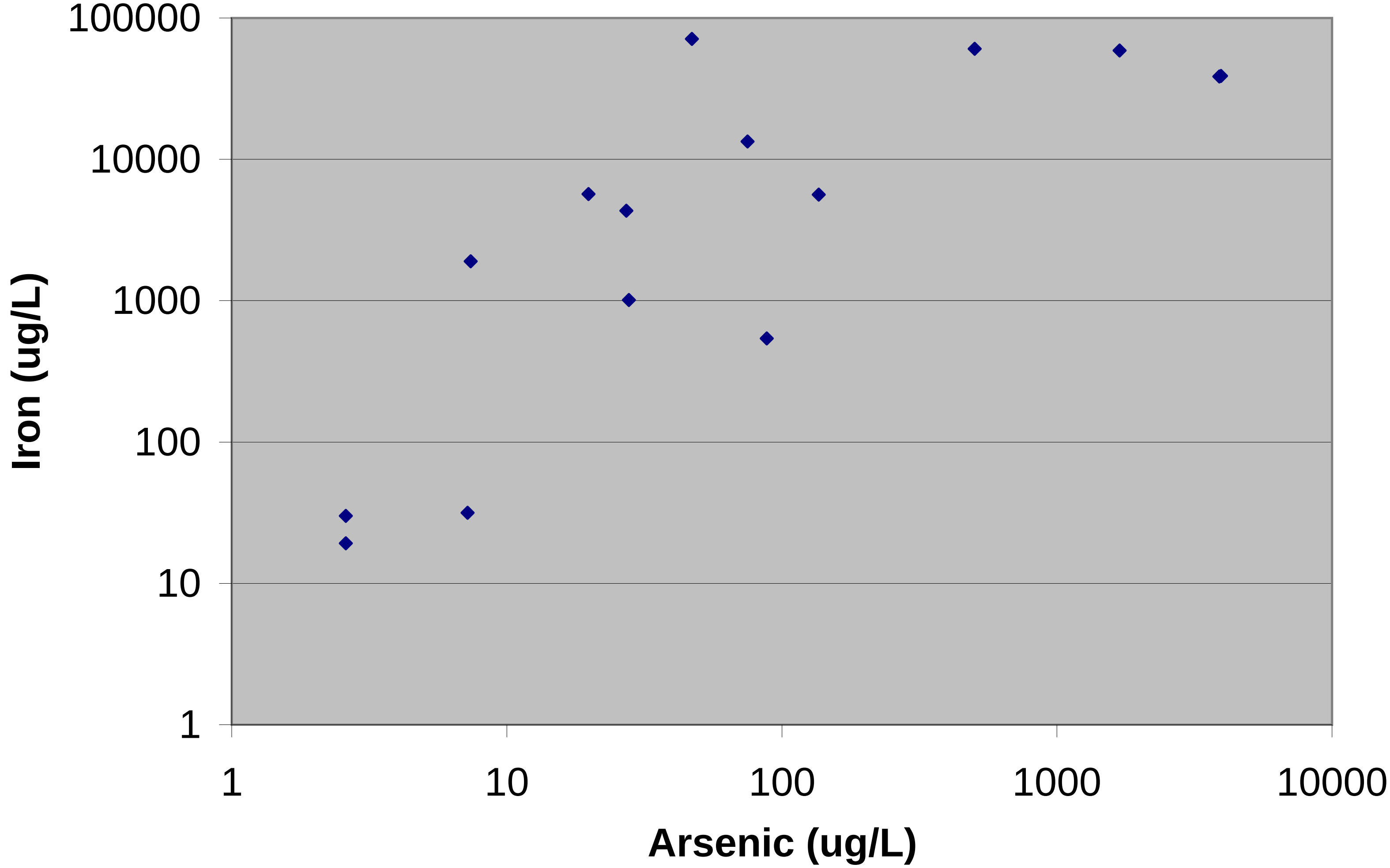
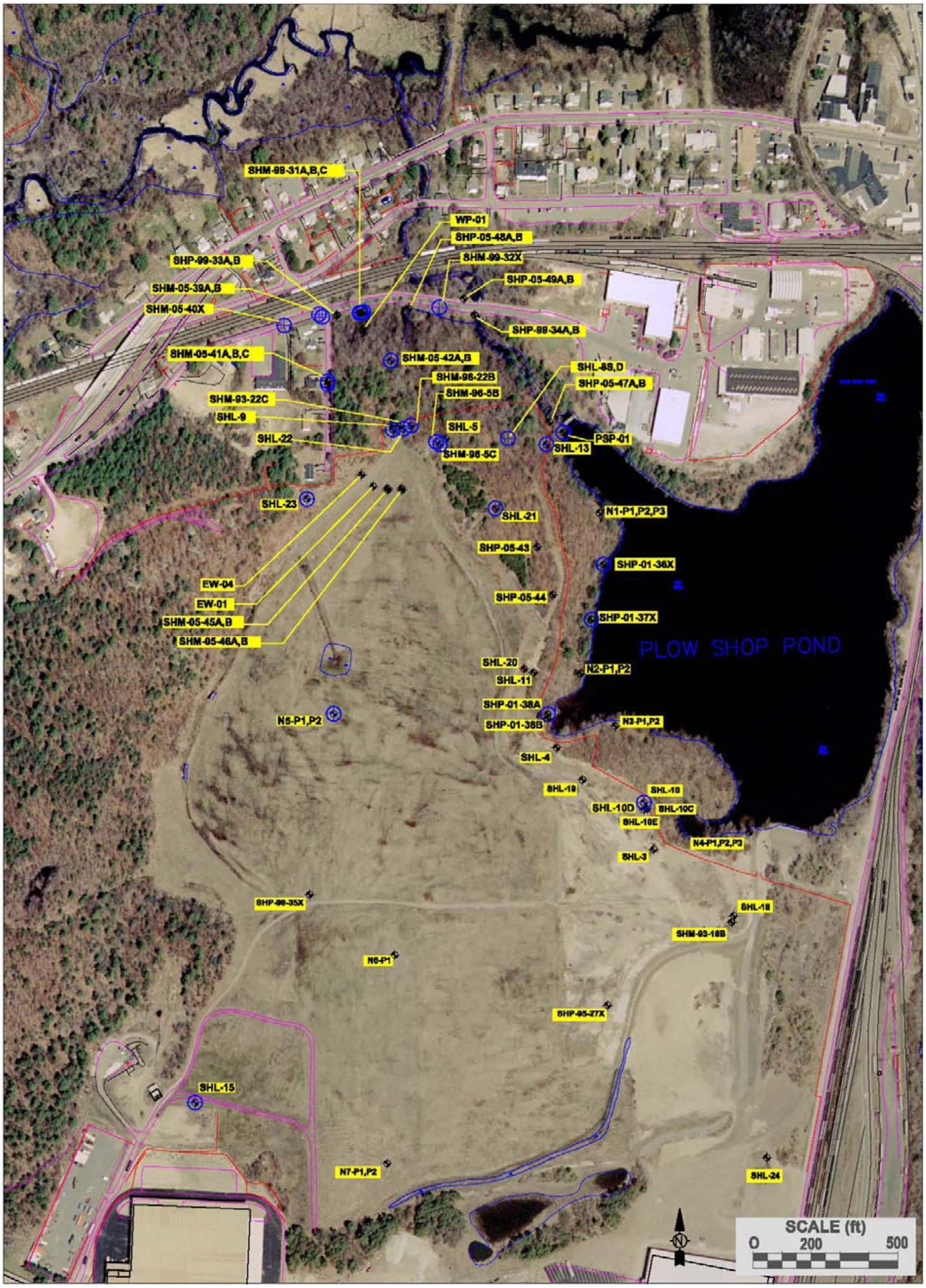


Figure 3-3
Correlation of Arsenic vs. Iron
Data Gaps Analysis Report
Shepley's Hill Landfill





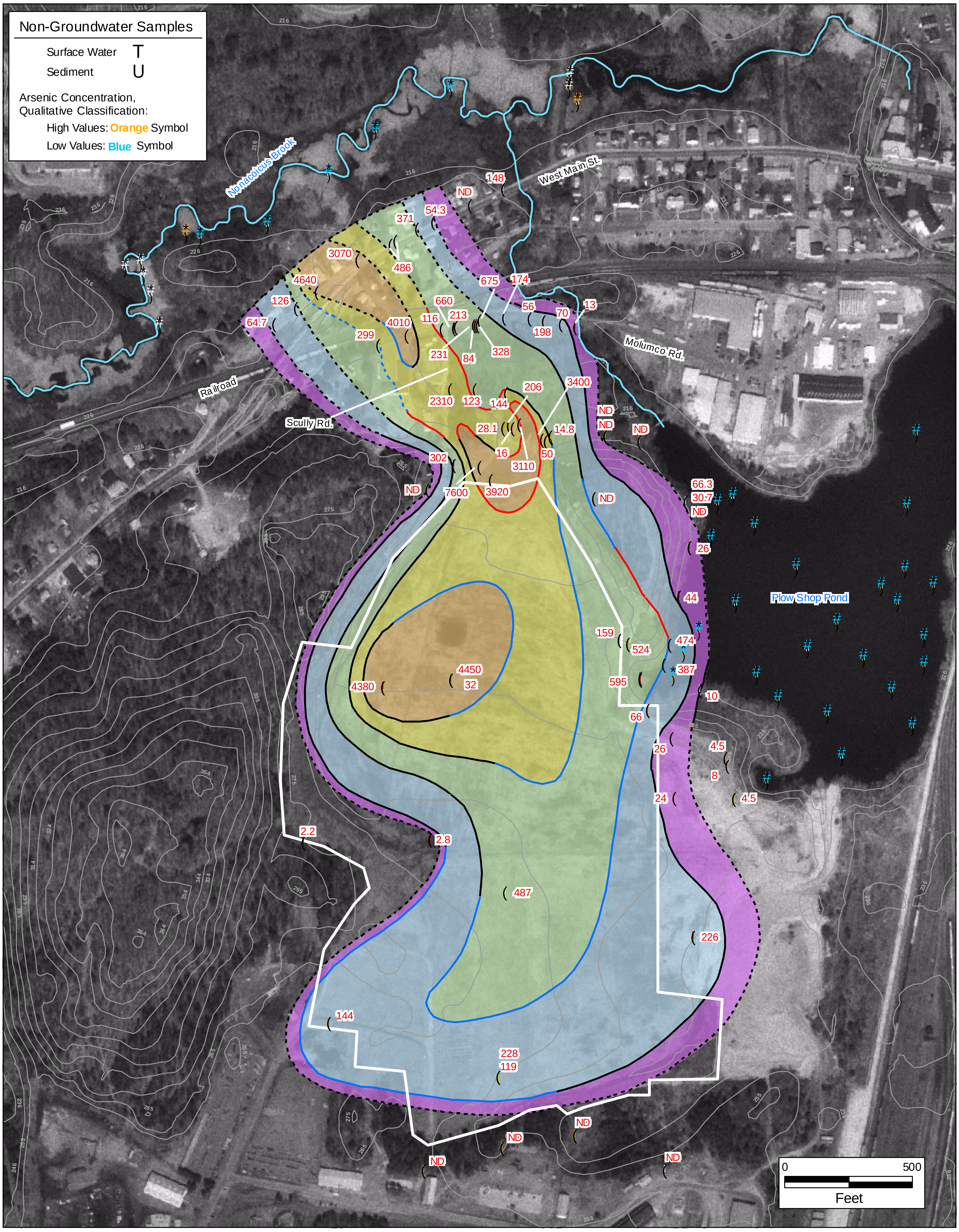
LEGEND

- Hydraulic Monitoring Network
- Geochemistry Sentinel Network

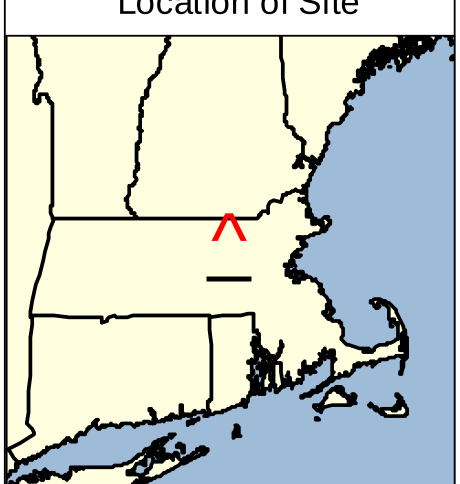
Note: New Well Locations Approximate (to be surveyed)

CH2MHILL

Figure 3-4
Performance Monitoring Network
Data Gaps Analysis Report
Shepley's Hill Landfill



Location of Site



Extent of Arsenic Plume in Groundwater
Shepley's Hill Landfill Area

Contours show interpreted, generalized plume extent during the third quarter of 2005. The concentration represented at any surface location is the maximum, regardless of depth.

Data from 2005 are used where available; in other locations, historic data are used. Contours are colored red where historic trends suggest consistent concentration increase, and blue where trends suggest consistent decrease. The suggested Increase/Decrease indications are for general illustration only and are not statistically rigorous.

Devens
Ayer, Massachusetts

AMEC Earth & Environmental, Inc.
239 Littleton Road, Suite 1B
Westford, MA 01886
(978) 692-9090

Legend

Sample Group	Arsenic Concentration, ug/L
61M	487 Well Sample
EW	
N1	10-50
N2	50-300
N3	300-1000
N5	1000-3000
N6	>3000
N7	Elevation, ft
SB	Landfill Boundary
SHL	Concentration Increase
SHM	Concentration Decrease
SHP	
SHX	
Wfld SB	Streams

FIGURE 3-5

Figure 3-6
Particle Track Simulation of McPherson Well Capture Zone
Data Gaps Analysis Report
Shepley's Hill Landfill

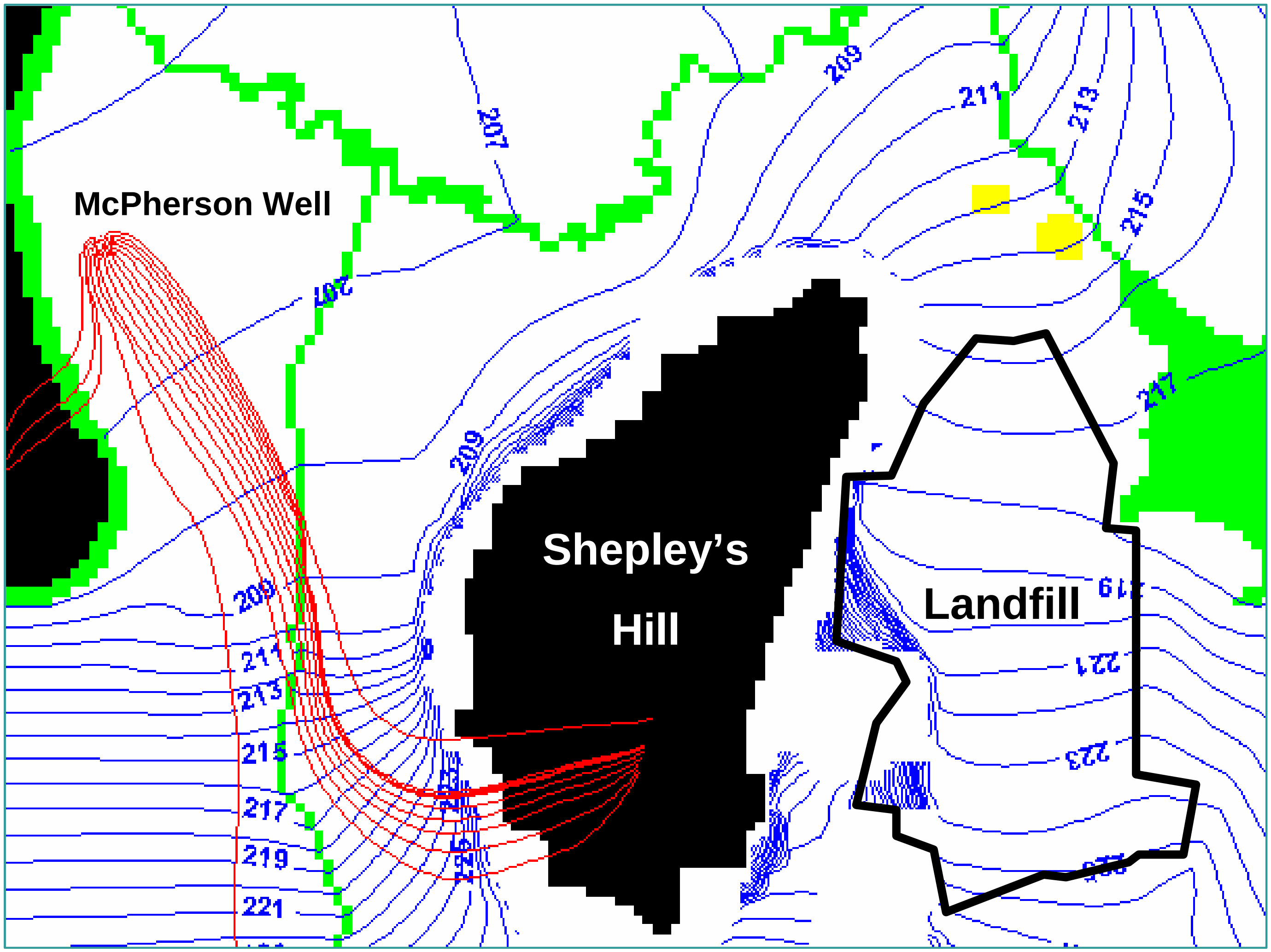


Figure 3-7: Site Scoring Map

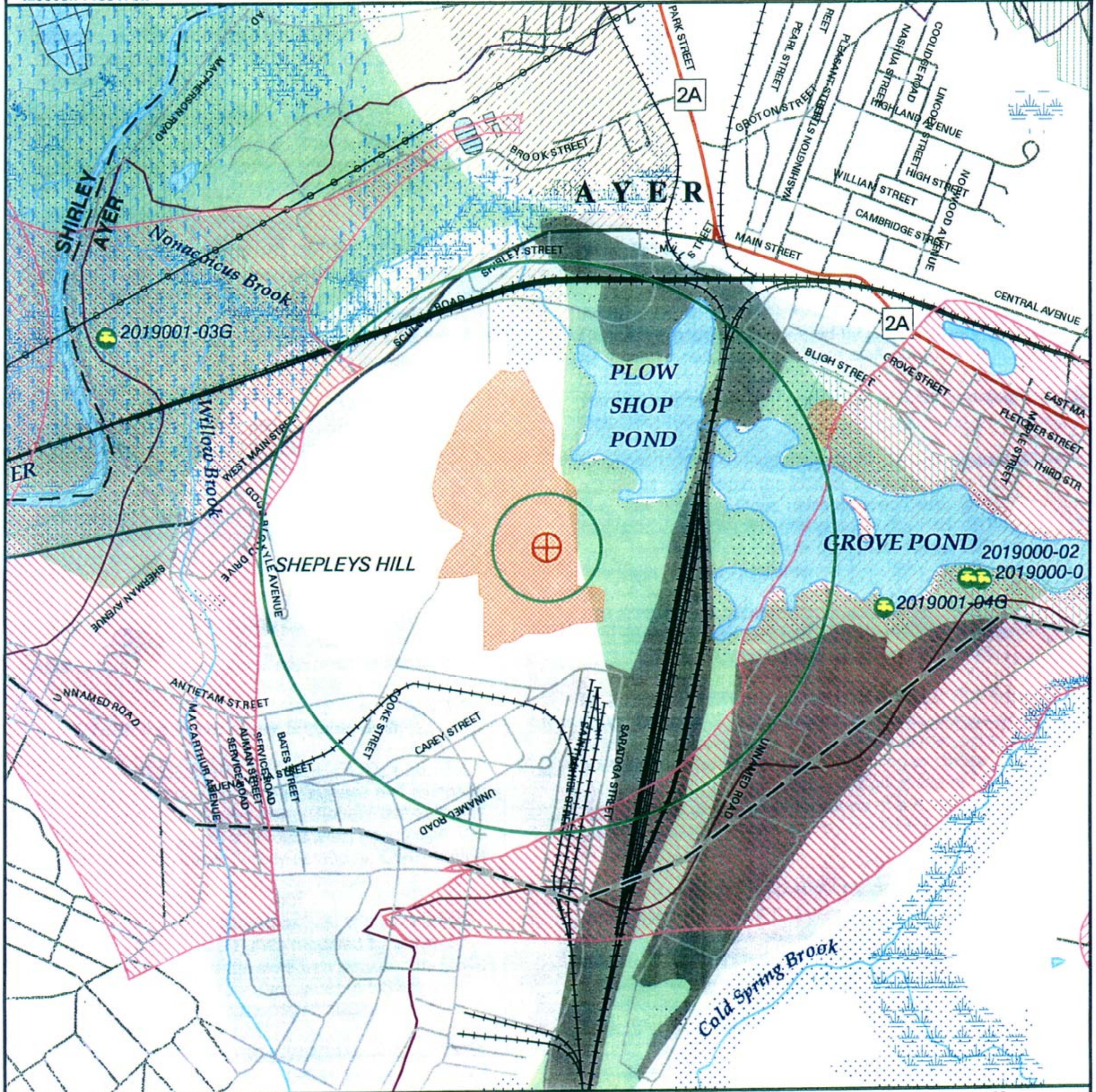
Site Scoring Map: 500 feet & 0.5 Mile Radii

SITE NAME:
Shepleys Hill Landfill
Fort Devens
NW of Antietam Street
AYER, MA 01432
423308n 713547ew

Site Location

The information shown on this map is the best available at the date of printing. Please refer to the data source descriptions document.

MASS GIS
Massachusetts Geographic Information System
Massachusetts Executive Office of Environmental Affairs - 2005



Roads: Limited Access, Divided, Major Road, Connector, Street, Track, Trail

Boundaries: Town, County, DEP Region; Train; Powerline; Pipeline; Aqueduct

Basins: Major, Sub; Streams: Perennial, Intermittent, Man Made Shore, Dams

Potentially Productive Aquifers: Medium, High Yield

Non-Potential Drinking Water Source Area: Medium, High Yield

EPA Sole Source Aquifer; FEMA 100-year floodplain

Public Water Supplies: Ground, Surface, Non Community

Approved Zone2; IWPA; Surface Water Supply Zone A

Hydrography: Water Features, Public Surface Water Supply

Wetlands: Fresh, Salt, NHESP Wetlands Habitat

Protected Open Space; ACEC

DEP Permitted Solid Waste Facilities; Certified Vernal Pools

N E S W

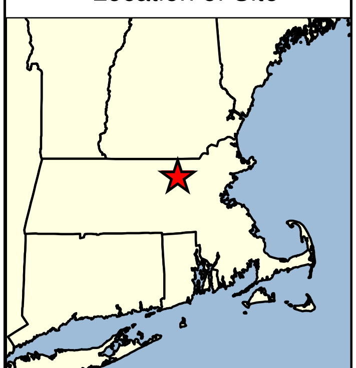
SCALE 1:15000

0 1/2 MILES

0 1/2 1 KILOMETERS

April 26, 2005

Location of Site



Red Cove Portion of
Plow Shop Pond

Shepley's Hill Landfill Area

Devens
Ayer, Massachusetts

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(978) 692-9090

Legend

Area of Plow Shop Pond:
28.9 acres

Approximate Extent of Red Cove:
0.6 acres

FIGURE
3-8

Table 1-1
Ongoing Work by Others
Data Gap Analysis Report
Shepley's Hill Landfill

Party	Activity	Schedule	Notes
EPA	Ecological Risk Assessment	Initial data presented at RAB June 2005. EPA issuing report January 2006.	Sediment toxicity testing found impact in Red Cove, Roundhouse. Biggest issue Hg in fish. Work also included evaluation of groundwater flux into Red Cove.
EPA ORD	Project: Transport of Arsenic in an Urban, Military Watershed	Research started September 2005. Field-based sampling will be carried out over a 12 month period.	The purpose of this study (USEPA, 2005a) is to 1) determine the migration mechanisms controlling arsenic transport at the Fort Devens Superfund Site and the Red Cove Study Area of Plow Shop Pond adjacent to Shepley's Hill Landfill (Figure 1-1), 2) provide an evaluation of the potential role of natural attenuation processes in mitigating arsenic transport and 3) provide guidance for determination of reasonable, cost effective treatment technologies for a river/lake/wetland in an urban watershed.
Army/ Nobis	Landfill maintenance	Field work October through December 2005.	Scope of work includes: improving access restrictions, improving drainage swales, filling subsidence depressions with soil and regarding, and installing gas probes.
Army/ CH2MHill	Groundwater extraction and treatment	Startup began September 2005; startup period continues for three months.	System performance monitoring includes: water levels at more than 60 points (mostly wells gauged manually or by datalogger, weekly becoming quarterly), and hydrochemistry at 31 wells + 1 surface point (weekly becoming quarterly), and also influent and effluent sampling.
Army/ CH2MHill	Elevation survey of all monitoring wells	Ongoing	Verbal communication R. Simeone
Army	Potential Release Abatement Measure (RAM) – pesticide containing soils	RAM Plan this fall, may implement Spring 2006	Conceptual plan is to place soils containing pesticides over northern end of cap on Shepley's Hill Landfill.
Army	Long-Term Monitoring Program	GW Sampling Spring and Fall of each year, Landfill Inspection and Gas Monitoring conducted annually	

Table 1-2
Summary of Technical Approach
Data Gaps Analysis Report
Shepley's Hill Landfill

Stakeholders' General Objectives	Technical Approach
1. Evaluate magnitude of plume impact to wetlands, if any.	Key groundwater samples, surface and groundwater elevation measurements, and groundwater model adjustments are designed to delineate the plume at all critical margins, especially toward the wetlands. These data will be used to estimate the contaminant concentrations that could reach the wetlands.
2. Evaluate magnitude of impact to McPherson water supply well, if any.	The elements of #1 above also address this goal. The current groundwater model indicates no impact to the McPherson well based on existing data. If new data suggest that the plume could reach the McPherson well, hydrogeologists will use the refined groundwater model to estimate the contaminant concentrations that could arrive at that well.
3. Evaluate landfill cap integrity and effectiveness at minimizing surface/groundwater intrusion and leachate generation.	An integrated physical and geophysical assessment will establish the geographic extent of the cap, its vertical transmissivity, and the degree to which it impedes groundwater underflow.
4. Assess Red Cove as an area of historic and possibly current leachate discharge.	At Red Cove, nested piezometers and sediment core samples will be used to estimate vertical hydraulic gradients and groundwater flow. The flow value will allow estimating the present contaminant flux to Red Cove, using a refined groundwater model. The USEPA is collecting data relevant to this issue.
5. Assess landfill gas issues and the non-vegetated cap areas along the southeast portion of the Landfill.	Non-vegetated cap areas will be specifically inspected, and their significance relative to cap integrity will be assessed. Field observations suggest that the lack of vegetation is due to poor soil quality. For landfill gas issues, a preliminary assessment suggests that landfill gas migration is not significant.
6. Complete and close all CERCLA related investigations/reporting.	The CSA/CAAA will: 1. Define project objectives, decisions and data requirements. 2. Establish data quality objectives and analyze data gaps. 3. Collect, evaluate and complete the site investigation; assess the landfill cap; and assess human health and ecological risk assessments. A protectiveness determination of the remedy for SHL was deferred in the 2005 Five Year Review until further information is obtained through the completion of the CSA and CAAA. The CSA and CAAA reports will meet a critical milestone obligation set forth in the 2005 Five Year Review.

Table 3-1
Focus of Data Gaps Analysis
Data Gaps Analysis Report
Shepley's Hill Landfill

Objectives	Report Section and DGA Topic: 3.2 Arsenic Geochemistry	3.3 Plume Assessment	3.4 Landfill Cover Assessment	3.5 Risk Assessment	3.6 Engineering Analysis for CAAA
Evaluation of the plume to determine whether the plume is impacting the wetlands and the potential magnitude of that impact, if any. *	♦	♦		♦	♦
Determination of any impact to the McPherson water supply well and the magnitude of such impact, if any.		♦		♦	
Evaluation of landfill cap integrity and its effectiveness at minimizing surface/ groundwater intrusion and leachate generation.*			♦		♦
Assessment of Red Cove as an area of historic and possibly current leachate discharge.*	♦	♦		♦	
Assessment of landfill gas issues and the non-vegetated cap areas along the southeast portion of the Landfill.*			♦		

* Other parties are collecting additional data; see Table 1-1.

Table 3-2
Pearson's Correlation of Selected Constituents and Parameters (Well Samples, 2004)
Data Gaps Analysis Report
Shepley's Hill Landfill

	As	*Ba*	*Cl*	*Fe*	*Mn*	*Na*	*Zn*	*Alkalinity*	*ORP*	*Sp. Cond.*	*SO4*	*TDS*
As	1											
Ba	0.75	1										
Cl	0.62	0.77	1									
Fe	0.79	0.81	0.45	1								
Mn	0.78	0.83	0.63	0.87	1							
Na	0.78	0.81	0.96	0.60	0.74	1						
Zn	0.14	-0.05	0.38	-0.10	0.15	0.37	1					
Alkalinity	0.71	0.79	0.93	0.58	0.76	0.95	0.32	1				
ORP	-0.80	-0.80	-0.51	-0.89	-0.81	-0.65	0.15	-0.64	1			
Sp. Cond.	0.75	0.81	0.93	0.63	0.79	0.95	0.31	0.99	-0.67	1		
SO4	-0.07	-0.03	0.07	-0.29	0.00	0.03	0.04	0.15	0.09	0.15	1	
TDS	0.71	0.79	0.93	0.58	0.78	0.95	0.33	1.00	-0.63	0.99	0.17	1

Note: [shaded] indicates |r| > 0.70

Table 3-3
Framework for Filling Data Gaps Related to Arsenic Occurrence and Speciation
Data Gaps Analysis Report
Shepley's Hill Landfill

Objective	Hypothesis	Preliminary Decision Rule	Data Gaps
Evaluate origin of As	As levels are naturally high in bedrock groundwater in central MA	If (a) upgradient data or (b) regional data show elevated concentrations of As, then concentrations near landfill are likely affected by local conditions.	(a) Data from upgradient wells (b) Literature reports regarding groundwater concentrations in central MA
	Reducing conditions imposed by the landfill are mobilizing naturally occurring As	If elevated levels of As are statistically related to parameters such as ORP, then reducing conditions may be mobilizing As.	Analyze groundwater samples for As, matrix metals (Ba, Ca, Fe, Mg, Mn, Mo, Na, Si) and trace metals (As, Cr, Zn). Also, alkalinity, COD, sulfur species (sulfate and sulfide), nitrogen species (TKN, ammonia, nitrate, nitrite), carbon species (total organic carbon, dissolved organic carbon, total inorganic carbon), chloride, hardness, TDS, TSS, DO, ORP, pH and specific conductivity.
Determine whether organic acids in peat are mobilizing As	Tannins in groundwater are mobilizing As	If tannin levels appear to correlate with arsenic in groundwater, then peat lenses may play a role in arsenic mobility.	Tannin concentrations (in concert with concomitant routine arsenic concentrations).
Determine whether biological activity is transforming arsenic to organic forms.	Reducing conditions favor the growth of anaerobic bacteria that are capable of the organification of inorganic arsenic to methylated forms of the element.	If the amount of methylated arsenic species in each sample does not exceed 10% of the total amount of arsenic, then it can be concluded that	Measurement of methylated arsenic species. Alternatively, measure As(III) and As(V) and subtract sum of both from Total Arsenic.

Table 3-3
Framework for Filling Data Gaps Related to Arsenic Occurrence and Speciation
Data Gaps Analysis Report
Shepley's Hill Landfill

Objective	Hypothesis	Preliminary Decision Rule	Data Gaps
		biomethylation processes within the landfill are not significant to mobilize a substantial portion of the waste.	
Determine whether arsenic solubility in groundwater is limited	Preliminary data analysis suggests that arsenic solubility does not increase any higher than 4-5 mg/L at elevated Fe/Mn and reducing ORP	If trend analysis shows stable levels of arsenic in GW for wells that routinely show low ORP/high Fe & Mn, then "solubility limit" hypothesis supported.	Continue with routine monitoring program, including wells with reducing conditions and historically elevated concentrations of arsenic.
Determine relative toxicity (based on speciation) at exposure points	Native microorganisms within subsurface soils converting inorganic arsenic to methlyated forms.	If As is not present as an organoarsenical, then risk or hazard will be determined based on the presence of inorganic species of arsenic alone.	As above (direct or indirect measurement of organic forms of arsenic).

Table 3-4
Framework for Filling Data Gaps Related to Plume Delineation
Data Gap Analysis Report
Shepley's Hill Landfill

Objective	Hypothesis	Preliminary Decision Rule	Data Needs
Delineate furthest downgradient extent (northern end) of plume near Nonacoicus Brook	Groundwater that carries arsenic exceeding local background discharges essentially completely into Nonacoicus Brook	If weight of evidence indicates that northward-moving groundwater is largely captured by Nonacoicus Brook, then conclude arsenic movement beyond brook is insignificant.	Stream gauging, vertical hydrochemical profiling, and vertical gradient measurement in multiple appropriate locations
Delineate northwestern plume extent, west and south of well SHM-05-39B	Plume does not extend westward beyond the longitude of the Main Street railroad overpass	If appropriately located borings yield multiple, vertically separated groundwater samples whose arsenic concs. are entirely below local background, then conclude plume is delineated there.	Two borings southeast of the overpass: (1) Near Scully Road, and (2) About 200 feet farther southeast toward the landfill; vertical profiles of groundwater samples in each boring.
Define groundwater discharge rate and estimate the current arsenic flux to Red Cove	There is a finite and measureable arsenic flux to Red Cove that is a minor contributor to risk	If magnitude of arsenic flux is small relative to other contributors to risk, then conclude further action will not lower cumulative risks in Plow Shop Pond.	Data from USEPA study, which may be supplemented with physically-based flux estimates; representation of discharge process in groundwater modeling.

Table 3-5
Framework for Filling Data Gaps Related to Landfill Cover Assessment
Data Gaps Analysis Report
Shepley's Hill Landfill

Objective	Hypothesis	Preliminary Decision Rule	Data Needs
Inventory visually apparent problems	Areas of subsidence, erosion, stressed vegetation, and/or leachate indicate areas where the cover may not be performing as designed	If visual observation suggests apparent problems with the landfill cover, then repairs may be necessary to enhance its function.	Detailed engineering reconnaissance; Review of Work Plan for maintenance work scheduled for Fall 2005, when available.
Determine if the PVC geomembrane is performing as designed, approved, maintained and installed	In areas that have not been subjected to undue stress post construction, the PVC geomembrane is performing adequately.	If field installation met standards for geomembranes at that time, then performance is likely to be adequate.	Continued review of detailed as-built drawings; construction quality assurance reports.
	In areas under stress, the PVC geomembrane may have been compromised	If visual inspection at stress locations indicates no apparent damage to the seams or the geomembrane itself, then the PVC geomembrane is performing adequately.	Carefully-excavated test pits to expose the liner for visual inspection at areas of apparent stress and probable satisfactory locations. Samples of the geomembrane will be tested for conformance with specifications only if absolutely necessary.
Determine whether subsidence has been substantial (and has thereby stressed the PVC geomembrane and distorted the horizontal gas vent piping).	Subsidence has occurred, based on visual observations.	If current elevations differ substantially from as-built elevations, then subsidence has occurred.	Visual observation and survey of elevations before repair work planned for Fall 2005. Based on these data, may select areas for inspection of the PVC geomembrane.
Cover soil quality and permeability	Inadequate amounts and wrong type of soils contribute to reducing durability of the PVC geomembrane.	If inadequate thickness and/or soils are wrong type, then PVC protective layer is in danger.	Measurements of soil thickness and soil classification will provide the necessary information.

Table 3-5
Framework for Filling Data Gaps Related to Landfill Cover Assessment
Data Gaps Analysis Report
Shepley's Hill Landfill

Objective	Hypothesis	Preliminary Decision Rule	Data Needs
Determine if drainage features and erosion control are adequate	Appropriate grades and erosion control features limit weathering of the cap.	If current and planned grades conform to the MADEP landfill closure technical standards, then likelihood of erosion and ponding are lessened.	Planned repair work by Nobis Engineering may address most of the current grading and erosion issues. A survey of current conditions and as-built data of the planned repairs must be obtained.
Determine cause for lack of vegetation in certain areas	Visual observation suggests that the soil is not of the quality to support vegetation. (One alternative hypothesis is that landfill gas has affected vegetation. However, landfill gas data, the complete absence of vegetation – rather than the presence of stunted vegetation – and the sandy appearance of the soil suggest that the condition is not related to landfill gases.)	If soil does not contain sufficient organic material or nutrients to support vegetation, then supplemental soils must be added to support plant growth. If landfill gas is impacting vegetation, then PVC repair and/or additional gas venting is needed.	Characterize organic content, nutrients in soil in non-vegetated areas. Check soil for landfill gas occurrence. Expose and examine PVC liner at select locations.
Determine adequacy of PVC anchoring to limit water infiltration into entering the refuse and limiting gas migration.	Irregular and poorly anchored PVC with unknown relationship to impermeable soil and bedrock enhances probability of increasing amount of rainfall infiltration to refuse and minimal restriction on gas migration.	If anchoring is unsatisfactory, then issue will be addressed as a major remedial action.	Geophysical testing is planned to characterize the relationship of the PVC to the surrounding earth materials.

Table 3-5
Framework for Filling Data Gaps Related to Landfill Cover Assessment
Data Gaps Analysis Report
Shepley's Hill Landfill

Objective	Hypothesis	Preliminary Decision Rule	Data Needs
Determine whether existing landfill gas monitoring program is adequate.	Existing data indicate that landfill gas migration is not a major issue, however, additional data may be necessary to characterize seasonal variation and other preferential landfill gas pathways.	If existing data do not cover seasonal variations with measurements or other buildings are of concern, then an expanded monitoring program is necessary.	Review and evaluation of all landfill gas monitoring data (including vents). Evaluate depths of monitoring vents.

Table 3-6
Framework for Filling Data Gaps Related to Risk Assessment
Data Gaps Analysis Report
Shepley's Hill Landfill

Objective	Hypothesis	Preliminary Decision Rule	Data Needs
Evaluate nature and extent of impacts from Landfill	Arsenic plume is not solely emanating from landfill	Arsenic concentrations in groundwater and surface water at upgradient/upstream locations is high (local conditions)	Nature and extent of background arsenic concentrations in groundwater and surface water
Determine if groundwater exposure are complete for drinking water pathway	Groundwater plume is not contributing significantly to drinking water wells	If area data show groundwater is designated as a Non-Potential Drinking Water source are based on MADEP Policy, groundwater is not used as drinking water, then drinking water exposure pathway is not complete.	Information regarding land size and use at Landfill and surrounding areas.
Evaluate complete exposure pathway to McPherson well	Groundwater plume is not contributing significantly to McPherson well	If refined groundwater modeling confirms that groundwater plume is not contributing to McPherson well, then exposure pathway is not complete.	Refined groundwater modeling
Evaluate whether the discharge of contaminated groundwater affected by the landfill to Nonacoicus Brook could represent an exposure pathway relevant to human health	Groundwater plume is not contributing significant As to Nonacoicus Brook relative to background.	If upstream surface water or sediment show elevated concentrations of As, then Brook concentrations affected by local conditions	Upstream surface water and sediment data, piezometer data

Table 3-6
Framework for Filling Data Gaps Related to Risk Assessment
Data Gaps Analysis Report
Shepley's Hill Landfill

Objective	Hypothesis	Preliminary Decision Rule	Data Needs
Evaluate whether the discharge of contaminated groundwater affected by the landfill to Nonacoicus Brook could represent an exposure pathway relevant to both human health and the ecosystem.	Groundwater plume is not contributing significant As to sediment or surface water As concentrations relative to background.	If upstream surface water or sediment show elevated concentrations of As, then brook concentrations affected by local conditions.	Refined groundwater modeling
		If groundwater plume modeling shows that the plume does not reach, or goes under, Nonacoicus Brook, then plume is not contributing to sediment or surface water As concentrations	Refined groundwater plume delineation and modeling
Evaluate whether the discharge of contaminated groundwater affected by the landfill to Plow Shop Pond could represent an exposure pathway relevant to human health and the ecosystem.	Groundwater plume is not contributing significantly to Red Cove sediment or surface water As concentrations	If new data and/or refined groundwater plume modeling shows that the plume does not reach Red Cove, then pathway is not complete	Flux data from EPA study; refined groundwater modeling

Table 3-7
Framework for Filling Data Gaps Related to CAAA
Data Gaps Analysis Report
Shepley's Hill Landfill

Objective	Hypothesis	Preliminary Decision Rule	Data Needs
Evaluate whether alternative remedial actions are necessary to eliminate unacceptable risks to human health or the environment.	Existing pump and treat system effectively limits migration to off-site receptors.	If pump and treat system effectively addresses risks, then no further remedial action is warranted.	Reports on start-up and subsequent operation, maintenance and monitoring.
	Sediments in Red Cove cause toxicity in bioassays.	If toxicity has significant effect on ecosystem, then remediation may be needed.	See Table 3-6.

Table 4-1
Data to be Collected to Satisfy Project Objectives
Data Gaps Analysis Report
Shepley's Hill Landfill

Objectives	Report Section and Type of Data Collection: 4.1 Landfill Cover Reconnaissance and Test Pit Survey	4.2 Borings, Profiles, and Wells	4.3 Surface Water and Sediment Sampling	4.4 Geophysical Studies	Data to be Collected by Others
Evaluation of the plume to determine whether the plume is impacting the wetlands and the potential magnitude of that impact, if any.		♦	♦		♦
Determination of any impact to the McPherson water supply well and the magnitude of such impact, if any.		♦			
Evaluation of landfill cap integrity and its effectiveness at minimizing surface/ groundwater intrusion and leachate generation.	♦			♦	♦
Assessment of Red Cove as an area of historic and possibly current leachate discharge.			♦		♦
Assessment of landfill gas issues and the non-vegetated cap areas along the southeast portion of the Landfill.					♦

Table 5-1
Summary of Data Gaps Closure Strategy
Data Gaps Analysis Report
Shepley's Hill Landfill

ISSUE	EXISTING DATA	DATA GAP(S)	DATA GAP "NEEDS"	PURPOSE	OUTCOME
1. Evaluate magnitude of plume impact to Nonacoicus Brook and wetlands, if any	• Existing wells, GW sample results from existing proximal wells • GW head data from wells	• Downgradient extent of plume undefined. • GW/SW interaction unclear. • Is stream/wetland a hydraulic barrier? • Are contaminants reaching wetlands, and if so, at what concentrations?	• Install wells and piezometers and collect key GW, SW and sediment samples. • Determine key SW and GW elevations. • Gauge upgradient/downgradient streamflows.	• Delineate plume at all critical margins, especially toward the wetlands. • Determine contaminant concentrations in the GW and SW at wetlands. • Support concept that stream/wetland is a hydraulic barrier. • Make appropriate GW model adjustments • Provide input for risk assessments.	Achieve adequate delineation of plume boundary and contaminant concentrations in wetlands attributable to Shepley's Hill Landfill to be used to complete the human health and ecological risk assessment for the CSA.
2. Evaluate potential for impact to McPherson water supply well.	• GW head data from existing wells in vicinity of currently defined plume. • Historic pumping rates of well. • Location of mapped Zone IIs	• Undefined plume boundary on NW side of plume. • Effectiveness of Willow Brook as hydraulic barrier. • Likelihood of plume reaching Zone II of well in future.	• Selected elements from #1 above. • Review/confirm derivation of Zone IIs. • Use refined groundwater model to determine if (and at what concentrations) contaminants could reach the well.	• Determine western plume boundary downgradient of SHL • Develop relevant information to confirm potential for contaminants to reach well.	Decision whether GW contamination is currently or could in the future impact McPherson Well and potential extent, if any, to complete the human health risk assessment for the CSA.
3. Evaluate landfill cap integrity and effectiveness at minimizing surface/groundwater intrusion and leachate generation.	• As-built and annual cap condition reports • Existing topo surveys • Site inspection reports.	• Accurate geographic extent of cap • Detailed inspection of cover and PVC condition • Cap tie-in to bedrock	• Test pits for direct liner-cover inspection, cap edge inspection and evidence of potential underflow. • Geophysical surveys for guiding test pit location, depth to bedrock, and potentially waste thickness.	• Determine if cap function is compromised due to subsidence. • Improved representation of cap and underflow process in GW model	Confirm significance of cap infiltration to GW and identify recommendations for mitigating any significant deficiencies.
4. Assess Red Cove as an area of historic and possibly current leachate discharge	• GW sample results from existing wells • GW head data	• Vertical hydraulic gradients • GW-to-SW flow. • Contaminant flux to Red Cove	• Compliment planned EPA studies at Red Cove • Analysis of hydraulic data from nested piezometers • Collect sediment core samples to estimate vertical hydraulic conductivity, gradients, and groundwater flow	GW discharge rate will be used to estimate the present contaminant flux to Red Cove and calibrate model representation of this process.	Determine Shepley's Hill Landfill contribution to historic (pre-capping), current, and future surface water and sediment contribution to complete the ecological risk assessment for the CSA.
5. Assess landfill gas issues and the non-vegetated cap areas along the southeast portion of the Landfill.	• Annual landfill gas sampling results. • Annual inspection reports.	• Results of proposed gas probe sampling along the northern edge. • Cause of lack of vegetation.	• Data from proposed gas probe sampling will be thoroughly reviewed relative to cap integrity or risk assessment. • Non-vegetated cap areas will be specifically inspected, and their significance relative to cap integrity will be assessed.	• Define potential for significant gas migration toward potential receptors. • To evaluate the integrity of the Shepley's Hill Landfill cap.	Confirm that gas migration is not a significant concern.
6. Human and Ecological Risk Assessment	• GW-1 and Zone II delineations • GW and SW sample results • Evaluate predicted GW fluxes from USEPA results due in January 2006	• Demonstration of complete exposure pathways for evaluating potential effects to people and to ecological receptors. • Improved confidence in GW model	• Elements of all preceding issues • Evaluate USEPA results due in January 2006 and decide whether to collect additional GW, SW, or sediment samples to fill new data gaps, if any. • As speciation. • Presence of domestic wells.	• Quantification of risk levels under present site conditions for human and ecological receptors	• Determination of acceptable/ unacceptable risk levels under present site conditions for human and ecological receptors • Recommendation for mitigating unacceptable risks
7. Complete CSA and CAAA Reports.	All of the above	All of the above	• Collect, evaluate and complete the site investigation; assess the landfill cap; and assess potential effects on human health and ecological receptors. • Collect pertinent geologic and hydraulic data to evaluate engineering feasibility of select alternatives.	• Define project objectives, decisions and data requirements. • Establish data quality objectives and analyze data gaps.	A protectiveness determination of the remedy for SHL was deferred in the 2005 Five Year Review until further information is obtained through the completion of the CSA and CAAA. The CSA and CAAA reports will meet a critical milestone obligation set forth in the 2005 Five Year Review.

Abbreviations: SHL = Shepley's Hill Landfill, GW = groundwater, SW = surface water

Appendix A

Document Inventory

Appendix A
Document Inventory

File number	Document Title	Author	Date
SHL-0001	Final Remedial Investigation Addendum Report Data Item A009 / Volume 1 Report Text	ABB Environmental	12/01/1993
SHL-0002	Final Remedial Investigation Addendum Report Data Item A009 / Volume 2 Appendices A - G	ABB Environmental	12/01/1993
SHL-0003	Final Remedial Investigation Addendum Report Data Item A009 / Volume 3 Appendices H	ABB Environmental	12/01/1993
SHL-0004	Final Remedial Investigation Addendum Report Data Item A009 / Volume 4 Appendices I - Z	ABB Environmental	12/01/1993
SHL-0005	Final Feasibility Study Shepley's Hill Landfill Operable Unit Data Item A009	ABB Environmental	02/01/1995
SHL-0006	Record of Decision Shepley's Hill Landfill Operable Unit Areas of Contamination 4,5 and 18	ABB Environmental	09/01/1995
SHL-0007	Final Work Plan Supplemental Groundwater Investigation at Shepley's Hill Landfill and Response to Comment Letter	Harding ESE	02/01/1999
SHL-0008	Revised Draft Shepley's Hill Landfill Supplemental Groundwater Investigation (Volume 1) text, figs and tables	Harding ESE	02/01/2002
SHL-0009	Revised Draft Shepley's Hill Landfill Supplemental Groundwater Investigation (Volume 2) Appendices	Harding ESE	02/01/2002
SHL-0010	Letter; Army is proceeding with implementation of modified SHL-9 as the final remedial action in conjunction with SHL-2	Ryan, Glynn / Chief BRAC- Atlanta	09/30/2004
SHL-0011	MADEP Issues for BCT Mtg. Dec 2, 2004; Shepley's Hill Landfill Pump and Treat	not named	12/02/2004
SHL-0012	EPA Technical Review Comments on the Draft Performance Monitoring Plan GW Extraction, Treatment and Discharge Project	EPA	01/13/2005
SHL-0013	MADEP (Lynne Welsh) Comments on the PWS for SHL CSA/CAAA	Welsh, L.	03/11/2005
SHL-0014	Leachate Mulumco Road / Brian Duval and David Salvador performed recon of Nonacoiecus Brook - collected sample leachate	Duval, D. / MADEP	10/12/2004
SHL-0015	SHL - Big Picture; Unresolved issues realted to the SHL GW Extraction, Treatment, and Discharge Contingency Remedy	Olson, Bryan / EPA	11/22/2004
SHL-0016	EPA comments (Lombardo, G) on Shepley's Performance-Based SOW for CSA	Lombardo, J. / EPA	02/23/2005
SHL-0017	MADEP (Lynne Welsh) comments on the Draft Explanation of Significant Differences Groundwater Extraction, Treatment, and Discharge Contingency Remedy of SHL dated February 2004	Welsh, L.	03/30/2005
SHL-0018	MADEP (Martin Suuberg) requests that EPA (Carol Keating) amend the Record of Decision for SHL Area of Contaminatin 4,5 and 18	Suuberg, M.	08/23/2004
SHL-0019	MADEP Sanitary Landfill Inspection Summary for Landfill Closure (handwritten doc)		08/11/2004
SHL-0020	MADEP (Lynne Welsh) to EPA (Carol Keating) Advisory letter for SHL to advise on the adequacies of the cap for SHL	Welsh, L.	07/07/2004
SHL-0021	PACE (People of Ayer Concerned About the Environment) to Benjamin Goff (BRAC) urge Army to implement MADEP recommendations	Creary, Carolyn., Doherty, Richard	09/09/2004
SHL-0022	EPA (Carol Keating) comments and recommendations on the Draft Statement of Work - SHL dated January 23, 2003	Keating, C.	07/24/2003
SHL-0023	BRAC (Benjamin Goff) response to EPA (7/24/03) and DEP (4/25/03) comments on the SHL Statement of Work Supplemental GW Investigation and Human Health Risk Assessment.	Goff, Benjamin / BRAC Devens	10/27/2004
SKL-0024	USACE Response to Mass DEP 11 August 2004 Observations at SHL	HTRW/Geotechnical Engineering Branch	08/18/2004
SHL-0025	MADEP comments on the Statement of Work-Draft January 23, 2003 (e-mail Backunas, M.)	MADEP	06/24/2003
SHL-0026	Additional EPA Comments on the PWS for SHL	EPA	03/15/2005
SHL-0027	A set of 8 compact discs provided by USACE (Maryellen Iorio) to AMEC (Mark Applebee) containing historical documents relative to SHL	Iorio, Maryellen	04/20/2005
SHL-0028	LRPCD Project Description and Quality Assurance Plan / arsenic migration / Red Cove Study Area of Plow Shop Pond		06/08/2005
SHL-0029	Arsenic Transport Study Work Plan Ground Water, Surface Water, Soil and Sediment Investigation / Natural Attenuation Study Work Plan (NAS WP) / Red Cove Study Area of Plow Shop Pond / Transport of Arsenic in an Urban, Military Watershed	Scheckel, K., Ford, R.	06/08/2005
SHL-0030	Draft 2004 Annual Report Shepley's Hill Landfill Long Term Monitoring & Maintenance Devens, Massachusetts	Matthews, Erik /USACE	08/01/2005
SHL-0031	Five year site review for AOC's 4,5 and 18 / section 3 only	Iorio, Maryellen	08/17/2005
SHL-0032	Army Draft Plow Shop Pond and Grove Pond Sediment Evaluation Data Item A009 / Volume I Sections 1.0 - 8.0 and Volume II Appendices A-M	ABB Environmental Services	09/01/1995
SHL-0033	Draft Cap Drainage Report Shepley's Hill Landfill Devens RFTA	USACE New England District	01/01/2003
SHL-0034	Explanation of Significant Differences Groundwater Extraction, Treatment, and Discharge Contingency Remedy	CH2M Hill, Inc.	06/01/2005
SHL-0035	EPA (Ginny Lobardo) presentation June 9, 2005 Fort Devens Plow Shop and Grove Ponds	EPA/Lockheed Martin	06/09/2005
SHL-0035	Toxicity Testing Results Using Surface Water Samples from Grove, Plow Shop and Flannagan Ponds Fort Devens Superfund Site	Lockheed Martin Information Technologies	05/13/2005

Appendix B

Descriptive Statistics Report

Descriptive Statistics Report

Page	1
Database	C:\NCSS60\DATA\SHEPLEY2.S0
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Summary Section of Arsenic

Count	Mean	Standard Deviation	Standard Error	Minimum	Maximum	Range
16	433.7375	1027.17	256.7924	2.6	3950	3947.4

Counts Section of Arsenic

Rows	Sum of Frequencies	Missing Values	Distinct Values	Sum	Total Sum Squares	Adjusted Sum Squares
16	16	0	15	6939.8	1.883622E+07	1.582617E+07

Means Section of Arsenic

Parameter	Mean	Median	Geometric Mean	Harmonic Mean	Sum	Mode
Value	433.7375	56.05	57.55949	12.88857	6939.8	2.6
Std Error	256.7924				4108.679	
95% LCL	-113.6027	7.4			-1817.643	
95% UCL	981.0776	136			15697.24	
T-Value	1.6891					
Prob Level	0.111881					
Count	16		16	16		2

Variation Section of Arsenic

Parameter	Variance	Standard Deviation	Unbiased Std Dev	Std Error of Mean	Interquartile Range	Range
Value	1055078	1027.17	1044.42	256.7924	242.5	3947.4
Std Error	788829	543.0322		135.7581		
95% LCL	575740	758.7753		189.6938		
95% UCL	2527279	1589.742		397.4354		

Skewness and Kurtosis Section of Arsenic

Parameter	Skewness	Kurtosis	Fisher's g1	Fisher's g2	Coefficient of Variation	Coefficient of Dispersion
Value	2.840754	9.943689	3.143484	10.2233	2.368183	7.422391
Std Error	1.297528	8.361871			0.5860634	

Trimmed Section of Arsenic

Parameter	5% Trimmed	10% Trimmed	15% Trimmed	25% Trimmed	35% Trimmed	45% Trimmed
Trim-Mean	262.3417	154.0344	97.40357	54.37917		
Trim-Std Dev	632.642	321.0612	129.2981	23.21399		
Count	14	12	11	4		

Mean-Deviation Section of Arsenic

Parameter	|X-Mean|	|X-Median|	(X-Mean)^2	(X-Mean)^3	(X-Mean)^4
Average	605.0984	416.025	989135.4	2.794585E+09	9.728796E+12
Std Error	154.1976		739527.2	1.961223E+09	6.776048E+12

Descriptive Statistics Report

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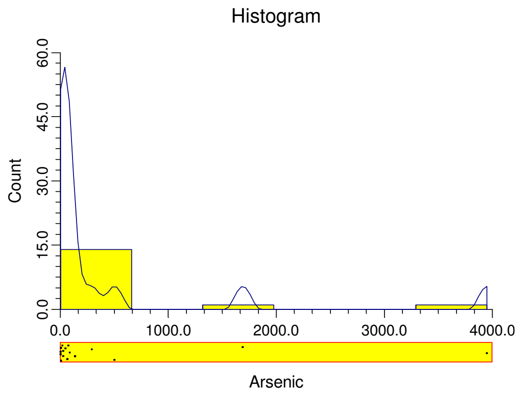
Quartile Section of Arsenic

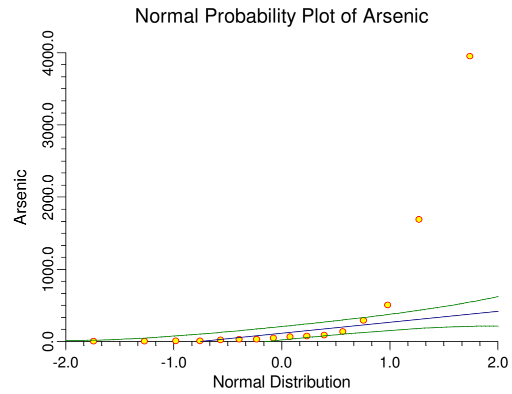
Parameter	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
Value	2.6	10.5	56.05	253	2368
95% LCL		2.6	7.4	65	
95% UCL		47.1	136	3950	

Normality Test Section of Arsenic

Test Name	Test Value	Prob Level	10% Critical Value	5% Critical Value	Decision (5%)
Martinez-Iglewicz	269.0403		1.267819	1.475586	Reject Normality
Kolmogorov-Smirnov	0.3673752		0.195	0.213	Reject Normality
D'Agostino Skewness	4.2694	0.000020	1.645	1.960	Reject Normality
D'Agostino Kurtosis	3.7109	0.000207	1.645	1.960	Reject Normality
D'Agostino Omnibus	31.9986	0.000000	4.605	5.991	Reject Normality

Plots Section of Arsenic





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Database	C:\NCSS60\DATA\SHEPLEY2.S0
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Percentile Section of Arsenic

Percentile	Value	95% LCL	95% UCL	Exact Conf. Level
99	3950			
95	3950			
90	2368			
85	1036.6			
80	418	65	3950	96.4849
75	253	65	3950	96.2847
70	131.21	47.1	3950	97.1003
65	90.495	27.8	1690	96.7381
60	77.62	27.2	502	96.2521
55	68.5	19.8	292	95.6935
50	56.05	7.4	136	95.0958
45	40.345	7.4	136	95.6935
40	27.68	7.2	88.1	96.2521
35	26.83	2.6	75	96.7381
30	20.54	2.6	65	97.1003
25	10.5	2.6	47.1	96.2847
20	7.28	2.6	47.1	96.4849
15	5.13			
10	2.6			
5	2.6			
1	2.6			

Percentile Formula: Ave X(p[n+1])

Stem-Leaf Plot Section of Arsenic

Depth	Stem	Leaves
8	0* |	00001224
8	. |	678
5	1* |	3
4	. |	
4	2* |	
4	. |	9
3	3* |	
3	. |	
3	4* |	
3	. |	
3	5* |	0
High	|	169, 395

Unit = 10   Example: 1 |2 Represents 120

Descriptive Statistics Report

Page	4
Database	C:\NCSS60\DATA\SHEPLEY2.S0
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Summary Section of Chloride

Count	Mean	Standard Deviation	Standard Error	Minimum	Maximum	Range
16	23037.5	18877.11	4719.277	1600	56700	55100

Counts Section of Chloride

Rows	Sum of Frequencies	Missing Values	Distinct Values	Sum	Total Sum Squares	Adjusted Sum Squares
16	16	0	15	368600	1.38368E+10	5.345178E+09

Means Section of Chloride

Parameter	Mean	Median	Geometric Mean	Harmonic Mean	Sum	Mode
Value	23037.5	24150	12355.26	5027.321	368600	1600
Std Error	4719.277				75508.43	
95% LCL	12978.6	1900			207657.6	
95% UCL	33096.4	34100			529542.4	
T-Value	4.8816					
Prob Level	0.000199					
Count	16		16	16		2

Variation Section of Chloride

Parameter	Variance	Standard Deviation	Unbiased Std Dev	Std Error of Mean	Interquartile Range	Range
Value	3.563452E+08	18877.11	19194.13	4719.277	37500	55100
Std Error	8.330891E+07	3120.621		780.1553		
95% LCL	1.944522E+08	13944.61		3486.153		
95% UCL	8.535708E+08	29215.93		7303.983		

Skewness and Kurtosis Section of Chloride

Parameter	Skewness	Kurtosis	Fisher's g1	Fisher's g2	Coefficient of Variation	Coefficient of Dispersion
Value	0.2935664	1.874503	0.3248508	-1.082427	0.8194078	0.6350932
Std Error	0.3522615	0.38402			0.1606722	

Trimmed Section of Chloride

Parameter	5% Trimmed	10% Trimmed	15% Trimmed	25% Trimmed	35% Trimmed	45% Trimmed
Trim-Mean	22358.33	21725	21296.43	22725		
Trim-Std Dev	17415.79	15805.71	14227.49	5401.194		
Count	14	12	11	4		

Mean-Deviation Section of Chloride

Parameter	|X-Mean|	|X-Median|	(X-Mean)^2	(X-Mean)^3	(X-Mean)^4
Average	15345.31	15337.5	3.340736E+08	1.792543E+12	2.092042E+17
Std Error	2833.81		7.81021E+07	2.199283E+12	7.105919E+16

Descriptive Statistics Report

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Time/Date 17:51:00 09-01-2005

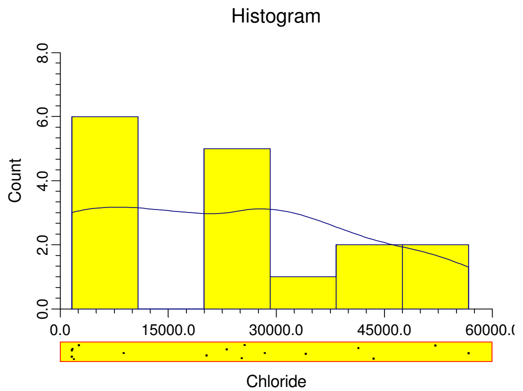
Quartile Section of Chloride

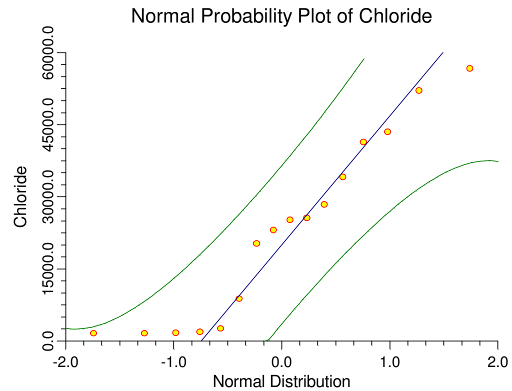
Parameter	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
Value	1600	2075	24150	39575	53480
95% LCL		1600	1900	25200	
95% UCL		23100	34100	56700	

Normality Test Section of Chloride

Test Name	Test Value	Prob Level	10% Critical Value	5% Critical Value	Decision (5%)
Martinez-Iglewicz	1.003392		1.267819	1.475586	Accept Normality
Kolmogorov-Smirnov	0.1730205		0.195	0.213	Accept Normality
D'Agostino Skewness	0.6057	0.544694	1.645	1.960	Accept Normality
D'Agostino Kurtosis	-1.2132	0.225062	1.645	1.960	Accept Normality
D'Agostino Omnibus	1.8387	0.398777	4.605	5.991	Accept Normality

Plots Section of Chloride





Descriptive Statistics Report

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Database	C:\NCSS60\DATA\SHEPLEY2.S0
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Percentile Section of Chloride

Percentile	Value	95% LCL	95% UCL	Exact Conf. Level
99	56700			
95	56700			
90	53480			
85	47370			
80	42660	25200	56700	96.4849
75	39575	25200	56700	96.2847
70	33530	23100	56700	97.1003
65	28685	20300	52100	96.7381
60	26160	8800	43500	96.2521
55	25340	2600	41400	95.6935
50	24150	1900	34100	95.0958
45	22120	1900	34100	95.6935
40	18000	1700	28400	96.2521
35	8490	1600	25600	96.7381
30	3220	1600	25200	97.1003
25	2075	1600	23100	96.2847
20	1780	1600	23100	96.4849
15	1655			
10	1600			
5	1600			
1	1600			

Percentile Formula: Ave X(p[n+1])

Stem-Leaf Plot Section of Chloride

Depth	Stem	Leaves
5	0* |	11112
6	. |	8
6	1* |	
6	. |	
8	2* |	03
8	. |	558
5	3* |	4
4	. |	
4	4* |	13
2	. |	
2	5* |	2
1	. |	6

Unit = 1000   Example: 1 |2 Represents 12000

Descriptive Statistics Report

Page	7
Database	C:\NCSS60\DATA\SHEPLEY2.S0
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Summary Section of Iron

Count	Mean	Standard Deviation	Standard Error	Minimum	Maximum	Range
16	21017.61	25650.18	6412.545	19.2	71100	71080.8

Counts Section of Iron

Rows	Sum of Frequencies	Missing Values	Distinct Values	Sum	Total Sum Squares	Adjusted Sum Squares
16	16	0	16	336281.8	1.693682E+10	9.868975E+09

Means Section of Iron

Parameter	Mean	Median	Geometric Mean	Harmonic Mean	Sum	Mode
Value	21017.61	5660	3470.312	131.9943	336281.8	19.2
Std Error	6412.545				102600.7	
95% LCL	7349.597	541			117593.5	
95% UCL	34685.63	39000			554970.1	
T-Value	3.2776					
Prob Level	0.005087					
Count	16		16	16		1

Variation Section of Iron

Parameter	Variance	Standard Deviation	Unbiased Std Dev	Std Error of Mean	Interquartile Range	Range
Value	6.579317E+08	25650.18	26080.94	6412.545	43891.75	71080.8
Std Error	1.711712E+08	4718.732		1179.683		
95% LCL	3.590234E+08	18947.91		4736.978		
95% UCL	1.575975E+09	39698.56		9924.64		

Skewness and Kurtosis Section of Iron

Parameter	Skewness	Kurtosis	Fisher's g1	Fisher's g2	Coefficient of Variation	Coefficient of Dispersion
Value	0.8278055	2.082978	0.916022	-0.7903324	1.220414	3.415174
Std Error	0.503711	0.9334045			0.2532323	

Trimmed Section of Iron

Parameter	5% Trimmed	10% Trimmed	15% Trimmed	25% Trimmed	35% Trimmed	45% Trimmed
Trim-Mean	19401.84	17878.48	16144.64	8477.083		
Trim-Std Dev	23613.87	21773.21	19518.67	7518.895		
Count	14	12	11	4		

Mean-Deviation Section of Iron

Parameter	|X-Mean|	|X-Median|	(X-Mean)^2	(X-Mean)^3	(X-Mean)^4
Average	22199.29	19329.89	6.168109E+08	1.268109E+13	7.924811E+17
Std Error	3850.575		1.60473E+08	5.555842E+12	2.576838E+17

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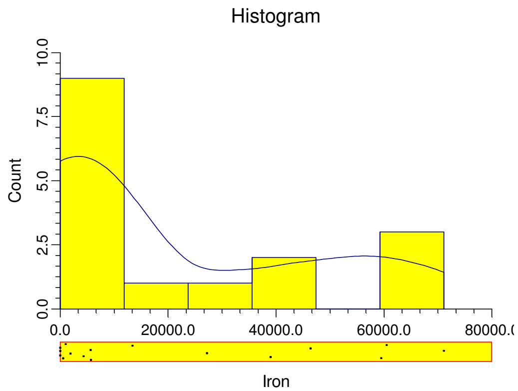
Quartile Section of Iron

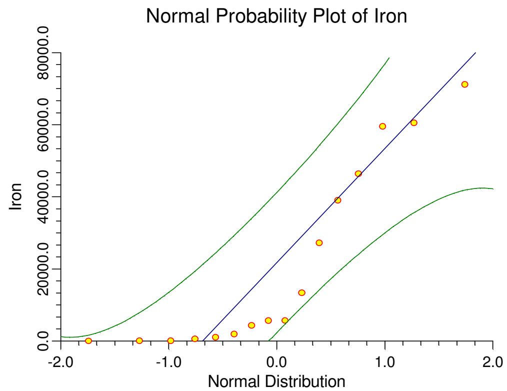
Parameter	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
Value	26.76	658.25	5660	44550	63680
95% LCL		19.2	541	5680	
95% UCL		5640	39000	71100	

Normality Test Section of Iron

Test Name	Test Value	Prob Level	10% Critical Value	5% Critical Value	Decision (5%)
Martinez-Iglewicz	6.728159		1.267819	1.475586	Reject Normality
Kolmogorov-Smirnov	0.2875645		0.195	0.213	Reject Normality
D'Agostino Skewness	1.6358	0.101875	1.645	1.960	Accept Normality
D'Agostino Kurtosis	-0.7326	0.463804	1.645	1.960	Accept Normality
D'Agostino Omnibus	3.2126	0.200625	4.605	5.991	Accept Normality

Plots Section of Iron





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Database	C:\NCSS60\DATA\SHEPLEY2.S0
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Percentile Section of Iron

Percentile	Value	95% LCL	95% UCL	Exact Conf. Level
99	71100			
95	71100			
90	63680			
85	59950			
80	54260	5680	71100	96.4849
75	44550	5680	71100	96.2847
70	37820	5640	71100	97.1003
65	27790	4330	60500	96.7381
60	16160	1900	59500	96.2521
55	8382	1010	46400	95.6935
50	5660	541	39000	95.0958
45	5181.5	541	39000	95.6935
40	3844	31.6	27200	96.2521
35	1855.5	30	13400	96.7381
30	1099	19.2	5680	97.1003
25	658.25	19.2	5640	96.2847
20	235.36	19.2	5640	96.4849
15	30.88			
10	26.76			
5	19.2			
1	19.2			

Percentile Formula: Ave X(p[n+1])

Stem-Leaf Plot Section of Iron

Depth	Stem	Leaves
(9)	0 |	000011455
7	1 |	3
6	2 |	7
5	3 |	9
4	4 |	6
3	5 |	9
2	6 |	0
1	7 |	1

Unit = 1000   Example: 1 |2 Represents 12000

Descriptive Statistics Report

Page	10
Database	C:\NCSS60\DATA\SHEPLEY2.S0
Time/Date	17:51:00 09-01-2005

Summary Section of Manganese

Count	Mean	Standard Deviation	Standard Error	Minimum	Maximum	Range
16	2271.6	2752.701	688.1753	1.9	8910	8908.1

Counts Section of Manganese

Rows	Sum of Frequencies	Missing Values	Distinct Values	Sum	Total Sum Squares	Adjusted Sum Squares
16	16	0	15	36345.6	1.962231E+08	1.136605E+08

Means Section of Manganese

Parameter	Mean	Median	Geometric Mean	Harmonic Mean	Sum	Mode
Value	2271.6	1183	545.7094	14.54448	36345.6	1.9
Std Error	688.1753				11010.8	
95% LCL	804.7891	332			12876.63	
95% UCL	3738.411	2340			59814.57	
T-Value	3.3009					
Prob Level	0.004850					
Count	16		16	16		2

Variation Section of Manganese

Parameter	Variance	Standard Deviation	Unbiased Std Dev	Std Error of Mean	Interquartile Range	Range
Value	7577364	2752.701	2798.93	688.1753	3221.5	8908.1
Std Error	2903865	745.9372		186.4843		
95% LCL	4134853	2033.434		508.3585		
95% UCL	1.815042E+07	4260.332		1065.083		

Skewness and Kurtosis Section of Manganese

Parameter	Skewness	Kurtosis	Fisher's g1	Fisher's g2	Coefficient of Variation	Coefficient of Dispersion
Value	1.26583	3.349829	1.400726	0.9846512	1.21179	1.632206
Std Error	0.559562	1.750207			0.2096481	

Trimmed Section of Manganese

Parameter	5% Trimmed	10% Trimmed	15% Trimmed	25% Trimmed	35% Trimmed	45% Trimmed
Trim-Mean	2028.894	1835.669	1634.275	1264		
Trim-Std Dev	2341.009	2014.417	1643.605	619.9552		
Count	14	12	11	4		

Mean-Deviation Section of Manganese

Parameter	|X-Mean|	|X-Median|	(X-Mean)^2	(X-Mean)^3	(X-Mean)^4
Average	2100.25	1930.9	7103779	2.396678E+10	1.690447E+14
Std Error	413.2324		2722373	9.767759E+09	7.981055E+13

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Quartile Section of Manganese

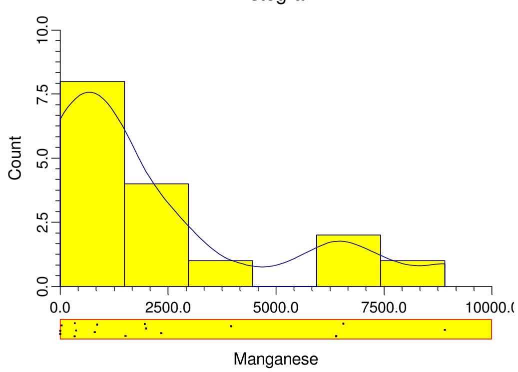
Parameter	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
Value	1.9	333.5	1183	3555	7265
95% LCL		1.9	332	1510	
95% UCL		856	2340	8910	

Normality Test Section of Manganese

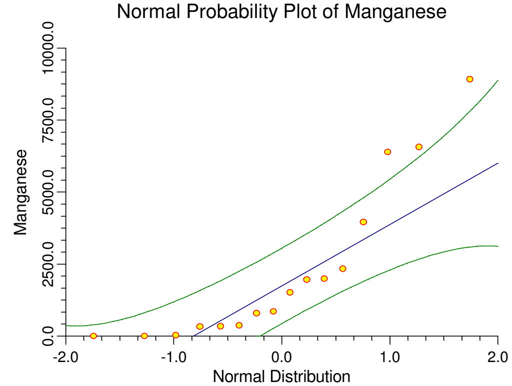
Test Name	Test Value	Prob Level	10% Critical Value	5% Critical Value	Decision (5%)
Martinez-Iglewicz	2.321127		1.267819	1.475586	Reject Normality
Kolmogorov-Smirnov	0.240088		0.195	0.213	Reject Normality
D'Agostino Skewness	2.3700	0.017790	1.645	1.960	Reject Normality
D'Agostino Kurtosis	1.0355	0.300432	1.645	1.960	Accept Normality
D'Agostino Omnibus	6.6890	0.035278	4.605	5.991	Reject Normality

Plots Section of Manganese

Histogram



Normal Probability Plot of Manganese



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Percentile Section of Manganese

Percentile	Value	95% LCL	95% UCL	Exact Conf. Level
99	8910			
95	8910			
90	7265			
85	6466.5			
80	5418	1510	8910	96.4849
75	3555	1510	8910	96.2847
70	2305	856	8910	97.1003
65	2007.5	798	6560	96.7381
60	1966	368	6390	96.2521
55	1667.5	338	3960	95.6935
50	1183	332	2340	95.0958
45	835.7	332	2340	95.6935
40	712	29.8	1990	96.2521
35	366.5	1.9	1960	96.7381
30	341	1.9	1510	97.1003
25	333.5	1.9	856	96.2847
20	150.68	1.9	856	96.4849
15	17.245			
10	1.9			
5	1.9			
1	1.9			

Percentile Formula: Ave X(p[n+1])

Stem-Leaf Plot Section of Manganese

Depth	Stem	Leaves
8	0 |	00033378
8	1 |	599
5	2 |	3
4	3 |	9
3	4 |	
3	5 |	
3	6 |	35
1	7 |	
1	8 |	9

Unit = 100   Example: 1 |2 Represents 1200

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Summary Section of ORP

Count	Mean	Standard Deviation	Standard Error	Minimum	Maximum	Range
16	46.375	156.4612	39.11531	-143	378	521

Counts Section of ORP

Rows	Sum of Frequencies	Missing Values	Distinct Values	Sum	Total Sum Squares	Adjusted Sum Squares
16	16	0	16	742	401612	367201.8

Means Section of ORP

Parameter	Mean	Median	Geometric Mean	Harmonic Mean	Sum	Mode
Value	46.375	-21.5	148.3244	-119.1049	742	-143
Std Error	39.11531				625.8449	
95% LCL	-36.9973	-85			-591.9568	
95% UCL	129.7473	133			2075.957	
T-Value	1.1856					
Prob Level	0.254224					
Count	16		7	16		1

Variation Section of ORP

Parameter	Variance	Standard Deviation	Unbiased Std Dev	Std Error of Mean	Interquartile Range	Range
Value	24480.12	156.4612	159.0888	39.11531	252.75	521
Std Error	7378.129	33.34452		8.336131		
95% LCL	13358.43	115.5787		28.89467		
95% UCL	58638.4	242.1537		60.53842		

Skewness and Kurtosis Section of ORP

Parameter	Skewness	Kurtosis	Fisher's g1	Fisher's g2	Coefficient of Variation	Coefficient of Dispersion
Value	0.760092	2.453401	0.8410924	-0.2713332	3.373827	-5.552326
Std Error	0.422878	0.8594733			2.466538	

Trimmed Section of ORP

Parameter	5% Trimmed	10% Trimmed	15% Trimmed	25% Trimmed	35% Trimmed	45% Trimmed
Trim-Mean	38.47222	30.75	25.07143	-4.416667		
Trim-Std Dev	136.489	117.0907	101.1231	47.58474		
Count	14	12	11	4		

Mean-Deviation Section of ORP

Parameter	|X-Mean|	|X-Median|	(X-Mean)^2	(X-Mean)^3	(X-Mean)^4
Average	130.7188	119.375	22950.11	2642672	1.292225E+09
Std Error	23.48778		6916.997	1428870	5.648052E+08

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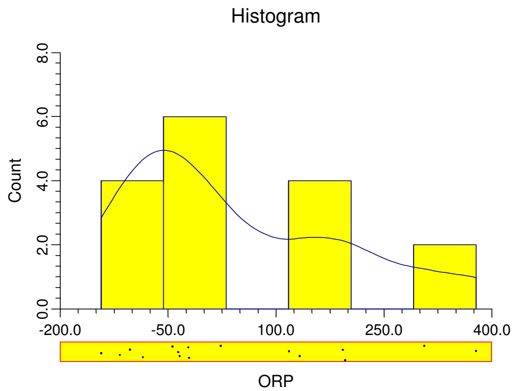
Quartile Section of ORP

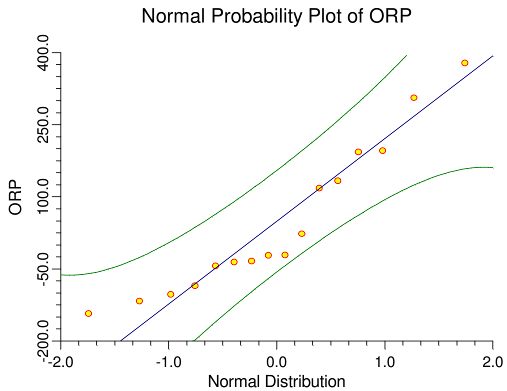
Parameter	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
Value	-124.8	-74.75	-21.5	178	327.6
95% LCL		-143	-85	-21	
95% UCL		-22	133	378	

Normality Test Section of ORP

Test Name	Test Value	Prob Level	10% Critical Value	5% Critical Value	Decision (5%)
Martinez-Iglewicz	1.156006		1.267819	1.475586	Accept Normality
Kolmogorov-Smirnov	0.2291269		0.195	0.213	Reject Normality
D'Agostino Skewness	1.5129	0.130314	1.645	1.960	Accept Normality
D'Agostino Kurtosis	-0.0590	0.952922	1.645	1.960	Accept Normality
D'Agostino Omnibus	2.2922	0.317867	4.605	5.991	Accept Normality

Plots Section of ORP





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Percentile Section of ORP

Percentile	Value	95% LCL	95% UCL	Exact Conf. Level
99	378			
95	378			
90	327.6			
85	245.5			
80	194.8	-21	378	96.4849
75	178	-21	378	96.2847
70	131.5	-22	378	97.1003
65	118.75	-34	306	96.7381
60	42	-36	196	96.2521
55	-5.6	-44	193	95.6935
50	-21.5	-85	133	95.0958
45	-26.2	-85	133	95.6935
40	-34.4	-103	118	96.2521
35	-36.4	-117	23	96.7381
30	-43.2	-143	-21	97.1003
25	-74.75	-143	-22	96.2847
20	-95.8	-143	-22	96.4849
15	-109.3			
10	-124.8			
5	-143			
1	-143			

Percentile Formula: Ave X(p[n+1])

Stem-Leaf Plot Section of ORP

Depth	Stem	Leaves
3	-1* |	410
4	. |	8
(5)	-0* |	43322
7	0* |	2
6	. |	
6	1* |	13
4	. |	99
2	2* |	
2	. |	
2	3* |	0
1	. |	7

Unit = 10   Example: 1 |2 Represents 120

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Summary Section of Sodium

Count	Mean	Standard Deviation	Standard Error	Minimum	Maximum	Range
16	19505	18093.49	4523.372	1020	56900	55880

Counts Section of Sodium

Rows	Sum of Frequencies	Missing Values	Distinct Values	Sum	Total Sum Squares	Adjusted Sum Squares
16	16	0	16	312080	1.099773E+10	4.910614E+09

Means Section of Sodium

Parameter	Mean	Median	Geometric Mean	Harmonic Mean	Sum	Mode
Value	19505	15150	9727.929	3899.144	312080	1020
Std Error	4523.372				72373.95	
95% LCL	9863.661	2040			157818.6	
95% UCL	29146.34	31000			466341.4	
T-Value	4.3120					
Prob Level	0.000617					
Count	16		16	16		1

Variation Section of Sodium

Parameter	Variance	Standard Deviation	Unbiased Std Dev	Std Error of Mean	Interquartile Range	Range
Value	3.273743E+08	18093.49	18397.35	4523.372	30620	55880
Std Error	8.750149E+07	3419.622		854.9056		
95% LCL	1.786432E+08	13365.75		3341.437		
95% UCL	7.841754E+08	28003.13		7000.783		

Skewness and Kurtosis Section of Sodium

Parameter	Skewness	Kurtosis	Fisher's g1	Fisher's g2	Coefficient of Variation	Coefficient of Dispersion
Value	0.5950486	2.143041	0.658461	-0.7061791	0.9276333	0.980693
Std Error	0.4112097	0.6167254			0.1732377	

Trimmed Section of Sodium

Parameter	5% Trimmed	10% Trimmed	15% Trimmed	25% Trimmed	35% Trimmed	45% Trimmed
Trim-Mean	18454.45	17692.5	17052.86	15751.25		
Trim-Std Dev	16167.63	14646.37	13272.47	7623.619		
Count	14	12	11	4		

Mean-Deviation Section of Sodium

Parameter	|X-Mean|	|X-Median|	(X-Mean)^2	(X-Mean)^3	(X-Mean)^4
Average	15395.63	14857.5	3.069134E+08	3.199457E+12	2.018655E+17
Std Error	2716.174		8.203265E+07	2.296007E+12	9.329179E+16

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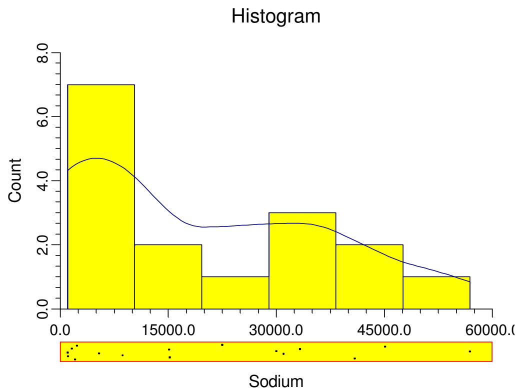
Quartile Section of Sodium

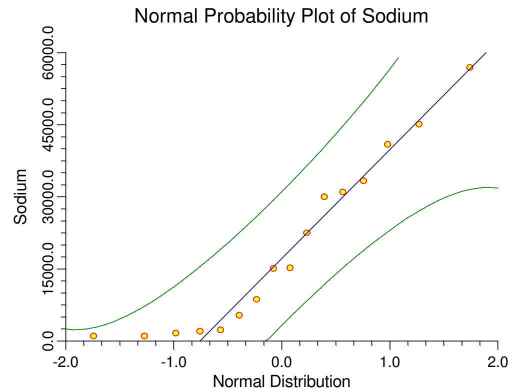
Parameter	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
Value	1048	2105	15150	32725	48640
95% LCL		1020	2040	15200	
95% UCL		15100	31000	56900	

Normality Test Section of Sodium

Test Name	Test Value	Prob Level	10% Critical Value	5% Critical Value	Decision (5%)
Martinez-Iglewicz	1.036541		1.267819	1.475586	Accept Normality
Kolmogorov-Smirnov	0.1632268		0.195	0.213	Accept Normality
D'Agostino Skewness	1.2031	0.228934	1.645	1.960	Accept Normality
D'Agostino Kurtosis	-0.6097	0.542047	1.645	1.960	Accept Normality
D'Agostino Omnibus	1.8192	0.402679	4.605	5.991	Accept Normality

Plots Section of Sodium





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Percentile Section of Sodium

Percentile	Value	95% LCL	95% UCL	Exact Conf. Level
99	56900			
95	56900			
90	48640			
85	42790			
80	37860	15200	56900	96.4849
75	32725	15200	56900	96.2847
70	30900	15100	56900	97.1003
65	30050	8650	45100	96.7381
60	24000	5390	40900	96.2521
55	17755	2300	33300	95.6935
50	15150	2040	31000	95.0958
45	12842.5	2040	31000	95.6935
40	7998	1620	30000	96.2521
35	5235.5	1060	22500	96.7381
30	2609	1020	15200	97.1003
25	2105	1020	15100	96.2847
20	1788	1020	15100	96.4849
15	1368			
10	1048			
5	1020			
1	1020			

Percentile Formula: Ave X(p[n+1])

Stem-Leaf Plot Section of Sodium

Depth	Stem	Leaves
5	0* |	11122
7	. |	58
7	1* |	
(2)	. |	55
7	2* |	2
6	. |	
6	3* |	013
3	. |	
3	4* |	0
2	. |	5
1	5* |	
1	. |	6

Unit = 1000   Example: 1 |2 Represents 12000

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Summary Section of Sp. Cond.

Count	Mean	Standard Deviation	Standard Error	Minimum	Maximum	Range
16	473.9375	348.7602	87.19005	26	1004	978

Counts Section of Sp. Cond.

Rows	Sum of Frequencies	Missing Values	Distinct Values	Sum	Total Sum Squares	Adjusted Sum Squares
16	16	0	16	7583	5418373	1824505

Means Section of Sp. Cond.

Parameter	Mean	Median	Geometric Mean	Harmonic Mean	Sum	Mode
Value	473.9375	449.5	297.7835	139.0693	7583	26
Std Error	87.19005				1395.041	
95% LCL	288.0963	138			4609.541	
95% UCL	659.7787	769			10556.46	
T-Value	5.4357					
Prob Level	0.000069					
Count	16		16	16		1

Variation Section of Sp. Cond.

Parameter	Variance	Standard Deviation	Unbiased Std Dev	Std Error of Mean	Interquartile Range	Range
Value	121633.7	348.7602	354.6172	87.19005	662.5	978
Std Error	22202.61	45.0155		11.25387		
95% LCL	66373.65	257.6308		64.40771		
95% UCL	291355	539.7731		134.9433		

Skewness and Kurtosis Section of Sp. Cond.

Parameter	Skewness	Kurtosis	Fisher's g1	Fisher's g2	Coefficient of Variation	Coefficient of Dispersion
Value	8.998149E-02	1.533114	9.957051E-02	-1.560746	0.735878	0.6628198
Std Error	0.3923791	0.2238843			0.1397245	

Trimmed Section of Sp. Cond.

Parameter	5% Trimmed	10% Trimmed	15% Trimmed	25% Trimmed	35% Trimmed	45% Trimmed
Trim-Mean	469.375	465.8281	462.9821	465.9583		
Trim-Std Dev	327.6913	304.5305	279.5467	146.0287		
Count	14	12	11	4		

Mean-Deviation Section of Sp. Cond.

Parameter	|X-Mean|	|X-Median|	(X-Mean)^2	(X-Mean)^3	(X-Mean)^4
Average	298.0547	297.9375	114031.6	3464901	1.993539E+10
Std Error	52.35548		20814.94	1.51161E+07	5.219257E+09

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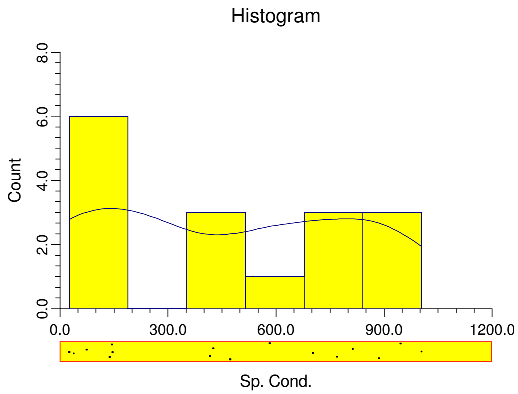
Quartile Section of Sp. Cond.

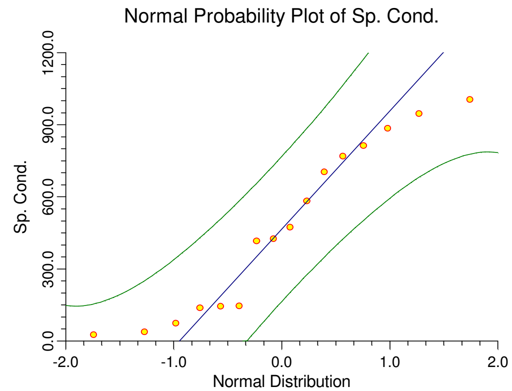
Parameter	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
Value	34.4	139.5	449.5	802	963.4
95% LCL		26	138	473	
95% UCL		426	769	1004	

Normality Test Section of Sp. Cond.

Test Name	Test Value	Prob Level	10% Critical Value	5% Critical Value	Decision (5%)
Martinez-Iglewicz	0.9798639		1.267819	1.475586	Accept Normality
Kolmogorov-Smirnov	0.2014669		0.195	0.213	Accept Normality
D'Agostino Skewness	0.1868	0.851793	1.645	1.960	Accept Normality
D'Agostino Kurtosis	-2.2600	0.023823	1.645	1.960	Reject Normality
D'Agostino Omnibus	5.1424	0.076445	4.605	5.991	Accept Normality

Plots Section of Sp. Cond.





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Percentile Section of Sp. Cond.

Percentile	Value	95% LCL	95% UCL	Exact Conf. Level
99	1004			
95	1004			
90	963.4			
85	912.45			
80	856.2	473	1004	96.4849
75	802	473	1004	96.2847
70	762.4	426	1004	97.1003
65	706.3	416	946	96.7381
60	606.2	146	885	96.2521
55	511.15	144	813	95.6935
50	449.5	138	769	95.0958
45	422.5	138	769	95.6935
40	362	74	703	96.2521
35	145.9	38	582	96.7381
30	144.2	26	473	97.1003
25	139.5	26	426	96.2847
20	99.6	26	426	96.4849
15	57.8			
10	34.4			
5	26			
1	26			

Percentile Formula: Ave X(p[n+1])

Stem-Leaf Plot Section of Sp. Cond.

Depth	Stem	Leaves
3	0 |	237
6	1 |	344
6	2 |	
6	3 |	
(3)	4 |	127
7	5 |	8
6	6 |	
6	7 |	06
4	8 |	18
2	9 |	4
1	10 |	0

Unit = 10   Example: 1 |2 Represents 120

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Summary Section of Sulfate

Count	Mean	Standard Deviation	Standard Error	Minimum	Maximum	Range
16	6503.75	5970.033	1492.508	860	22400	21540

Counts Section of Sulfate

Rows	Sum of Frequencies	Missing Values	Distinct Values	Sum	Total Sum Squares	Adjusted Sum Squares
16	16	0	15	104060	1.2114E+09	5.346194E+08

Means Section of Sulfate

Parameter	Mean	Median	Geometric Mean	Harmonic Mean	Sum	Mode
Value	6503.75	4450	4469.356	3090.886	104060	6400
Std Error	1492.508				23880.13	
95% LCL	3322.544	2000			53160.71	
95% UCL	9684.956	6400			154959.3	
T-Value	4.3576					
Prob Level	0.000563					
Count	16		16	16		2

Variation Section of Sulfate

Parameter	Variance	Standard Deviation	Unbiased Std Dev	Std Error of Mean	Interquartile Range	Range
Value	3.564129E+07	5970.033	6070.292	1492.508	8400	21540
Std Error	1.57709E+07	1867.948		466.987		
95% LCL	1.944891E+07	4410.092		1102.523		
95% UCL	8.53733E+07	9239.768		2309.942		

Skewness and Kurtosis Section of Sulfate

Parameter	Skewness	Kurtosis	Fisher's g1	Fisher's g2	Coefficient of Variation	Coefficient of Dispersion
Value	1.391099	4.132753	1.539344	2.081605	0.917937	0.9176967
Std Error	0.5292899	1.888225			0.1331682	

Trimmed Section of Sulfate

Parameter	5% Trimmed	10% Trimmed	15% Trimmed	25% Trimmed	35% Trimmed	45% Trimmed
Trim-Mean	5934.167	5557.813	5258.929	4558.333		
Trim-Std Dev	4749.812	3934.713	3361.943	1086.238		
Count	14	12	11	4		

Mean-Deviation Section of Sulfate

Parameter	|X-Mean|	|X-Median|	(X-Mean)^2	(X-Mean)^3	(X-Mean)^4
Average	4460.625	4083.75	3.341371E+07	2.68686E+11	4.61412E+15
Std Error	896.2145		1.478522E+07	1.532472E+11	2.878729E+15

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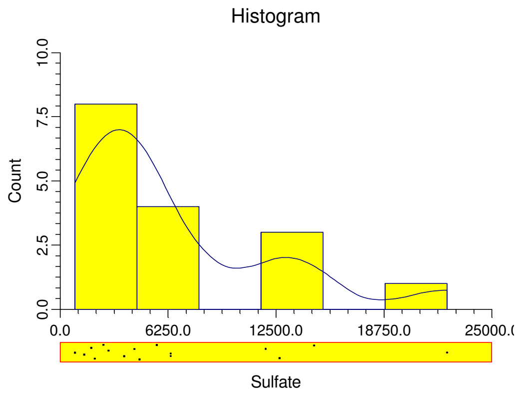
Quartile Section of Sulfate

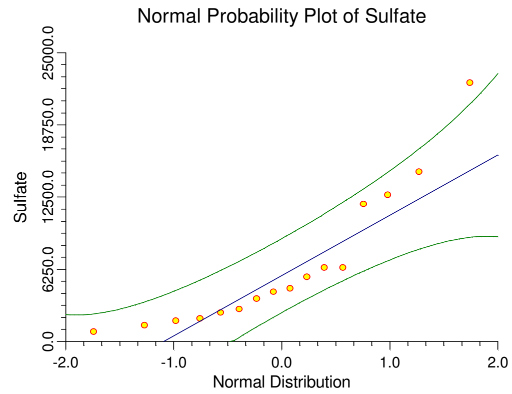
Parameter	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
Value	1238	2125	4450	10525	17010
95% LCL		860	2000	4600	
95% UCL		4300	6400	22400	

Normality Test Section of Sulfate

Test Name	Test Value	Prob Level	10% Critical Value	5% Critical Value	Decision (5%)
Martinez-Iglewicz	2.08734		1.267819	1.475586	Reject Normality
Kolmogorov-Smirnov	0.2569326		0.195	0.213	Reject Normality
D'Agostino Skewness	2.5606	0.010451	1.645	1.960	Reject Normality
D'Agostino Kurtosis	1.6682	0.095269	1.645	1.960	Accept Normality
D'Agostino Omnibus	9.3394	0.009375	4.605	5.991	Reject Normality

Plots Section of Sulfate





Descriptive Statistics Report

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Percentile Section of Sulfate

Percentile	Value	95% LCL	95% UCL	Exact Conf. Level
99	22400			
95	22400			
90	17010			
85	13600			
80	12380	4600	22400	96.4849
75	10525	4600	22400	96.2847
70	6400	4300	22400	97.1003
65	6400	3700	14700	96.7381
60	5760	2800	12700	96.2521
55	4950	2500	11900	95.6935
50	4450	2000	6400	95.0958
45	4090	2000	6400	95.6935
40	3520	1800	6400	96.2521
35	2785	1400	5600	96.7381
30	2530	860	4600	97.1003
25	2125	860	4300	96.2847
20	1880	860	4300	96.4849
15	1620			
10	1238			
5	860			
1	860			

Percentile Formula: Ave X(p[n+1])

Stem-Leaf Plot Section of Sulfate

Depth	Stem	Leaves
3	0* |	011
7	T |	2223
(3)	F |	445
6	S |	66
4	. |	
4	1* |	1
3	T |	2
2	F |	4
1	S |	
1	. |	
1	2* |	
1	T |	2

Unit = 1000   Example: 1 |2 Represents 12000

Descriptive Statistics Report

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Database	C:\NCSS60\DATA\SHEPLEY2.S0
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Summary Section of TDS

Count	Mean	Standard Deviation	Standard Error	Minimum	Maximum	Range
16	257875	184353.2	46088.31	15000	547000	532000

Counts Section of TDS

Rows	Sum of Frequencies	Missing Values	Distinct Values	Sum	Total Sum Squares	Adjusted Sum Squares
16	16	0	15	4126000	1.573784E+12	5.097918E+11

Means Section of TDS

Parameter	Mean	Median	Geometric Mean	Harmonic Mean	Sum	Mode
Value	257875	268000	166862.1	81022.27	4126000	268000
Std Error	46088.31				737412.9	
95% LCL	159640.1	64000			2554242	
95% UCL	356109.9	408000			5697759	
T-Value	5.5952					
Prob Level	0.000051					
Count	16		16	16		2

Variation Section of TDS

Parameter	Variance	Standard Deviation	Unbiased Std Dev	Std Error of Mean	Interquartile Range	Range
Value	3.398612E+10	184353.2	187449.2	46088.31	349500	532000
Std Error	6.534585E+09	25064.11		6266.027		
95% LCL	1.854571E+10	136182.6		34045.66		
95% UCL	8.140858E+10	285321.9		71330.47		

Skewness and Kurtosis Section of TDS

Parameter	Skewness	Kurtosis	Fisher's g1	Fisher's g2	Coefficient of Variation	Coefficient of Dispersion
Value	0.0581064	1.591498	0.0642986	-1.478946	0.7148938	0.576959
Std Error	0.3855676	0.2258394			0.1369055	

Trimmed Section of TDS

Parameter	5% Trimmed	10% Trimmed	15% Trimmed	25% Trimmed	35% Trimmed	45% Trimmed
Trim-Mean	255305.6	253078.1	251910.7	262708.3		
Trim-Std Dev	171827.6	157475.2	144562.1	75164.72		
Count	14	12	11	4		

Mean-Deviation Section of TDS

Parameter	|X-Mean|	|X-Median|	(X-Mean)^2	(X-Mean)^3	(X-Mean)^4
Average	155890.6	154625	3.186199E+10	3.304709E+14	1.615666E+21
Std Error	27674.9		6.126174E+09	2.205412E+15	4.706045E+20

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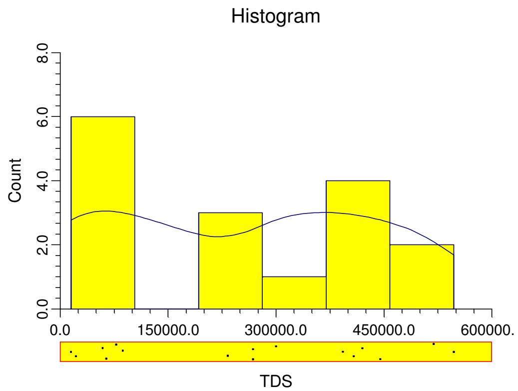
Quartile Section of TDS

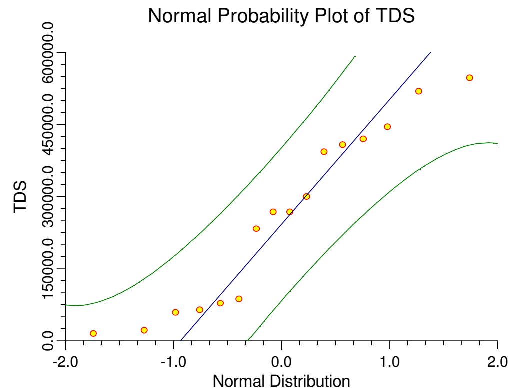
Parameter	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
Value	19900	67500	268000	417000	527400
95% LCL		15000	64000	268000	
95% UCL		268000	408000	547000	

Normality Test Section of TDS

Test Name	Test Value	Prob Level	10% Critical Value	5% Critical Value	Decision (5%)
Martinez-Iglewicz	0.9922761		1.267819	1.475586	Accept Normality
Kolmogorov-Smirnov	0.1980079		0.195	0.213	Accept Normality
D'Agostino Skewness	0.1207	0.903933	1.645	1.960	Accept Normality
D'Agostino Kurtosis	-2.0502	0.040343	1.645	1.960	Reject Normality
D'Agostino Omnibus	4.2180	0.121362	4.605	5.991	Accept Normality

Plots Section of TDS





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Percentile Section of TDS

Percentile	Value	95% LCL	95% UCL	Exact Conf. Level
99	547000			
95	547000			
90	527400			
85	478300			
80	435000	268000	547000	96.4849
75	417000	268000	547000	96.2847
70	406500	268000	547000	97.1003
65	393750	233000	519000	96.7381
60	318600	87000	445000	96.2521
55	279200	78000	420000	95.6935
50	268000	64000	408000	95.0958
45	255750	64000	408000	95.6935
40	203800	59000	393000	96.2521
35	86550	22000	300000	96.7381
30	78900	15000	268000	97.1003
25	67500	15000	268000	96.2847
20	61000	15000	268000	96.4849
15	42350			
10	19900			
5	15000			
1	15000			

Percentile Formula: Ave X(p[n+1])

Stem-Leaf Plot Section of TDS

Depth	Stem	Leaves
2	0* |	12
6	. |	5678
6	1* |	
6	. |	
7	2* |	3
(2)	. |	66
7	3* |	0
6	. |	9
5	4* |	024
2	. |	
2	5* |	14

Unit = 10000   Example: 1 |2 Represents 120000

Descriptive Statistics Report

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Database	C:\NCSS60\DATA\SHEPLEY2.S0
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Summary Section of Zinc

Count	Mean	Standard Deviation	Standard Error	Minimum	Maximum	Range
16	5.83125	5.273167	1.318292	1.5	24.6	23.1

Counts Section of Zinc

Rows	Sum of Frequencies	Missing Values	Distinct Values	Sum	Total Sum Squares	Adjusted Sum Squares
16	16	0	16	93.3	961.15	417.0944

Means Section of Zinc

Parameter	Mean	Median	Geometric Mean	Harmonic Mean	Sum	Mode
Value	5.83125	4.55	4.737506	4.076524	93.3	1.5
Std Error	1.318292				21.09267	
95% LCL	3.021378	3.4			48.34204	
95% UCL	8.641123	5.7			138.258	
T-Value	4.4233					
Prob Level	0.000493					
Count	16		16	16		1

Variation Section of Zinc

Parameter	Variance	Standard Deviation	Unbiased Std Dev	Std Error of Mean	Interquartile Range	Range
Value	27.80629	5.273167	5.361724	1.318292	2.875	23.1
Std Error	22.49506	3.016481		0.7541203		
95% LCL	15.17347	3.895314		0.9738286		
95% UCL	66.60575	8.161235		2.040309		

Skewness and Kurtosis Section of Zinc

Parameter	Skewness	Kurtosis	Fisher's g1	Fisher's g2	Coefficient of Variation	Coefficient of Dispersion
Value	3.024576	11.47148	3.346895	12.36389	0.9042945	0.5370879
Std Error	1.375755	10.38025			0.193983	

Trimmed Section of Zinc

Parameter	5% Trimmed	10% Trimmed	15% Trimmed	25% Trimmed	35% Trimmed	45% Trimmed
Trim-Mean	5.029167	4.771875	4.721428	4.575		
Trim-Std Dev	2.878248	1.394598	1.155331	0.2253652		
Count	14	12	11	4		

Mean-Deviation Section of Zinc

Parameter	|X-Mean|	|X-Median|	(X-Mean)^2	(X-Mean)^3	(X-Mean)^4
Average	2.846875	2.44375	26.0684	402.565	7795.577
Std Error	0.7916018		21.08912	307.2762	5595.247

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Database	C:\NCSS60\DATA\SHEPLEY2.S0
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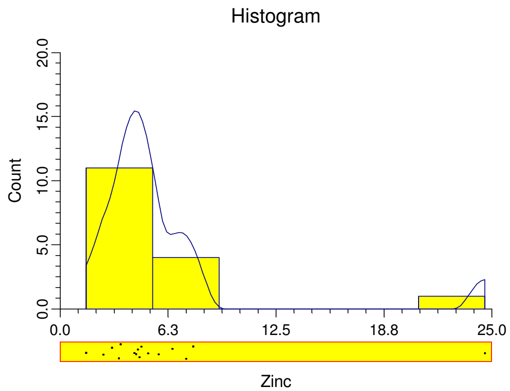
Quartile Section of Zinc

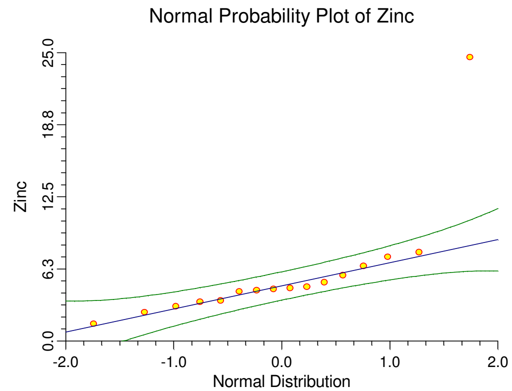
Parameter	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
Value	2.2	3.425	4.55	6.3	12.77
95% LCL		1.5	3.4	4.6	
95% UCL		4.5	5.7	24.6	

Normality Test Section of Zinc

Test Name	Test Value	Prob Level	10% Critical Value	5% Critical Value	Decision (5%)
Martinez-Iglewicz	9.502763		1.267819	1.475586	Reject Normality
Kolmogorov-Smirnov	0.2990239		0.195	0.213	Reject Normality
D'Agostino Skewness	4.4367	0.000009	1.645	1.960	Reject Normality
D'Agostino Kurtosis	3.9761	0.000070	1.645	1.960	Reject Normality
D'Agostino Omnibus	35.4932	0.000000	4.605	5.991	Reject Normality

Plots Section of Zinc





Descriptive Statistics Report

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Database	C:\NCSS60\DATA\SHEPLEY2.S0
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Percentile Section of Zinc

Percentile	Value	95% LCL	95% UCL	Exact Conf. Level
99	24.6			
95	24.6			
90	12.77			
85	7.48			
80	6.98	4.6	24.6	96.4849
75	6.3	4.6	24.6	96.2847
70	5.64	4.5	24.6	97.1003
65	5.13	4.4	7.7	96.7381
60	4.78	4.3	7.3	96.2521
55	4.635	3.5	6.5	95.6935
50	4.55	3.4	5.7	95.0958
45	4.465	3.4	5.7	95.6935
40	4.38	3	5.1	96.2521
35	4.26	2.5	4.7	96.7381
30	3.58	1.5	4.6	97.1003
25	3.425	1.5	4.5	96.2847
20	3.16	1.5	4.5	96.4849
15	2.775			
10	2.2			
5	1.5			
1	1.5			

Percentile Formula: Ave X(p[n+1])

Stem-Leaf Plot Section of Zinc

Depth	Stem	Leaves
1	1 |	5
2	2 |	5
5	3 |	045
(5)	4 |	34567
6	5 |	17
4	6 |	5
3	7 |	37
High	|	246

Unit = .1   Example: 1 |2 Represents 1.2

Appendix C

Follow-up Comment Letters and Final Response to Comments

February 21, 2006

Mr. Robert Simeone
BRAC Environmental Coordinator
BRAC Environmental Office
30 Quebec Street, Box 100
Devens, MA 01434

Re: **Response to Comments**
Stakeholder Draft
Data Gaps Analysis Report
Shepley's Hill Landfill
Devens, Massachusetts
Prepared by AMEC Earth & Environmental, Inc., February 2006

Dear Mr. Simeone:

EPA has completed its review of the "Response to Comments on Stakeholder Draft, Data Gaps Analysis Report, Shepley's Hill Landfill", dated February 5, 2006, as prepared by AMEC Earth & Environmental, Inc. Our follow-up comments are enclosed.

Underlying the technical objectives of this effort and the purpose and process of a Comprehensive Site Assessment and Corrective Action Alternatives Analysis at Shepley's Hill Landfill (SHL) are several fundamental questions: (1) what is the "source" of elevated arsenic in groundwater (i.e., gaining a better understanding of how this problem was created); (2) what is the current and potential extent of the arsenic plume; (3) are there human health and/or ecological risks associated with the elevated levels of arsenic in groundwater underneath and originating from SHL; and, (4) what can be done to mitigate unacceptable risks, considering the effectiveness of the current cover system and the recently installed extraction and treatment system.

The Army's responses reflect significant concern with "intrusive investigations" to characterize the waste within the landfill and delineate potential arsenic sources in the landfilled materials and the responses generally seem to reflect a reluctance to focus efforts on the "source" question. EPA recognizes that the "source" question at SHL is very complex. Although the prevailing conceptual site model appeals to the behavior of naturally-occurring arsenic in the bedrock and soils, little has been done to rule out the presence of waste-derived arsenic. As such, waste alone or a combination of waste-derived and naturally-occurring arsenic may be responsible for the elevated levels of arsenic in groundwater at this site. Without further clarification of this signification issue, it is not clear that the contingency remedy will be the most effective long-term solution. EPA believes that the Army could utilize existing information, including historical exploratory borings and test pits, topographic maps, water table information, and historical aerial photography to refine the conceptual site model and re-evaluate prior estimates of the landfilled-waste volume and configuration. In addition, EPA believes that information regarding the landfilling of potentially arsenic-bearing wastes must be evaluated. The Draft DGA Report acknowledged the importance of this information on page 13: *"Finally, it is important to investigate the possibility that arsenic is being mobilized by the bacterial methylation of inorganic arsenic, which may be present as a result of contaminated fill material (e.g., lead arsenates)."* It is known that potentially arsenic-bearing wastes were disposed in the landfill (e.g., incinerator ash). Existing information that could support or refute the disposal of these wastes and/or the general location of these waste sources is critical to the conceptual site model for the landfill. It is also significant to the evaluation of the performance monitoring system (i.e., it would be clearly worthwhile to monitor downgradient of these potential source areas and to ensure that flow lines through these areas are adequately captured by the extraction and treatment system).

EPA's priorities for the CSA/CAAA effort are the timely investigation of off-site risks and evaluation of alternatives to mitigate those risks. However, it is important that we expend an appropriate amount of effort on determining the "source" of arsenic in order to evaluate associated risks and appropriate remedies. In addition, EPA's other priority for the CSA/CAAA effort is evaluating the effectiveness and integrity of the landfill cover system.

Note that without verification that arsenic-bearing wastes are absent from the landfill, EPA will not accept any remedial conclusions that are based on the argument that elevated arsenic in groundwater at SHL is solely derived from a naturally-occurring source (e.g., peat, rock, soil). In this case, the Army's remedial decision-making process at SHL will need to conservatively assume that arsenic-bearing wastes in the landfill are contributing to elevated arsenic in groundwater. More accurate identification and/or delineation of any significant landfill waste source would further inform and improve remedial decision making.

EPA suggests that the Army's responses, as amended to address EPA's enclosed follow-up comments, be incorporated into a Final Data Gaps Analysis Report for EPA concurrence, eliminating a Draft-Final version of the Data Gaps Analysis Report, in order to streamline the process and move more quickly to the CSA Scope of Work (SOW) effort. EPA requests that our December 2005 comments on the draft report, the Army's Response to Comments package, these EPA follow-up comments, and other stakeholder comments be incorporated into the Final Data Gaps Analysis Report as an Appendix.

EPA would like the opportunity to discuss next steps for the CSA/CAAA, including the schedule for this effort, with the Army and MassDEP. EPA requests that the Army host a meeting within the next 2 - 3 weeks so that Army, EPA and MassDEP management can reach consensus on an approach that continues to moves this critical project forward and strives for a completion date of December 2007.

We look forward to continuing to work with the Army, its contractors, and the BCT members on the CSA/CAAA effort. The next deliverable, the CSA Scope of Work, will be a key document and EPA looks forward to evaluating the SOW to ensure that it adequately addresses comments and concerns that were deferred to that effort and adequately addressed our priorities. Please contact me to schedule a meeting. Thank you.

Sincerely,

Ginny Lombardo
Remedial Project Manager
Federal Facilities Superfund Section

cc: Randy Godfrey, USACE
Lynne Welsh, MA DEP
Dave Salvadore, MA DEP
Ron Ostrowski, MassDevelopment
Bill Brandon, EPA
Jean Choi, EPA
Rick Sugatt, EPA
Jim Murphy, EPA
Robert Ford, EPA-ORD
Dave McTigue, Gannett Fleming
Laurie Nehring, PACE
Richard E. Doherty, Engineering & Consulting Resources, Inc.
Ron McGuigan, Southern Container
Charles Kibbee, Equity Industrial Partners, Ltd.

EPA Follow-Up Comments on
Responses to EPA Comments on
Stakeholder Draft
Data Gaps Analysis Report
Shepley's Hill Landfill

Response 1: The Response suggests that the intent of the original comment regarding three-dimensional mapping of the fill may have been misinterpreted, particularly with respect to intrusive investigation. EPA believes that there is existing information that could be evaluated to create a reasonable conceptual site model (CSM) and 3-dimentional map of the waste and to re-evaluate the existing estimates of thickness and volume of the buried waste and percentage below the water table. In addition, geophysical surveys may prove useful in this effort, once basic research has identified the most promising areas to survey. Existing information that should be considered, include:

- Review of available historic aerial photography;
- Review of available historic mapping (topographic, land-use, Sanborn, etc.);
- Records of landfill development; and,
- Test boring logs, test pit logs and other historical characterization efforts.

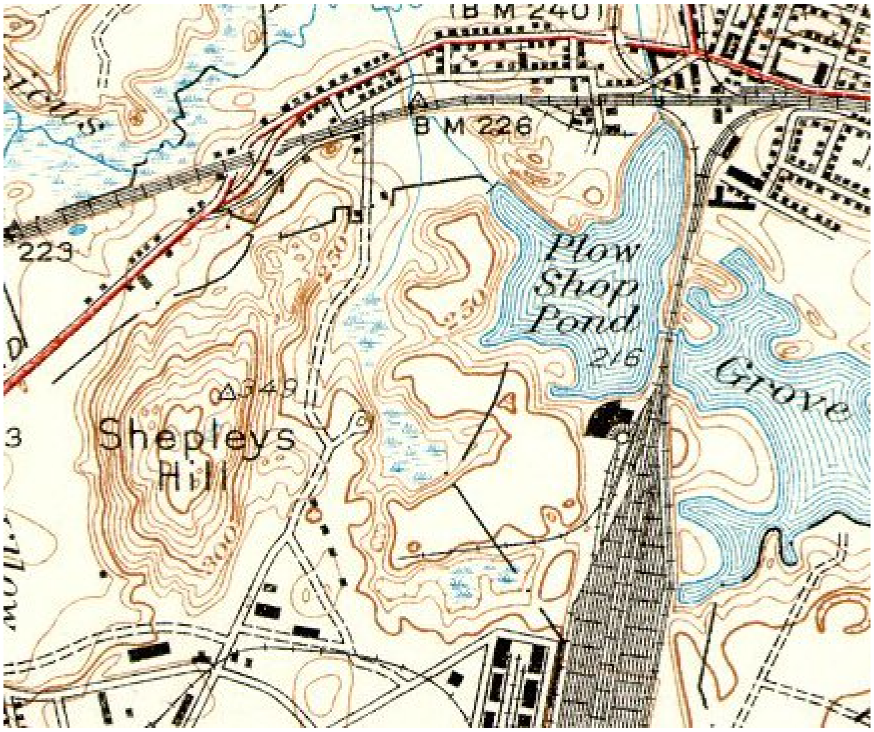
In addition, EPA reiterates the need for 3-dimentional visualizations (e.g., schematics in plan view and associated cross-sections) of the key hydrogeochemical parameters and their lithological associations (i.e., see the other examples noted in the 4th bullet of the original comment). Existing information that should be considered to support both the CSM for the buried waste and evaluation of key hydrogeochemical parameters include:

- Existing geophysical surveys;
- Hydraulic data (e.g., water levels in monitoring wells, etc.);
- Hydro-geologic cross sections;
- Model information (e.g., layer surface configurations, predicted flow-pathways, etc.);
- Aqueous geochemical data;
- Solid-phase geochemical data;
- Hydraulic and chemical data from start-up of the extraction and treatment system;
- Etc.

It is EPA's expectation that the available information will be compiled into a GIS system so that the existing information may be spatially referenced to a common datum, so that volumetric calculations, area determinations, and/or other manipulations of the data may be performed.

A key element of the working conceptual model is that groundwater intersects buried waste in at least some portion(s) of the landfill, and that this interaction influences the groundwater geochemistry to favor the mobility of arsenic. If this is the case, it would be of great utility in weighing remedial alternatives to be able to project flowlines from those portions of the landfill where groundwater interacts with buried waste to possible areas of impact (e.g., Red Cove / Plow Shop Pond, etc.). This task is consistent with the stated technical objectives of assessing the effectiveness of the cap and evaluation of off-site impacts.

The historical topographic map (portion of 1939 USGS 7.5 minute Ayer quadrangle) presented below provides a ready example of the power of existing information. There are significant low-lying areas within the area of the current landfill cap which are mapped as 'wetland' areas on this map. It is likely that dumping was focused to these areas in order to fill the depressions. As such, since the wetland areas also represent the probable location of the water table at that time period, the map also may point to areas where the waste/water table interactions are most likely.



In addition, EPA requests that information regarding the landfilling of potentially arsenic-bearing wastes be evaluated. The Draft DGA Report acknowledged the importance of this information on page 13: *"Finally, it is important to investigate the possibility that arsenic is being mobilized by the bacterial methylation of inorganic arsenic, which may be present as a result of contaminated fill material (e.g., lead arsenates)."* Existing information points to at least two potentially significant "source areas", a former incinerator ash disposal area and a former locomotive ash disposal area. It is known that ash from the former site incinerator was disposed within the landfill and that the building debris from the demolition of the incinerator was disposed within the landfill. The 1939 topographic map above shows a cul-de-sac on the north-south access road adjacent to Shepley's Hill. Could this have been a location where trucks containing ash or other wastes dumped their loads and turned around? It is noteworthy that this location is generally consistent with well N5-P1/P2, where the highest arsenic levels have been detected in groundwater to date. In any event, records should be re-visited to determine if the location of ash and/or incinerator waste/debris can be established to any reasonably degree of specificity. EPA also believes that ash from the former Railroad Roundhouse was disposed within the landfill. A portion of the 1939 USGS topographic map included above clearly shows the railroad roundhouse which formerly existed adjacent to Plow Show Pond (present SA-71). The map also depicts a railroad spur leading from the Railroad Roundhouse, terminating within the limits of the present landfill cap. The location of this railroad spur terminus and the boggy low-lying area to the south of the spur may be a major focal area of ash disposal from the railroad operations.

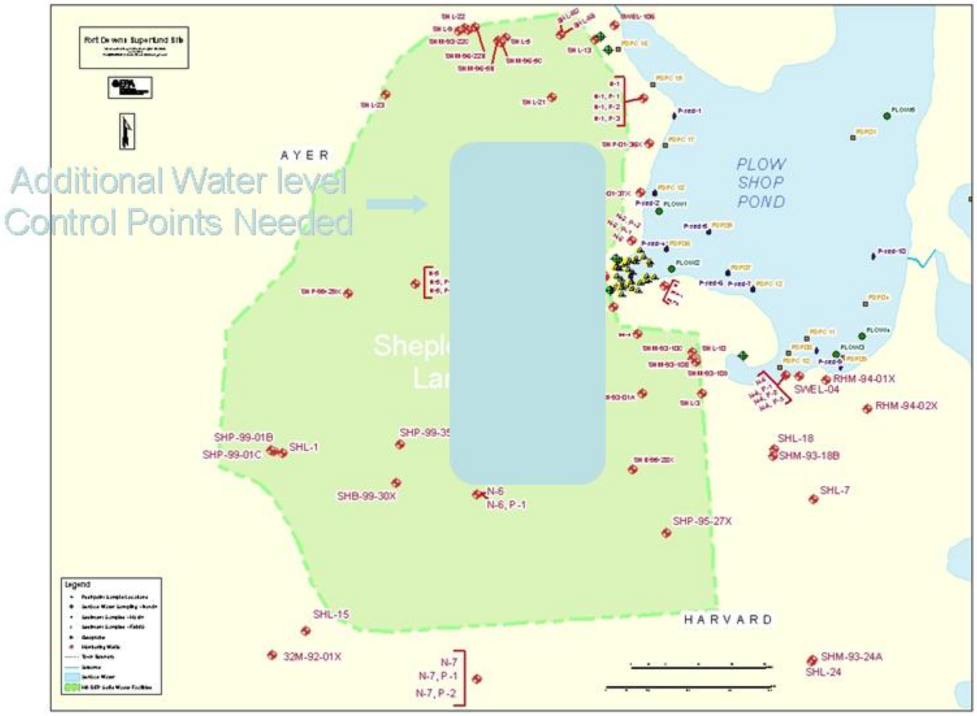
These 2 ash sources to the landfill are 2 possible arsenic-bearing sources that may be in the landfill. The “lead arsenates” referenced on page 13 on the Draft DGA Report may be another. EPA does not propose that exact delineation of these potential arsenic sources within the landfill is needed. However, existing information that could support or refute the disposal of these wastes and/or the general location of these waste sources is critical to the conceptual site model for the landfill. It is also critical to the evaluation of the performance monitoring system (i.e., it would be clearly worthwhile to monitor downgradient of these potential source areas and to ensure that flow lines through these areas are adequately captured by the extraction and treatment system).

A relatively straightforward test for evaluating the disposal of coal ash in the landfill may be utilizing existing data for trace metals in site groundwater. In particular, it is noted that coal ash is typically high in a number of trace metals, including As, V, Ti, Cr, Co, Se, Ba, Cu, Ni, and Sb. Among these, As, V, Se, and Sb are often present in groundwater as oxyanions, and are therefore relatively mobile. For this reason, elevated As derived from coal ash might be expected to be associated with elevated V, Se, and Sb. These associations should be sought in the existing data to identify or refute possible origins of coal ash.

Finally, without verification that arsenic-bearing wastes are absent in the landfill, EPA will not accept any remedial conclusions that are based on the argument that elevated arsenic in groundwater at SHL is from a naturally occurring source (e.g., peat, rock, soil) and any potential effect that may have on remedial decisions. That is, any Army remedial decisions at SHL will have to conservatively assume that arsenic-bearing wastes in the landfill are contributing to elevated arsenic in groundwater.

<u>Response 2:</u> The Army’s response is general in nature, and does not address many of the specific issues identified in the original comment. EPA is willing to defer further discussion regarding the adequacy of the existing well network at meeting the objectives of the CSA until our review of the CSA SOW, performance data from the start-up of the extraction and treatment system, information from the EPA ORD’s investigation at Red Cove, etc. is complete. However, EPA reiterates that the adequacy of the current monitoring well network will need to be critically evaluated in three-dimensions, for each aquifer zone, as new information becomes available. For example, the image provided on the next page was excerpted from EPA’s June 9, 2005 presentation to the BCT. Our analysis indicates that there is presently no water level information over a huge pivotal area in the central portion of the landfill (shown in light blue on the figure). As such, resolution on flow pathways within the landfill is poor, which inhibits the ability to discriminate between those flow lines which are ultimately captured by the extraction and treatment system to the north and those which discharge to other areas (e.g., Red Cove). EPA has commented previously that there are concerns with the model’s ability to accurately simulate capture as the model in necessarily limited by this weakness in water level coverage.

Sampling Locations – SHL and Red Cove



With respect to the identification of potential arsenic source areas within the landfill, discussed in follow-up to Response 1 above, it will be incumbent on the BCT to insure that the existing monitoring well network addresses potential source areas, if identified. If existing wells are not properly located, it may be necessary to selectively install a limited number of additional monitoring points within the landfill footprint to monitor these source areas and/or the regions immediately downgradient of them.

Response 3: See follow-up comments to Response 1.

Response 4: Accepted.

Response 5: Accepted – details to be provided in CSA SOW.

Response 6: In the CSA SOW, within the details to be provided for the updating of the model, provide the value of the infiltration rate through the cap that was used or will be used (average versus maximum) in the groundwater modeling analysis, and explain how the infiltration rates were/will be distributed across the site. Also, it is assumed that details for determining leakage rates, if applicable, will be provided in the SOW. EPA also recommends that aerial photography and GIS analysis be used to determine the percentage of the cap which contains standing water, and how this area changes seasonally.

Response 7: Accepted – specific steps for updating the model to be provided in CSA SOW.

Response 8: See follow-up comments to Response 1.

Response 9: It is agreed that the first approach to assessment of the possible role of various sources of organic carbon in influencing the groundwater geochemistry is to synthesize existing data, possibly supplemented by additional analytical work utilizing the existing well network. Analysis of tannins can certainly be a useful part of this assessment. If the analysis for tannins demonstrates that they are absent, EPA would agree that the possibility of arsenic mobilization by peat-derived organic acids can be eliminated. However, EPA does not agree that the presence of tannins would prove that naturally-occurring arsenic is being mobilized by peat-derived organic acids. Evidence in addition to measurement of the presence/absence of tannins would be needed to support the hypothesis that naturally-occurring arsenic is being mobilized by peat-derived organic acids.

With regard to the spatial distribution of peat deposits, EPA believes that existing information from old topographic maps and existing boring information may be used to construct a map or maps showing the areal extent and thickness of peat deposits at the site. Such information would be critical to understanding the role of the peat, if any, in arsenic mobilization.

Additionally, it is noted that carbon isotope analyses may also address critical questions regarding the age(s) and source(s) of organic and inorganic carbon in site groundwater and the role of carbon in mobilizing arsenic, without further intrusive investigation. In particular, 14-C (radiocarbon) is used in age dating and may be valuable in discriminating among carbon sources of various ages. In addition, delta-13-C data would shed light on carbon transformations within the system and would supplement interpretations of mixing of various hydrogeochemical groundwater facies.

Response 10: Accepted

Response11: Accepted.

Response 12: See follow-up comments to Response 1.

Response 13: Accepted.

Response 14: Accepted.

Response 15: Accepted.

Response 16: Accepted. The original comment recommended that the existing and new groundwater data be displayed in three dimensions, to the extent possible, because the vertical distribution of arsenic in site groundwater, as well as the vertical distribution of relevant geochemical parameters, is central to the continued improvement of the conceptual model and to the well-informed evaluation of remedial alternatives.

Response 17: Accepted. The original comment suggested that the groundwater flow model may need refinement (e.g., additional layers to resolve vertical gradients in the overburden, a more realistic representation of the bedrock, etc.). The Response acknowledges that the model "… would benefit from additional validation."   Please note that validation is only a part of this process, and that model *refinement* may be called for. The Response is adequate for present purposes, but it is anticipated that there will be ongoing discussion of the modeling objectives and approach.

Response 18: Accepted.

Response 19: Accepted.

Response 20: See follow-up comments to Response 2.

Response 21: Accepted.

Response 22: Accepted.

Response 23: Accepted. However, some consideration should be given to a more detailed analysis of existing landfill gas data in conjunction with an updated evaluation of the configuration of peat and waste deposits. The gas data may improve the overall CSM (See follow-up comments to Response 1.)

Response 24: Refer to the Revised Draft SGI (May 2003), section 2.6 (page 2-8), section 3.4.2 (pages 3-10 - 3-11) and Table 2-6, which provide data on arsenic levels in bedrock core and soil samples taken at SHL.

Response 25: Accepted.

Response 26: Accepted.

Response 27: Accepted. In the CSA SOW, within the details to be provided for the updating of the model, provide the values of the infiltration rates and upward leakage rates that were used and/or that will be used for the groundwater modeling analysis and provide the rationale for the values.

Response 28: Accepted – details to be provided in CSA SOW.

Response 29: Accepted.

Response 30: Accepted.

Response 31: See follow-up comments to Response 9.

Response 32: A positive correlation between dissolved arsenic and iron is often attributed to reductive dissolution of ferric oxyhydroxides and release of sorbed arsenic; this mechanism is inferred from the data in Figure 3-3, but the original comment indicates that this correlation breaks down at higher concentrations. The Response suggests that the solubility limit of siderite ($FeCO_3$) controls ferrous iron concentrations, at a value around 14 mg/L. Please note that this solubility depends upon pH and alkalinity; at pH < 7 and/or if alkalinity is limiting, iron concentrations may be much higher. Also, other geochemical mechanisms may influence iron concentrations, depending upon local conditions.

Response 33: Accepted.

Response 34: Accepted.

Response 35: Accepted.

Response 36: Accepted.

Response 37: Accepted.

Response 38: Accepted.

Response 39: Accepted – criteria to be added to the document.

Response 40: Accepted.

Response 41: Details of this aspect of the groundwater characterization should be provided in the CSA SOW.

Response 42: Accepted.

Response 43: Accepted.

Response 44: Accepted.

Response 45: Accepted.

Response 46: See follow-up comments to Response 2.

Response 47: See follow-up comment to Response 9.

Response 48: Accepted.

Response 49: Accepted.

Response 50: Accepted.

Response 51: Accepted, but the issue of "upgradient" sources of arsenic should be revisited in context of an updated CSM.

Response 52: See follow-up comments to Response 2.

Response 53: The Response is accepted, in that the Army leaves the option open to install a bedrock borehole on the west side of the landfill, if supported by results of other proposed activities. It is reiterated that the chemistry of bedrock groundwater upgradient of SHL to the west is a critical element of any conceptual model that attempts to assess the roles of bedrock and overburden as potential arsenic sources, influences on geochemistry, transport pathways potential for cap underflow, etc. Characterization of bedrock groundwater upgradient of the landfill offers an opportunity to examine the chemistry in the absence of any landfill impact.

Response 54: Accepted. In the CSA SOW, within the details to be provided for the updating of the model, provide the recharge values that were used and/or that will be used for the groundwater modeling analysis and provide the rationale for the values.

Response 55: Accepted – EPA will defer further comment on the model until our review of the CSA SOW which is to include details on the updating of the model.

Response 56: See follow-up comment to Response 53. Note that determining the true extent of "run-under" should be considered an important project objective. For example, if all of the precipitation falling on the hill area is found to run-off the hill, under the cap, and into the landfill (i.e., in accordance with the topographic gradient), clearly this would have implications to the overall remedy. A better understanding of 'bulk permeability' of the bedrock would help constrain the degree of runoff "efficiency", and thereby greatly improve the model.

Response 57: See follow-up comments on Response 2.

Response 58: EPA requests that the Army consider EPA Region I's Cap Design Guidance (www.epa.gov/region1/superfund/resource/C524.pdf) regarding the landfill cover system.

Response 59: Accepted.

Response 60: To further evaluate the use of electrical leak location survey equipment, EPA refers the Army to Glenn Darilek, of Leak location Services, Inc. (www.leaklocationservices.com).

Response 61: Accepted. See follow-up comment on Response 58.

Response 62: Accepted.

Response 63: Accepted. We note, however, that the response assumes an updated flow model, which appeals to a more refined understanding of the McPherson well in relation to SHL than is currently available. Further discussions on this issue are therefore required in conjunction with the model update details to be provided in the CSA SOW.

Response 64: Accepted – agree that further discussions are needed. The Army suggests that the presence of floc in Red Cove is not of concern to aquatic organisms because it does not affect pelagic organisms and affects the habitat of only a limited (2%) area of the pond. EPA disagrees with the suggestion of no impact for the following reasons: 1) although Red Cove is 2% of the total pond area, it is certainly more than 2% of the available, more productive shallow habitat; 2) elimination of 2% or more of the benthos food supply to pelagic organisms has unknown indirect impacts on the pelagic populations, especially if they are already stressed by other pollutants; 3) potential resuspension and dispersion of arsenic in the Red Cove floc due to weather and dissolved oxygen reduction has an unknown impact; 4) the extent of direct impact on benthos in Red Cove is unknown; and, 5) the extent of floc-induced abiotic zones constituting "readily apparent harm" under the MCP and in violation of Massachusetts Surface Water Standards is unknown. Although EPA looks forward to further discussion, it is contrary to EPA, MassDEP and Tri-Service ecological risk assessment guidance and sound science to *a priori* "write off" any percentage of habitat or component of the ecosystem (i.e. non-pelagic organisms) without further investigation of the risks and/or impacts to local populations. EPA requests that the language suggesting that floc is not of concern be eliminated from the Final Data Gaps Analysis report, because the suggestion is not supported by risk assessment guidance, sound science, or available data.

Response 65: EPA does not accept the revisions made to Table 3-7. Although EPA agrees that the effectiveness of the contingency remedy must be evaluated and weighed within the CAAA, EPA also expects that alternative remedial actions that could either supplement the contingency remedy or supplant the contingency remedy will be considered in the alternatives analysis. By deleting the 2^{nd} and 3^{rd} rows of the original draft Table 3-7, the Army is proposing to limit the evaluation of alternatives to only those that would supplement the contingency remedy, if needed to address risks.

Response 66: Refer to follow-up comment to Response 58 and 60. It is still unclear whether the proposed approach will result in a sufficient level of information. For example, the area of proposed test pitting covers only about $1/100^{th}$ of a percent of the area of the cap. Why is this considered representative of overall PVC conditions at the site as a whole? Also, EPA remains concerned that the proposed approach has the potential to damage the PVC cap. Further discussions are needed.

Response 67: Accepted.

Response 68: Accepted.

Response 69: Accepted. See follow-up comment to Response 53 - 56. As discussed in the original comments and follow-up comments above, EPA believe that additional bedrock characterization, including borings/monitoring wells, etc., will be needed on the western, upgradient side of the landfill. EPA agrees that it is prudent to wait for the results of the geophysical surveys, etc. Since the specifics of these surveys, such as the areas of coverage, grid spacing, transect locations, etc. have not yet been provided, EPA will defer further comment until such details are provided in the SOW.

Response 70: Accepted – details to be provided in CSA SOW.

Response 71: See follow-up comments to Response 1 and 2. EPA believes that plume continuity (i.e., extent, configuration in 3-dimensions) is a first-order issue which is central to the CSM. For example, is there more than one “source area”? Is there one or more than one process contributing to arsenic in groundwater? How does the plume morphology and iso-concentration field support this understanding? EPA believes that these issues need to be well defined in order to support a successful remedial strategy for the site.

Response 72: Accepted.

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January 21, 2006

RE: Comments - Shepley's Hill Landfill Data Gaps Analysis (DGA) Response to Comment

Dear Mr Simeone:

Massachusetts Department of Environmental Protection, Federal Facility Section (MassDEP), has reviewed the above referenced document in accordance with the Department of Defense Memorandum of Agreement and provides the following comments to aid the Army and it's consultant, AMEC, in preparing a draft Scope of Work for the SHL CSA

DGA Responses to Comments are identified in within each numbered comment:

1 AMEC's response to MassDEP Comment 1:

a. The Technical Objectives stated in the Performance Work Statement referenced the Technical Guidance Document (TGD) per MA Solid Waste Regulation as guiding the CSA/CAAA and indicated the work would be in conformance with the TGD. The five (5) items in MassDEP Comment 1 identifies/clarifies additional issues that should be used in formulating the direction of both the CSA and the CAAA.

b. The statement that the 'CAAA will evaluate corrective action alternatives necessary to address unacceptable risks,' implies only offsite areas will be focused upon, as the SHL soils themselves are not posing a risk. In addition to risks from offsite migration of leachate and contamination, the CAAA needs to evaluate 'options for corrective actions to eliminate or mitigate the potential adverse impact caused by conditions at the [landfill] facility and to complete the final closure in accordance with [Landfill Closure Requirements]. To that end MassDEP wants to ensure that the CSA and CAAA appropriately evaluates all necessary measure to correct identified landfill capping system inadequacies and address all potential risks posed by SHL contaminant migration.

c. The Army was notified in an advisory letter to US EPA from Martin Suuberg, MassDEP Regional Director dated August 23, 2004 that 1996 SHL Remedy had failed and that while the implementation of the Contingency Remedy was a prudent step to take, additional remedial measures would be necessary. So AMECs contention that '.....additional remedial actions would only be warranted if the CSA/CAAA negated the conclusions in the ROD and ESD'..... is difficult to understand.

2. AMEC's response to MassDEP Comment 2, CSM:

a. The SW Technical Guidance (TGD) for the CSA indicates that hot spots identification should be determined and as the Technical Objectives required a CSA/CAAA be conducted as outlined in the TGD, MassDEP believes that it is a necessary component of the CAS. We believe this will be important information to have in evaluating alternatives during the CAAA. MassDEP understand the hesitance to conduct intrusive investigations but AMEC will need to present work items in the CSA Work Plan to address this need.

c. AMEC will need to evaluate the length of time for any remedial method in the CAAA in order provides adequate comparisons. MassDEP is identifying this, as a need for the CAAA will work with the Army, EPA and AMEC to develop the necessary criteria.

3. AMEC's response to MassDEP Comment 6, Shallow and Deep investigation at NB:

MassDEP is hopeful that AMEC will be able to gather the data needed to determine the hydraulic nature of the NB system in relation to the SHL arsenic plume. This is a necessary area of investigation and notes the difficulty in installing piezeometers in this area, but also identifies this as required data and will look for AMEC to gather developed contingency methods if there are problems with the proposed task.

4. AMEC's response to MassDEP Comment 9, Impacts at Red Cove:

MassDEP notes the type of toxicity test performed at Red Cove but does not believe that discounts the results.

5. AMEC's response to MassDEP Comment 10, Landfill Gas Assessment:

Landfill gas assessment should be expanded to encompass both the effectiveness of the collection system and to include dissolved landfill gas in the plume migrating off-site as evidenced in the recent discovery at the P/T system.

6. AMEC's response to Loureiro Comment 7: Geophysical Studies of Background Groundwater Quality and Hydrogeology along the Upgradient Side of SHL:

Section 2.2 (Element #6, page 9) of AMEC's May 2005 proposal to the Army indicates in Section 2.2 (Element #6, page 9) that AMEC plans to investigate:

a. The hydraulic transmissivity and saturation state of the uppermost bedrock and overlying unconsolidated sediments along the western edge of the landfill; and
b. The hydrochemistry of the groundwater in that area.

This portion of the May 2005 proposal also states "..... the results of these investigations may demonstrate that most eastbound inflow travels within the overburden above bedrock, and that this 'background' groundwater may locally carry high concentrations of arsenic. The dominance of flow within the overburden offers the prospect that static engineering controls can be effective in permanently lowering the water table within and beneath the Shepley's Hill Landfill waste. If this can be achieved, there is a fair prospect for reducing conditions to be damped sufficiently that arsenic migration can be substantially limited. The possibility that significant arsenic may locally enter the site offers the prospect that a relatively inexpensive local control can be implemented. Further, documenting high background concentrations of arsenic may assist in substantiating an elevated site-specific remedial goal."

Item b above would appear to refer to an evaluation of background groundwater quality, which is a requirement of 310 CMR 19.132(1)(c), and is routinely include in the Comprehensive Site Assessment (CSA) Scope of Work (SOW) as presented in the TGD.

c. The Data Gaps Analysis (DGA) Report only discusses implementation of a test pit program and geophysics investigation along the western portion of the landfill, with no mention of a drilling\monitoring well installation program (other than soil borings along the western edge of SHL to "define the soil profile and to assess the constructability of remedial alternatives"). It is unclear how the test pit program and geophysics investigation will evaluate the groundwater chemistry along the western edge of the landfill and determine whether the "background groundwater may locally carry high concentrations of arsenic." MassDEP offers that supplementing the monitoring well network along the upgradient western edge of the landfill, along with groundwater sampling and in-situ hydraulic conductivity testing, is necessary to complete this task. In addition, the installation of bedrock wells and shallow\deep overburden wells would allow for a more complete evaluation of bedrock versus overburden "run-under" along the western edge of SHL. This data may also be useful in refining the conceptual site model and groundwater flow model, which are proposed by AMEC.

MassDEP would like clarification/greater detail on how the CSA would investigate the hydrochemistry of the groundwater along the western edge of SHL in the CSA SOW and recommends the CSA SOW outline an alternative approach to GPR, and suggests that the aforementioned well installation\monitoring program be considered for verifying background groundwater quality or augmenting the GPR investigation.

7. AMEC's response to Loureiro Comment 7: Investigation of the Western side of SHL:

Regarding this same issue, the Army's response to EPA Comment #53 states that if the results of the proposed investigation program "... reveal that a west-side monitoring well is desirable, its location will be best selected with data from the proposed program." At a minimum, the Army should clarify what outcome of the proposed test pitting and geophysics investigations would justify installation of an upgradient well(s).

If you have any questions or need further clarification, please contact me at the letterhead address or call (508) 849-4007.

Very truly yours,

D. Lynne Welsh

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Kathleen Sellers, AMEC

Preface
We share the common goal of adequately characterizing and remediating significant risks to human health and the environment. Remedial actions to date support that goal; the Comprehensive Site Assessment and Corrective Actions Alternatives Analysis will assess progress toward that goal and examine means to achieve it. The Data Gaps Analysis is the first step in that process. Two principles guided the responses to comments on the Data Gaps Analysis. First, each datum must contribute to the understanding of the site necessary to assess potential risks and determine appropriate corrective actions, if necessary to supplement previous remedial actions. Second, each datum must fulfill one of the five Technical Objectives for the project determined by the EPA, MassDEP, and the Army. Those technical objectives are:

1. Evaluation of the plume to determine whether the plume is impacting the wetlands and the potential magnitude of that impact, if any.
2. Determination of any impact to the McPherson water supply well and the magnitude of such impact, if any.
3. Evaluation of landfill cap integrity and its effectiveness at minimizing surface/groundwater intrusion and leachate generation.
4. Assessment of Red Cove as an area of historic and possibly current leachate discharge.
5. Assessment of landfill gas issues and the non-vegetated cap areas along the southeast portion of the Landfill.

The responses to comments also reflect remedial actions taken to date, namely:

- 1985 closure plan approved; landfill closed in five phases 1987 – 1993 per 310 CMR 19.000
- 1995 Record of Decision incorporated landfill cap and defined contingency remedy
- 2005 construction of pump and treat system as contingency remedy complete
- 2005-2006 landfill maintenance work
- March 2006 anticipated start up pump and treat system

Those remedial actions were selected and constructed to protect human health and the environment from unacceptable risks. The CSA will fill post-ROD data gaps needed to assess the protectiveness of those remedies. Alternative remedial actions will be considered in the CAAA if additional remedial actions are necessary to address risks not mitigated by current actions. In the words of the MassDEP's Landfill Technical Guidance,

> In-depth exploration of corrective actions must be undertaken only when the CSA and Risk Assessment(s) indicate a threat and there is a need to undertake mitigation or prevent pollution associated with the landfill from affecting public health and/or the environment.

General Comments

1. It is recognized that a central part of the Comprehensive Site Assessment (CSA) is to develop and refine a conceptual site model (CSM) for arsenic (As) in SHL groundwater (e.g., source, transport pathways, geochemical controls, receptors, etc.). Elements that will require further development include:

- the role of bedrock groundwater (e.g., chemistry, upward leakage from bedrock to overburden beneath the landfill, etc.),
- the possible role of sulfide phases in controlling As mobility under highly reducing conditions,
- discrimination of direct impacts of the landfill on groundwater chemistry from naturally occurring conditions in the aquifer, and
- 3-dimensional visualization of key hydrogeochemical parameters and their lithological associations (e.g., map in 3-D the landfill waste/fill, water table, groundwater flow direction and gradient, key stratigraphic units, leachate plume and As plume, ORP field, geochemical indicators (to see the oxic, mixing or anoxic groundwater zones), stream or brook (receptor), etc.).

Response:
We agree that the CSA must produce a CSM which represents complex site conditions with reasonable accuracy to satisfy the Technical Objectives for the project. The types of data listed in the comment will be considered carefully. Due to the heterogeneous nature of landfills, the data will be more variable and complex than from natural subsurface environs. It is therefore important to first approach the CSM from the standpoint of the available data at hand (e.g., a thorough statistical analysis of ALL data sets) and, from there, formulate geochemical or geospatial relationships as appropriate for the CSA/CAAA. For example, the presence of trace organics constituents in groundwater and their subsequent mineralization by microorganisms may be more relevant to the mobilization of arsenic (Delemos et al., 2006) than the presence of sulfide anions.

With respect to the comment that the landfill waste should be mapped in three dimensions, AMEC will utilize GIS maps and cross-sectional interpretations where appropriate to illustrate and understand waste volume and position with respect to the water table. Those depictions will be based on available historical landfill records, historical maps, and previous site characterization work, as discussed in the EPA's letter of February 21, 2006 (attached).

We do not believe that the waste within an old, heterogenous landfill of this size can be accurately characterized without an intrusive investigation so extensive as to compromise the integrity of the landfill cap. Further, detailed mapping does not support the Technical Objectives defined for this project which are focused on the effectiveness of the cap and evaluation of off-site impacts.

Those objectives are in keeping with EPA guidance on landfill remediation, which state a presumption that source containment is the appropriate remedy. (See USEPA 1991; 1993; 1996.) That guidance discourages the investigation and remediation of hot spots unless they are relatively small in size and their location is known based on some form of documentation or physical evidence such as aerial photography. Landfills which have operated over long periods, particularly before the era of modern environmental laws, do not necessarily lend themselves to precise waste delineation. The Shepley's Hill Landfill operated for approximately 80 years. Detailed records of waste disposal practices were not maintained, in keeping with the practice of the times. Thus, determining the nature and distribution of the wastes in the landfill would require an extensive and intrusive investigation program. Some exploratory borings and test pits have been installed to characterize the general quantity and nature of the waste; see, for example the Supplemental Groundwater Investigation Report. Those data will suffice for the CSA/CAAA.

References:

Delemos, JL, Bostick, BC, Renshaw, CE, Sturup, S and Feng, X, 2006. Landfill-Stimulated Iron Reduction and Arsenic Release at the Coakley Superfund Site. Environ. Sci. Technol. 40, 67 – 73.

USEPA, 1991. Conducting Remedial Investigations/Feasibility Studies for CERCLA Municipal Landfill Sites. EPA/540/P-91/001. February 1991.

USEPA, 1993. Presumptive Remedy for CERCLA Municipal Landfill Sites. EPA 540-F-93-035. September 1993.

USEPA, 1996. Application of the CERCLA Municipal Landfill Presumptive Remedy to Military Landfills. EPA/540/F-96/020. December 1996.

2. A comprehensive assessment of the strengths and weaknesses of the existing well network is needed. All relevant hydro-stratigraphic units (e.g., shallow water-table, overburden aquifer, deep overburden aquifer, shallow fractured bedrock aquifer, etc.) need to be identified and existing wells need to be assigned to the appropriate category. With this as a starting point, well locations/depths can be evaluated with respect to their individual locations on groundwater flow paths. Upgradient and downgradient wells can be identified as such, and any gaps in coverage can be identified. Additionally, well coverage in intermediate and cross gradient areas used to define flow pathways from upgradient to downgradient areas need to be compiled and tabulated. It is EPA's interpretation (as presented at the June 2005 BCT and RAB meetings) that there are gaps in the monitoring well network in many areas of the site. BCT consensus on the appropriate well network is a necessary prerequisite to performing the additional geochemical and other analyses proposed in the DGA.

Response:
The current well network has been approved by the Agencies for evaluation of the performance of the contingency remedy (the pump and treat system) (CH2MHill, 2005). With respect to the five Technical Objectives in the Performance Work Statement, the Army believes that the key questions regarding off-site plume impacts will be adequately and efficiently addressed by the existing well network, as supplemented with the proposed wells described in the Data Gaps Analysis Report. In general, the well network in the Red Cove area is considered adequate for the purposes of evaluating horizontal and vertical hydraulic gradients and sampling groundwaters from bedrock as well as shallow and deep overburden. The network in the northern downgradient area is expected to become adequate as augmented by the proposed well installation programs. At this time, no additional wells are considered critical to assessing off-site migration, nor to completing a CAAA. Should data from the proposed wells so indicate, additional wells will be considered at a later time.

Reference:

CH2MHill, 2005. Performance Monitoring Plan, Groundwater Extraction, Treatment, and Discharge Contingency Remedy, Shepley's Hill Landfill, Fort Devens, MA.

3. Ash Disposal Cell: Ash disposal has been reported as a potential source of As contamination at DoD sites (http://www.serdp.org/Research/CU/CU_1374.pdf). A more complete understanding of the incinerator ash deposits in the landfill is needed. The location, geometric configuration and volume of the ash disposal cell (which is mentioned in some site documents) should be clarified. The potential for ash materials to be acting as a source of the As has not been addressed by previous work and needs to be directly assessed by this study. This may require additional intrusive work (e.g., monitoring wells, borings, test pits) depending on the location of any accumulation of ash materials in relation to existing information.

   Response:
   As discussed in the response to General Comment #1, identifying arsenic waste sources within the landfill is not consistent with the Technical Objectives in the Performance Work Statement. Further, accurately defining such materials could be extraordinarily difficult without seriously compromising the geomembrane. In summary, we believe that due to the nature of historical waste disposal practices, the size of the landfill, and the importance of maintaining the cap, it is imprudent to perform an intrusive investigation into the landfill. Instead, remedies will be evaluated in the CAAA based on the existing definition of the waste in the landfill.

4. McPherson Well: In order to better evaluate any potential site-related impacts to the McPherson well, the hydrogeologic context of the McPherson well needs to be better integrated with this study. At a minimum, the following information from the well should be compiled and assessed: well construction details, geologic boring logs, production history, monitoring network (depths, hydrostratigraphic zones), monitoring history/results for production well and associated monitoring network, etc

   Response:
   As part of the CSA, available data (from MassDEP, MassDevelopment, and Town files) regarding well construction and Zone II delineation will be reviewed and integrated with data collected under the proposed field program to evaluate potential site-related impacts to the McPherson well.

5. Plume Delineation/Flux Determinations: The Work Plan should provide details on actions which will be taken to address the goal of quantifying flux to the north. In particular, the specific location of vertical transects, borings, monitoring wells, etc., which are planned to address this data gap should be clearly identified on appropriate figures. The plume centroid which is partially depicted on Figure 3-5 will need to be mapped out fully (in 3-D) in the downgradient directions.

Response:
As the commenter suggests, the Work Plan (more formally, the CSA Scope of Work) will provide details on how the site investigation will be performed.

6. Cap Integrity Assessment: Please clarify whether the steps outlined in the DGA will result in a quantitative re-estimation of infiltration into the cap. For example, Table 1-2 lists establishing the "vertical transmissivity" of the cap as a specific data gap to be addressed. Are the field data collection efforts expected to produce a quantitative re-estimation of infiltration? Will the existing model be used to develop this estimate? Will the model be recalibrated based on the improved infiltration estimates using a range of better-constrained assumptions? Please clarify the overall approach.

   Response:
   Initially, a qualitative assessment of cap integrity will be performed as part of the proposed test pitting program. If the geomembrane is found to be in good condition the current assumption of negligible infiltration will be upheld. If the potential for leaks is identified, then an estimate of the leakage rate will be developed and used in recalibration of the model.

7. CSM and Numerical Model: It is clear from the DGA report that the groundwater model will be relied on heavily in order to further evaluate the landfill related impacts. However, the specific steps which will be taken to update the model are not specified. Which CSM elements will require commensurate modifications to the model? What specific steps will be taken to update the model with the new information? BCT discussions are needed so that a consensus can be reached on the overall approach with respect to the model.

   Response:
   The numerical model will be one of many tools used to evaluate the landfill related impacts. Specific steps for updating the model will be discussed further in the CSA Scope of Work. However, one example would be to refine the simulation of groundwater-surface water interactions in the Red Cove area by revising this boundary condition to correspond to field estimates of groundwater discharge developed through proposed analyses of gradient and permeability, as well as the findings of EPA's ongoing studies (where appropriate).

   The BCT will certainly have input to the model revisions through review of the draft Scope of Work. As the Army begins to develop the Scope of Work, it may be appropriate to get BCT input in a technical meeting.

8. Waste Configuration/Volume: A more accurate delineation of the waste is needed (in 3-dimensions). In particular, it should be ascertained whether the waste material is a continuous mass or rather a series of trenches (as has been implied by some observers) separated by less disturbed or undisturbed material. The use of non-destructive geophysical methods could be expanded to meet this objective. The trench scenario would have implications to As fate and transport such as groundwater flow patterns, etc. The waste volume should be recalculated once the 3-dimensional configuration of the waste mass is better defined. (Note: The proposed geophysical studies, section 4.4, will support this objective, but consideration should be given to expanding the program.)

Response:
Without complete excavation it is highly unlikely that geophysics or even a boring program would provide detailed waste emplacement geometry and, in order to determine the influence of a complex geometry on flow patterns, hydraulic properties and gradients would also have to be known in detail. It is the Army's opinion that this level of characterization would not affect the outcome of the CAAA. See also response to comment 1.

9. Peat Deposits/Tannins: The DGA notes that naturally occurring organic materials (e.g., peats) may be playing a role in As fate and transport. Specifically, the text notes that tannins from buried peats may leach As from the substrate. It might also be noted that, in addition to effects on pH, oxidation of naturally occurring organic carbon may contribute to the reducing conditions (which may 'mobilize' As). How will effects attributable to peat be distinguished from similar effects attributable to degradation of non-peaty organic wastes? It should be a goal of the CSA to assess the relative importance of these two alternative "drivers" for reducing groundwater conditions at SHL, as it bears on potential remedies. It is not clear that "tannin concentrations (in concert with concomitant routine As concentrations)" (Table 3-3) will be sufficient to address this issue. Are tannins only associated with peat? Are tannins mobile in groundwater? Or are they retarded? As a first step, a detailed representation of the subsurface distribution, depth, and thickness of the peat materials needs to be constructed.

Response:
Because groundwater characterization necessitates the interpretation of discrete data from individual wells, the role of peat lenses and/or the tannins that may leach from them will first be approached through a careful analysis of the statistical or graphical interpretations of analytical data. If this analysis shows that organic compounds in groundwater may play a significant role in the fate and transport of arsenic beneath the SHL, then the analysis of tannins may shed additional light on what type of organic compounds may contribute to any mobilization phenomenon. Similar to characterization of Ash deposits, it would be extremely difficult to define detailed peat distribution without invasive techniques that risk violating the integrity of the landfill cap and the need for this information relative to the CAAA is unclear.

Specific Comments:

10. <u>Page ES-2, Bullet Points</u>: Another key question which should be addressed is whether or not the recently implemented pump and treat action will be sufficient to address the identified risks, or whether other (or different) approaches are needed. Also, it will be important to consider that, with the recent start-up and planned re-start of the groundwater extraction and treatment system, hydrogeologic and geochemical conditions on the existing arsenic plume will be changing and these changes will need to be incorporated in the evaluation of data for the CSA/CAAA effort.

Response:
The Corrective Actions Alternatives Analysis (CAAA) will, as the commenter suggested, address the efficacy of the groundwater extraction and treatment system based on operating

data and groundwater monitoring results.

11. Page 1, Section 1.1: It might be noted that there are reports of peat mining in the 19th century in the vicinity of Plow Shop Pond, which may bear on subsurface lithologies and chemistry of overburden groundwater. (See, e.g., memo from H. R. Cutting to L. Chappell, MassDEP, 9/8/92.)

    Response:
    Comment noted. AMEC has requested a copy of the cited memo for review.

12. Page 1, Section 1.1: The text provides some important reference information on the thickness and volume of the buried waste, and the percentage estimated to be below the water table. It is recommended that an attempt be made to map the buried waste in 3-dimensions, and its relationship to the water table. Areas in which the waste may be interacting directly with groundwater are significant to the conceptual model for the impact of the landfill on the hydrogeochemistry. Are these areas on groundwater pathlines intersecting Red Cove in Plow Shop Pond, Nonacoicus Brook and associated wetlands, etc.? See, also, general comment 8.

    Response:
    As part of the CSA, the thickness and extent of buried waste and the portion that may be saturated will be assessed based on existing borings, cross-sections, and a comparison of the predevelopment and current topographic maps and current water table elevations. This information will be developed to the extent necessary to support the CAAA in light of the Technical Objectives for this project. See also response to general comment 1.

13. Page 2, Section 1.2: It is noted that the Human Health Risk Assessment (HHRA) is described as quantitative, while the Ecological Risk Assessment (ERA) is described as qualitative. What is the rationale for making this distinction? Please explain this difference. This objective should be changed to "quantitative" because, at a minimum, the concentrations of As in Red Cove sediments, Nonacoicus Brook, and the intervening wetlands will need to be compared quantitatively with benchmarks for surface water, sediment and/or soils.

    Response:
    While the MassDEP Landfill Technical Guidance requires that a qualitative risk assessment (Chapter 8 III) be done prior to the preparation of the scope of work for the quantitative risk assessment (Chapter 8 IV), the requested change will be made. "Qualitative" will be replaced with "quantitative."

14. Page 4, Section 1.2.1: The ROD casts the cleanup goals in terms of risk reduction. Has the risk assessment been repeated since the RI and the ROD, or are all subsequent decisions based solely on As concentrations (without recalculating risk)? Please clarify.

    Response:
    The Supplemental Groundwater Investigation included a risk assessment.

According to the ROD, as cited in Section 1.2.1 of the DGA Report,

- In general, reduction of risk, rather than reduction in concentration, will be the measure of progress toward attaining cleanup levels.
- For Group 1 wells, which met cleanup goals at the time of the ROD, the data would be evaluated to determine if a statistically significant increase in concentration in an individual well pushed the concentration of a target compound over the cleanup criterion.
- For Group 2 wells, success was defined as:
    - 50% reduction in calculated risk by January 1998, and
    - 75% (cumulative) reduction in calculated risk by January 2003, and
    - Attainment of cleanup levels by January 2008.

As you know, five year reviews were performed in 2000 and 2005 to evaluate progress against these criteria. For further clarification of conclusions regarding progress (via risk reduction vs. concentration reduction), please see those reports.

Because this section of the DGA Report was citing the ROD, the language will not be changed in response to this comment.

15. Page 4, Section 1.2.2: CSA technical objectives should address the relationship between the landfill and groundwater quality.

    Response:
    Section 1.2.2 of the DGA Report reflects the Technical Objectives that the BCT discussed and specified in the Performance Work Statement for this project. As groundwater is the primary medium through which the potential impacts cited in the first four technical objectives would occur, the overarching objective stated in the comment is implied.

16. Page 5, Section 1.2.2: The first bullet notes that the DGA report includes "a preliminary plume delineation." It is noted that this preliminary assessment (e.g., Figure 3-5) is essentially 2-dimensional. It should be a goal of the ultimate CSA to develop a 3-dimensional delineation of the high-As groundwater and relevant geochemical parameters, to the extent possible using all available and appropriate data. The vertical distribution data of the As plume and the leachate plume emanating from the landfill are not currently defined. It is, thus, difficult to understand at what depth (or soil layer) elevated As concentrations are occurring at the site and evaluate how or why.

    Response:
    A 3-dimensional delineation of the As plume will be provided based on available data and at a level of detail appropriate to support the CSA/CAAA.

17. Page 6, Section 1.4: The text states that, "the existing CSM and numerical groundwater model provide a good technical basis for the proposed work." It should be noted that the numerical model, while useful for some purposes (e.g., remedial design) is limited in the issues that it can address. In particular, it is probably inadequate to address bedrock/overburden groundwater interactions or to resolve vertical gradients within the

overburden. See, also, general comment 7.

Response:
The Army agrees that while it is a useful tool, the model has certain limitations and would benefit from additional validation. Comment noted.

18. Page 6, Section 1.4: The text notes that the CSA will consider "background levels and speciation of As." It is agreed that discussion of "background" is of great significance in this context; however, this is a complex issue due to the number of variables (including natural and anthropogenic factors) that control As behavior. Continuing discussion with members of the BCT will be necessary in order to decide what constitutes an acceptable "background" database for this application.

    Response:
    Comment noted.

19. Page 7, Section 1.4: The third bullet suggests that flow through the landfill might be limited by routing water around it. Such an approach would require a careful assessment of the potential impact on the hydrology in 3-dimensions. For example, would such a solution increase upward leakage from the underlying bedrock (cf., high As concentration recorded in the N5-P1 piezometer, which is screened in bedrock)? If so, what are the potential consequences of such a solution?

    Response:
    Comment noted. The CSA will fill post-ROD data gaps that must be filled to assess the protectiveness of the remedies now in place, which were selected and designed to mitigate risks. If the CSA determines additional remedial actions are needed to protect human health and the environment, they will be considered in the CAAA. In order to clarify this position the word "focus" in the first sentence of the third paragraph in Section 1.4 will be replaced with "determine the need for additional".

20. Page 8, Section 2.1: EPA does not concur that the "18 monitoring wells" are adequate for refining the model. In particular, EPA has articulated concerns with respect to the current model's accuracy relative to groundwater flow in the Red Cove area. Additional well control points may be needed. See, also, general comment 2.

    Response:
    Please see response to comment 2.

21. Page 9, Section 2.2.1: The text states, "… the most recent long term monitoring data indicate no significant changes relative to historic As values." It is not clear whether this statement refers to short-term changes (e.g., from 2003 to 2004) or to longer-term trends (e.g., since the characterization performed for the RI in the early 1990s). In any event, it is critical to the development of a defensible conceptual model to consider the significant changes in As concentrations observed at a number of key monitoring points. For example, significant increases in As have been observed at MW-5B and MW-22B from 1995 to 2005.

Are these changes related to hydrogeochemical adjustments in response to cap construction? Also, all available data should be exploited in this assessment, including other analytes (e.g., chloride, sulfate, etc.). Some of these, too, have undergone significant long-term changes.

Response:
The conclusion presented is paraphrased directly from the draft Five Year Review document, and therefore addresses changes since 2000. The statement will be amended with the phrase "... over the last five years ...". The Army concurs that all available data should be exploited in assessing hydrogeochemical trends and constructing a conceptual model.

22. Page 9, Section 2.2.2: Soil chemistry is relevant to a full understanding of the groundwater chemistry. Please note that CH2MHill has performed limited soils analyses on samples collected in conjunction with the installation of the extraction system and associated monitoring. Also, CH2MHill has archived some soil samples from their drilling program, in the event that additional soil analytical data should be required.

    Response:
    Comment noted.

23. Page 10, Section 2.2.3: Steps should be taken to better understand and explain the "highly varying concentrations of methane and carbon dioxide." The CSM should be updated accordingly.

    Response:
    Measurements from landfill gas monitoring points in a typical landfill environment often reveal a high variation of concentrations and constituents. In order to more fully understand the cause and effect of the variation, it would be necessary to establish a sophisticated landfill gas testing program involving measuring barometric pressure responses at the land surface and at depth over a period of time along with the monitoring of concentration variations. Since the gas monitoring information to date does not indicate an off site migration scenario, performing an intrusive gas testing program does not appear to be warranted. The present annual gas monitoring program coupled with the new gas probes installed under the Cap Maintenance Program is considered to be adequate for the purposes of the CSA and CAAA.

24. Page 11, Section 3.1.1: Item 2 states that the "… bedrock is known to contain elevated concentrations of As …." Does this statement refer to specific analyses performed on bedrock samples collected from beneath SHL, or to general knowledge of the regional geology? Please provide support for this statement, including the appropriate "reference" (i.e., "elevated" relative to what?).

    Response:
    Harding ESE performed rock chip testing of bedrock in 2002 and found that Arsenic concentrations in local bedrock ranged from 1 to 43 ppm around the landfill and from 3 to 81 ppm within bedrock adjacent to the landfill. In addition, electron microprobe analysis was

performed on several bedrock samples collected adjacent to the landfill and found that the mineral Cobaltite (CoAsS) contained As up to 40% by weight and showed significant weathered haloes which contained significantly decreased As levels (As was leached out) (Mayo, 2003). A reference to USGS (2003) publication on the Arsenic Belt in Central Massachusetts will be added to the text.

25. Page 12, Section 3.1.1: Item 4 notes that buried organic waste below the water table can promote reducing conditions. In Section 3.2, the text notes that naturally occurring organic materials (e.g., peats) may also play a role. See general comment 9.

    Response:
    Comment noted.

26. Page 12, Section 3.1.1: Item 4 notes reducing conditions can mobilize As by dissolution of Fe and Mn oxide phases. It should also be noted that, under sufficiently reducing conditions, As mobility is again limited by the formation of sulfide phases. Data from SHL appear to be consistent with this scenario (see, e.g., http://www.epa.gov/ord/scienceforum/2005/pdfs/regionposter/Stein_Regions29.pdf). Please consider the possible role of sulfide formation in the CSM. This is of significance because of the potential for either reductive dissolution of oxide phases or oxidation of sulfide phases to increase dissolved As concentrations.

    Response:
    Relationships between arsenic in groundwater and any parameter that may contribute to its mobility (e.g., ORP, sulfide, etc.) will be considered in the CSA.

27. Page 12, Section 3.1.1: Item 6 outlines the conceptual water balance for the aquifer beneath the landfill. Explain the basis of the statement "negligible inflow (vertical recharge) occurs through the cap". It might be noted that there may be a contribution to the water balance from the underlying bedrock. That is, there may be significant "leakage" upward from the bedrock to the overburden due to the elevated recharge area on Shepley's Hill and the elimination of recharge over the area of the landfill cap.

    Response:
    In the present CSM (and numerical model) negligible recharge is assumed to pass through the landfill cap. The validity of this assumption will be evaluated through the proposed test pitting program (as discussed in Response to EPA General Comment 6). In contrast, upward leakage to the landfill footprint from the bedrock aquifer is assumed to occur and is already represented in the numerical model.

28. Page 12, Section 3.1.2: The 2nd bullet indicates that the risk assessment will consider "background levels of As." What background data set will be the basis for the comparison? Establishment of appropriate "background" conditions will require discussion with the BCT. This issue is particularly complex for groundwater because of the sensitivity of As concentrations to local geochemical and geological conditions. See, also, comment 18.

Response:
Details regarding the background evaluation will be provided in the CSA Scope of Work. That Scope of Work will reflect information provided in the Devens Arsenic Background Study and previous BCT discussions on that study, as that information pertains to this project.

29. Page 13, Section 3.1.3: Item 1 indicated that "arsenic-bearing waters strongly affect the arsenic concentrations in the receiving waters…" Note that, as indicated in Section 3.1.1, items 3 and 5, the discharge rates of As-bearing waters or leachate may affect the As concentrations in the sediments as precipitates rather than receiving waters under the presumably oxic conditions. Please clarify. Sediment is an important medium with respect to characterization, exposure, and risk determination, most particularly in the groundwater/surface water interface.

    Response:
    The phrase will be rewritten as follows: "…strongly affect arsenic concentrations in the receiving waters *and associated sediments*...".

30. Page 13, Section 3.2: The text states, "…As geochemistry is controlled by co-precipitation reactions with oxides…" Please see comment 26 regarding the possible role of sulfides, as well.

    Response:
    The potential relationship of As with reducing species in groundwater will be considered.

31. Page 13, Section 3.2 and Page 20, Section 3.2.4, 5th bullet: Clarification is needed relative to the hypothesized role of naturally occurring tannins/humic acids (derived from "natural lenses of peat") relative to As mobilization. Specifically, it is unclear whether As mobilization is being attributed to 1) degradation of natural organic compounds that lead to the development of reducing conditions or 2) more direct chemical interaction with "peat-derived organic acids" leading to enhanced As solubilization and transport. It is not clear how the influence of natural and landfill-derived organic compounds can be differentiated within the boundaries of the landfill. See, also, general comment 9.

    Response:
    The role of peat in the mobilization of arsenic is speculative at this time. Whether peat has any effect on the movement of arsenic cannot be discerned until tannins are directly measured in wells that are elevated with respect to arsenic.

32. Page 13, Section 3.2, Page 18, Section 3.2.3, and Figure 3-3: The relationship between As and iron documented in Figure 3-3 indicates that there is a partial dependence of As on soluble iron, primarily in the mid- to lower-concentration range (note that these data are plotted on a logarithmic scale). However, at higher concentrations there appears to be a weakening of this correlation. Given that the disposal of lead arsenates is identified as part of the "contaminated fill material" (pg. 13), further data collection is warranted to better delineate the potential sources of landfill-derived As. See, also, general comments 3 and 8

and comment 12.

Response:
It is known, based on a case study published for the Coakley Landfill in New Hampshire (Delemos et al., 2006), that the linear relationship between arsenic and soluble iron "breaks down" when iron [siderite] concentrations approach their limit of solubility (~ 14 mg/L).

33. Page 14, Section 3.2.1.1: The report states that As "… can range … to 50 [micrograms per liter] in New England." What is the source of these figures? (It is noted that considerably higher concentrations have been observed in numerous locations.)

Response:
A reference to the USGS (2003) publication "Arsenic in Groundwater in Eastern New England: Occurrence, Controls, and Human Health Impacts" will be added to the text.

34. Page 14, Section 3.2.1.1: The text states, "Typically groundwaters with pH values of 8 or higher have had high As concentrations." Please review and comment on typical pH values for SHL groundwater in order to tie this observation to the site. (A quick review of historic low-flow field parameters from SHL indicates pH typically in the range 6 – 7.) Are As concentrations correlated with pH in the existing database?

Response:
It is acknowledged that typical pH values at SHL do not exceed 7. While this statement is paraphrased directly from the USGS (2003) publication, the third paragraph will be deleted from the document for clarity.

35. Page 15, Section 3.2.1.2: The last paragraph of this section addresses other influences on As mobility. This list should include sulfate and alkalinity. Sulfate is a product of sulfide oxidation, and alkalinity is related to consumption of organic matter. Both may inhibit sorption of As.

Response:
Both sulfate and alkalinity will be included in the more detailed statistical analysis that will be run during the CSA. Monitoring for these two analytes will be continued if a strong positive correlation can be discerned with dissolved arsenic.

36. Page 15, Section 3.2.1.3: The 2nd paragraph refers to "a recent study" without a specific citation. Please provide the relevant reference.

Response:
The reference in question (Mayo, 2003) appears in the subsequent paragraph. The text will be modified appropriately.

37. Page 16, Section 3.2.1.3: The text cites USGS work at the Saco Landfill, Maine, stating that As concentrations as high as 700 mg/L are observed. This should read micrograms per liter. Please check units.

Response:
This typographical error will be corrected.

38. Page 17, Section 3.2.2: The text states that aluminum is among the metals present in SHL groundwater at concentrations <10 micrograms per liter. A brief review of SHL data indicates that Al concentrations as high as a few hundred ppb have been observed. Please verify and revise accordingly.

    Response:
    Al will be removed from this list.

39. Page 17, Section 3.2.2: Clarification is needed relative to the decision criteria for excluding some "General Chemistry" variables due to "low variability". One of the excluded variables included pH, which is reported using a logarithmic scale. For this variable, a change in pH of 1 is equivalent to an order-of-magnitude change in hydrogen ion activity. It would be useful if the magnitude of variation in site data was reported for the excluded variables relative to those variables used in the statistical analysis.

    Response:
    The criteria for excluding selected "general chemistry" parameters based on historic variability will be added to the document.

40. Page 18, Section 3.2.3: Please note that the extent of the negative correlation between As concentration and ORP is not fully defined by the range of data used to construct Figure 3-1. There are data from the SHL system that extend to considerably lower ORP, and these values are associated with low dissolved As concentrations. See, e.g., http://www.epa.gov/ord/scienceforum/2005/pdfs/regionposter/Stein_Regions29.pdf).

    Response:
    A limited data set was used to perform the preliminary statistical evaluation, as described in the DGA Report. The CSA will include statistical analyses run on more complete data sets from data collected during the CSA.

41. Page 19, Section 3.2.3: The text speculates that there is a "solubility limit" around 4-5 mg/L, above which As levels cannot go. How is this reconciled with the observation of 7.6 mg/L at one of the extraction wells (Fig. 3-5)? The extraction well has a 25-foot screen, and it seems likely that the sample from this well represents a mix of water at much lower concentration and water at concentrations much higher even than the 7.6 mg/L average.

    Response:
    The limitation of arsenic solubility is speculative, and based on a preliminary statistical analysis. This potential aspect of the groundwater characterization will be refined in the CSA.

42. Page 19, Section 3.2.3: Methylated forms of As in water are volatile only when converted to

gaseous arsines. Common methylarsenic species, such as monomethylarsonic acid and dimethylarsinic acid, are volatile only when converted to monomethylarsine and dimethylarsine via microbial action. The methylarsenic species typically measured in aqueous samples are not the volatile forms. In addition, for consistency throughout the document, inorganic As species should be referred to as either 'arsenate' [As(V)] or 'arsenite' [As(III)] or 'inorganic As(V) or As(III)'. The use of the notation 'As+5' and 'As+3' to describe arsenate and arsenite should be avoided, since this implies that these species possess a positive ionic charge in water.

Response:
The phrase "if converted to monomethylarsine or dimethylarsine gas" will be inserted before "they are volatile…".

The document will be revised with the recommended notation.

43. <u>Page 19, Section 3.2.3</u>: Assessment of organic forms of As needs to be directed to representative hydrostratigraphic units. At a minimum, conditions at the north plume and Red Cove should be independently evaluated.

Response:
In the CSA geochemical data for each hydrostratigraphic unit or area of interest will be evaluated separately, as appropriate.

44. <u>Page 19, Section 3.2.4</u>: The 1st bullet recommends evaluation of a list of "matrix metals." Please add potassium (K) to this list for completeness. This will allow analysis of "major-element" chemistry, and will complement analytes currently being measured for the Peformance Monitoring Program for the extraction and treatment system. In addition, the 1st bullet recommends analysis for Cr and Zn. Please provide the rationale for these particular choices. The last sentence in the 1st bullet recommends elimination of several parameters that were "negative" (ND?) in past sampling. The list includes Cr, which is recommended for inclusion earlier in the bullet. Please check for consistency.

Response:
Potassium will be added to the list of matrix metals. The rationale for including the listed trace metals is that they are typically analyzed as a suite, however, this may only be of value as an initial screening step. In this regard Cr may still be one of the parameters that should be eliminated from long term monitoring.

45. <u>Page 20, Section 3.2.4</u>: The 2nd bullet on this page recommends that upgradient and downgradient wells be sampled for "selected metals and general chemistry parameters." It is recommended that the analyses performed for these wells include the complete major-element suite (cations: Ca, Mg, Na, K; anions: sulfate, chloride, nitrate, alkalinity). This will complement available data from the groundwater treatment system Performance Monitoring Program to support assessment of groundwater sources and possible mixing.

Response:
The Army agrees with the recommendation. Details of the proposed sampling program will be provided in the CSA Scope of Work.

46. Page 20, Section 3.2.4: The adequacy of the existing monitoring well network should be evaluated in detail. Additional monitoring control is likely needed in several areas of the site (including 'upgradient' and 'downgradient' areas). Please see general comment 2, above.

Response:
Please see response to comment 2.

47. Page 20, Section 3.2.4: The last bullet states that: "Selected groundwater samples should be analyzed for presence/absence of tannins in order to eliminate the possibility that peat-derived organic acids may be mobilizing As from naturally-occurring subsurface material." Please provide support (text or citations) that the presence of tannins is evidence that they have mobilized As. Although this is likely a good indicator for the presence of peat material, a more direct indicator would be examination of boring logs for mention of peat. The cause of As mobilization should not be attributed solely to the presence of tannins unless accompanied by measurement of low pH or further support of this phenomenon from the literature. See, also, general comment 9.

Response:
As part of the CSA, existing borings logs will be reviewed for evidence of peat. Tannins are water soluble compounds that will be measured in selected groundwater samples to detect the presence of peat lenses. It is unknown at this time whether they will be detected and, if so, whether concentrations of tannins will correlate with any other water quality parameter. The DGA Report did not conclude that the mobilization of As could be "attributed solely" to the presence of tannins.

48. Page 20, Section 3.2.4: It would also be potentially useful to attempt to segregate the available geochemical data by lithologies. That is, identify samples by their association with the bedrock, the deep fine sand unit (e.g., SHL-22, SHL5B), shallow overburden, etc. (or some appropriate grouping), in order to identify any characteristic hydrogeochemical facies that may be present.

Response:
Please see response to comment 43.

49. Page 21, Section 3.3.1: Figure 3-5 shows an interpretation of the As concentration field, based on the maximum observation at any location (i.e., over both time and any vertical profile that may have been sampled). While this is a useful visualization, a longer-term goal of the proposed investigation should be to delineate the As in 3-dimensions. The depth associations may be a key element in refining the CSM. It will be important to define the horizontal and vertical extent of the plume for appropriate evaluation of the groundwater remedy. See general comment 1.

Response:
See response to comment 16. Comment noted.

50. Page 21, Section 3.3.1: The text notes that there are limited areas where As concentrations have increased over the duration of the monitoring program. As the conceptual model for the groundwater hydrology and geochemistry develops, it should be a goal to rationalize these observations.

    Response:
    Comment noted. The CSM in the CSA will build on the analyses and observations of previous work, such as the assessment of data trends in the 2005 Five Year Review.

51. Page 21, Section 3.3.1: The 3rd paragraph states, "… the upgradient data lack simultaneous field measurements of Oxidation-Reduction Potential, and therefore the "nondetect" values do not effectively substantiate that the upgradient As contribution to groundwater is insignificant." While it is agreed that the lack of ORP data in the upgradient domain is a gap in knowledge of the geochemistry of groundwater moving under the cap, it is not clear how this bears on conclusions about upgradient As. If As is ND in upgradient groundwater, the advective flux of As entering the domain beneath the cap is negligible. Please clarify the intent of this statement.

    Response:
    As stated in the sentence preceding the one cited in the comment, elevated As has been historically detected in some upgradient wells. In this context, simultaneous ORP measurements would be useful in understanding the potential for upgradient contributions of As. The phrase will be rewritten as follows: "… the upgradient data lack simultaneous field measurements of Oxidation-Reduction Potential, and therefore *it is difficult to* substantiate that the upgradient As contribution to groundwater is insignificant."

52. Page 21, Section 3.3.1: Plume Delineation: Generally, it is EPA's interpretation of existing well data that additional well/boring coverage may be needed in areas beyond the two general regions of deficiency mentioned here. A thorough review of present well coverage (locations, depths, hydro-stratigraphic units) needs to be evaluated by the BCT. See, also, general comment 2.

    Response:
    Please see response to comment 2.

53. Page 21, Section 3.3.1: The last paragraph on this page discusses the need for data along the western margin of the high-As region. Another data gap on the west side of SHL is the characterization of bedrock groundwater chemistry. The bedrock groundwater may exert significant influence on the chemistry of the overburden groundwater beneath the landfill. It is likely that there is upward leakage from the bedrock to the overburden (as supported, for example, by the 4th bullet on page 22, section 3.3.2, which states that >50% of the recharge beneath the landfill is derived from the bedrock), and very high As is observed at N5-P1 (screened in bedrock). It is recommended that one or more boreholes be installed on the

west side of the landfill to characterize the bedrock groundwater chemistry. The boreholes should be sampled at multiple depths. Installation of permanent monitoring wells should also be considered.

Response:
The Army believes that the monitoring well network, as proposed to be augmented, is adequate to address the significant questions regarding downgradient arsenic distribution and transport related to the Technical Objectives. In regard to the contribution of arsenic from upgradient areas west of SHL, we note that the proposed geophysical and physical investigations in this area are expected to generate data providing control on the magnitude of groundwater influx. If results of the proposed program reveal that a west-side monitoring well is desirable, its location will be best selected with data from the proposed program.

54. <u>Page 22, Section 3.3.2, 3rd and 4th Bullets</u>: It is unclear how the recharge values were estimated. Provide the basis for these values.

    Response:
    These water budget components have been determined directly from the existing numerical model which quantifies all groundwater fluxes through the aquifer system. However it is acknowledged that they are not field estimates, though the model is calibrated to field data (primarily aquifer heads). The language of the draft DGA report, specifically the sentence which introduces those bullets, will be revised to read as follows: "The current model indicates the following components of the water budget through the landfill:".

55. <u>Page 22, Section 3.3.2</u>: Groundwater Flow Modeling: While the pre-existing groundwater model is a useful tool, it is not clear, as it is currently configured and calibrated, that it is sufficiently accurate to achieve the two objectives listed in this section, i.e.; 1) quantitative estimation of As flux to Red Cove and Nonacoicus Brook; and 2) evaluation of potential impacts to the McPherson well. Understanding of the site is greatly improved since the model was constructed, and improvements to the CSM need to be more completely reflected in the numerical model before it can be reliably used for the stated purposes. EPA has previously pointed out potential shortcomings of the existing model with respect to its depiction of groundwater flow lines in the vicinity of Red Cove. Analysis of synoptic head data (EPA presentation at the June BCT and RAB meetings) suggests a greater level of discharge to Red Cove, and more importantly, a vast region east of the cove (within the landfill footprint) was identified as needing additional monitoring well control in order to further clarify this issue. EPA's previous analysis also used the model output (in part) to conclude that significant gaps in monitoring well coverage existed at the north end of the landfill. Although additional control has been added to the north pursuant to the extraction well installation effort, additional control points, and incorporation of the new data into the model, are needed before the model can be reliably used to evaluate potential impacts to the McPherson well. See, also, general comment 7 and comment 17.

    Response:
    All data collected during the course of the CSA investigation, including water levels from recently installed monitoring wells in the north area (which were yet to be surveyed at the

time this report was prepared) and data generated by EPA studies in the Red Cove area will be used to reconfigure and recalibrate the model as necessary. When that effort is complete, the revised model will be used to evaluate the potential for impacts to the McPherson well as well as discharge to Red Cove, and thereby confirm or refute the results of the preliminary analysis presented here.

56. Page 23, Section 3.3.3: Although the gradient in the bedrock aquifer likely follows the topographic gradient, it is not certain that Shepley's Hill "prevents" flow to the west (e.g., fracture-controlled flow). Additional bedrock control is needed along the western margin of the site. See comment 53.

    Response:
    If the hydraulic gradient in the bedrock aquifer follows the topographic gradient, then groundwater must flow from the crest of Shepley's Hill east toward the landfill and therefore the hill does preclude flow toward the west. While discrete fracture permeability certainly occurs in bedrock aquifers, as stated by the commenter, it is not expected that hydraulic gradients exist such that flow would be driven counter to the topographic slope and, further, such a process would directly contradict the current hypothesis that Shepley's Hill is a source of "run-under."

57. Page 25, Section 3.3.4.3: In addition to the ongoing EPA work, additional monitoring well control is needed in the central portion of the landfill west of Red Cove in order to clarify larger-scale flow patterns in relation to Red Cove.

    Response:
    Please see response to comment 2. Installation of monitoring wells within the landfill footprint would risk violating the integrity of the cap and would not support the Technical Objectives and, therefore, is not recommended.

58. Page 26, Section 3.4: The 1st bullet of the last paragraph indicates the relative importance of the PVC competence over "minor surface conditions" to overall landfill cover performance. EPA is concerned with the de-emphasis of surface conditions here. Insufficient performance of the sand drainage layer above the PVC and of the landfill surface (slope and length) could cause major surface erosion and flooding during rain storm events resulting in significant water infiltration through any PVC defects. Poor surface conditions are of primary concern and may require redesign of the landfill cap to minimize the water infiltration in the long term.

    Response:
    The major barrier to precipitation infiltration into the landfill mass is the PVC geomembrane. The overlying sand drainage layer and topsoil/vegetation layers also provide important functions for the integrity of the PVC cover, such as UV protection, prevention of physical damage, drainage, and erosion prevention. The CSA will include visual inspection and limited physical characterization of the cap layers above the geomembrane to assess their functionality. Minor conditions that do not necessarily require an equal level of investigation and interpretation include such items as shallow ATV ruts, small patches of nonvegetated soil, an erosion rill a few inches deep, or an isolated small animal burrow or animal tracks.

Please see the related response to comment 61.

59. <u>Page 27, Section 3.4</u>: How will it be determined when limited testing of PVC is "absolutely needed"?

    Response:
    The field investigation program for the landfill cap focused on the CSA and CAAA provides for two phases. The first phase essentially involves uncovering the PVC in selected locations and visually examining the PVC as well as the overlying soil. As an outcome of the initial evaluation, the second phase will commence. If the PVC appears to be satisfactory at all locations when examined, then additional test pitting will be conducted to verify the conditions observed. If indicators of deterioration are observed in any of the test pits, then additional test pits will be performed and samples of the PVC will be extracted and submitted to a geotechnical lab for physical testing. Examples of deterioration indicators include deep stone or sharp object depressions or penetrations, PVC crumbling in the hand and split seams.

    Extraction of PVC samples, even with patching, comprises a minor but significant breach in the landfill cap. Even though the patch may prevent water infiltration for many years, lateral stresses on the PVC through surcharging and settling may allow some infiltration to pass through the patch in the near or far future. In consideration of this consequence, testing will not be considered absolutely necessary unless the PVC is visibly and substantially degraded.

60. <u>Page 27, Section 3.4</u>: In addition to the bulleted "Data to be collected", EPA requests that the use of electrical leak location survey equipment be employed to detect leaks in the geomembrane.

    Response:
    As discussed in the response to comments on the Nobis Engineering work plan, AMEC evaluated the potential use of electrical leak location survey equipment and determined that it was not appropriate for this site. That response is repeated below for ease of reference.

    On 4/27 and 4/28/05 Art Lazarus of AMEC spoke to Ian Peggs, President of I-Corp International regarding the application of electrical methods for leak detection in the SHL. I-Corp is a leading international firm providing liner integrity and leak location surveys since 1987.

    In an email to AMEC dated 4/28, he states that the" conventional applied potential electrical technique will not be effective since the soil on top of the liner is connected to the subgrade soil around the periphery". Instead he suggested we consider infrared spectroscopy that measures methane leaks in liners. However, gas collection piping systems can severely limit effectiveness. Given the uncertainty, AMEC did not propose to rely on either method.

    Regarding the inquiry from the EPA about ASTM Standard D7007-03 for detecting leaks in geomembranes, Art Lazarus called Ian Peggs again in November 2005 . He stated that his electrical method is more advanced than the ASTM standard but the electrical method in the ASTM standard has the same limitation regarding soil connected to the periphery. In addition, the original conversation was revisited regarding the electrical method and his opinion has not changed even with the additional site information gathered since April 2005.

61. Page 27-28, Section 3.4.4: This section explains that an analysis will be conducted to determine whether current and planned grades conform to the MDEP landfill closure technical standards. However, it is unclear whether redesign of the cap (e.g., increased slopes) to reduce water infiltration will be considered in the CAAA. EPA anticipates that redesign of the cap, including redesign of surface grades (slope and slope length) and perimeter drainage swales (to control infiltration through the cap into the waste) will need to be evaluated in the CAAA. If redesign of the cap needs to be considered as an alternative, are data gaps adequately covered for this exercise?

Response:
The CAAA Scope of Work will define the options to be considered in the CAAA based on the findings of the landfill cap assessment and the conclusions of the risk assessments. The MassDEP Landfill Technical Guidance Manual identifies a four step process for the CAAA. The second and third steps call for listing and screening appropriate technologies. Redesign of the cap in its current condition and as modified by the 2005 cap maintenance and repair plan (by Nobis) will be included in the CAAA process if such actions might be necessary to protect human health and the environment. A review of existing and available original closure documents is included in the CSA and CAAA, and will include the 2006 landfill repair documents to be prepared by Nobis Engineering. No other major data gaps have been identified in this regard.

62. Page 29, Section 3.4.7: The evaluation of landfill gas will need to consider the installation of additional gas monitoring probes or wells along the southern boundary adjacent to commercial properties to investigate any landfill gas migration (especially in winter). Additional gas probes are planned for installation in this area as part of the Cap Maintenance Contract. In addition, it is unclear how the results of the "field geophysical investigations" on the location of the "anchored PVC geomembrane" would affect the installation of additional gas probes, as mentioned here. Please explain.

Response:
The Work Plan for Landfill Cap Maintenance prepared by Nobis Engineering called for the installation of 10 gas monitoring probes along 1000 feet of the southern perimeter of the landfill. According to Nobis 9 of 10 were successfully installed in December 2005 and data are pending. The probes are the perimeter compliance points to monitor the migration of landfill gas offsite along the southern boundary.

The decision to install additional probes will highly depend on interpretation of the geophysical investigation results. If geophysical investigations to determine the spatial relationship between the nearest bedrock surface and the PVC geomembrane reveal that the two are very close (e.g., less than 10 feet), additional gas probes may not be needed. If the distance is much greater (e.g., 20 feet or more) additional gas probes may be in order where gas migration can continue beyond the perimeter.

63. Page 29-30, Section 3.5.1: The text presents an argument to the effect that, if the aquifer downgradient of the landfill is not designated GW-1 under the MCP, then it will not be used as a source of drinking water. The text indicates that a human health risk assessment for drinking water would not be needed if the groundwater in the plume is not considered a potential drinking water source area. It should be noted, however, that this designation may have little influence on individuals who wish to install a private well. If the Army does not evaluate drinking water risk, then institutional controls will be needed to prevent the use of a private drinking water well. This is problematic since the Army does not own the downgradient properties. This will need to be further discussed by the BCT.

Response:
The Army acknowledges that if private wells are installed downgradient of the landfill or have the potential to be installed downgradient of the landfill, ingestion of groundwater as drinking water will have to be evaluated. Based on a review of the current GIS maps for the area, groundwater located under the landfill and immediately to the north and west of the landfill is located in a medium yield aquifer. Furthermore, the area located immediately to the west and northwest of the landfill also lies within a medium yield aquifer. Based on this information, the groundwater in the area beneath and immediately surrounding the landfill may be classified as GW-1 indicating that groundwater is designated as current or potential source of drinking water. That determination may be modified, however, by the presence of the landfill and an exemption of waste disposal areas from GW-1 classification. The Army proposes to review MassDEP policy related to Non-Potential Drinking Water Source Areas (NPDWSA) (WSC-97-701) to determine if the landfill, by classification as a "Waste Disposal" area and surrounding land uses should be excluded from GW-1 designation. Furthermore, The Army is reviewing local by-laws to determine if policies have been adopted that restrict the installation of private drinking water wells in the areas between the landfill and Nonacoicus Brook and Willow Brook due to their locations relative to the landfill, railroad right-of way, and current NPDWSA. Additionally, the McPherson well is located on the other side of Willow Brook and may not be hydrologically connected to groundwater flowing from the landfill. However, should additional information be obtained indicating that groundwater is or could be used as a source of drinking water, then the human health risk assessment will consider this exposure pathway as complete and will evaluate in the HERA.

Please note that the detailed protocols for the risk assessment will be defined in the HERA Work Plan. Therefore, since the DGA Report refers to the possibility of these further analyses during the CSA changing conclusions regarding GW-1 classification, we do not propose to modify the text of the DGA Report.

64. Page 32, Section 3.5.2.1: The 1st full paragraph suggests that the presence of floc in Red Cove is not of concern to aquatic organisms because it does not affect pelagic organisms and affects the habitat of only a limited (2%) area of the pond. EPA disagrees with this assessment for several reasons and suggests that this be discussed by the BCT. BCT discussions could serve to develop appropriate assessment and measurement endpoints for

the ecological risk assessment that is needed to determine whether the impacts of floc and As in sediment will need to be remediated.

Response:
The Army agrees that discussion of, and agreement on, assessment endpoints with the BCT would expedite the preparation of the Scope of Work for the CSA and the ecological risk assessment that will be included in the CSA. The text will be revised to state: "…the presence of floc *may not be* a concern."

65. Page 34, Section 3.6: The document advances a concept of a barrier wall/drain on the upgradient side of the landfill to limit the underflow of groundwater, and suggests that this may reduce inflow of water beneath the landfill by as much as 50%. As this concept is explored, the effect on the hydrology (e.g., the vertical gradient driving upward flow from bedrock to overburden) should be evaluated. Reducing the lateral inflow of groundwater may increase the upward leakage from bedrock. This highlights the need for more complete characterization and better understanding of the role of bedrock groundwater in the As transport picture at SHL.

Response:
See response to comment 19. It should be clarified that the remedial concept cited in the comment is one example of an approach that may be considered in the CAAA. Ultimately, the findings of the CSA with regard to unacceptable risks not mitigated by the contingency remedy specified in the ROD will determine which if any remedial alternatives are evaluated. To clarify this point in the document the final sentences in paragraphs three and four of Section 3.6 (pages 33 and 34) will be deleted and Table 3-7 will be revised.

66. Pages 36-38, Section 4.1.2 and 4.1.3: It is recommended that a minimum number of test pits be advanced within the landfill to minimize any damage to the PVC geomembrane and that test pitting efforts be concentrated around the landfill boundary to identify the exact limit of the landfill (or investigate other purposes). It is also recommended that the test pits be performed to verify the facts, only after non-intrusive methods (e.g., electrical leak location survey, GPR, EM, etc.) have been employed.

Response:
We share the commenter's goal to protect the integrity of the PVC geomembrane. At the first level of test pit investigations, it is proposed to perform up to 10 test pits up to 30 feet in length within the fill above the PVC geomembrane covering the landfill. That represents a minimum amount desirable of about one test pit per eight acres. The second level of field investigations then proceeds after an initial determination of the observed conditions. If the PVC is determined to be satisfactory, up to five additional test pits will be done to verify conditions. If observed conditions are questionable or deterioration is evident, up to 10 additional test pits will be completed with selected locations providing PVC samples for testing. The proposed test pitting method minimizes the potential for penetrating the PVC by machine. It is anticipated that GPR will provide subsurface information relative to the ending and anchoring of the PVC along the perimeter. It is highly unlikely that electrical leak location survey would be applicable to this site, therefore, test pitting remains as the primary means

of evaluating PVC conditions.

67. Page 37, Section 4.1.2, 1st Para.: It is not clear that the work proposed in the DGA will unambiguously address the issue of whether lateral migration of landfill gas is responsible for the un-vegetated areas. Please clarify whether or not soil gas measurements are called for in the un-vegetated areas (i.e., new point-data measurements in areas which are not currently in the gas monitoring program). If not, this should be considered.

    Response:
    Within the non-vegetated areas, hand held combustible gas indicator (CGI) readings will be obtained promptly and recorded. The CGI will be placed within small hand dug holes, in advance of the use of a backhoe.

68. Page 38, Section 4.1.3: Some of the ASTM D numbers (1593, 1209, etc) are not correct. Please correct the references.

    Response:
    The test numbers will be corrected as follows: Water Adsorption (ASTM D570), PVC Thickness (ASTM D1593), Seam Strength (ASTM D751), Dimensional Change (ASTM D1204), and Permeability Under Load (ASTM D5493).

69. Page 38, Section 4.2: Please see comments 52 and 56 regarding characterization of bedrock groundwater on the western, upgradient side of the landfill. One or more bedrock boreholes and well clusters are recommended in this area. Also, additional detail is needed concerning the proposed locations/coverage of additional explorations to delineate the plumes. See general comment 5, above.

    Response:
    Please see responses to comments 52, 53, and 56. The details of proposed locations of additional explorations will be presented in the CSA Scope of Work.

    While the Army concurs that one or more upgradient wells in this area could be useful, the planned geophysical program is likely to provide information that is critical to making this determination, and to well siting if additional wells are indeed indicated. Therefore, the Army believes it is prudent to await the results of the proposed program before planning additional monitoring wells.

70. Page 39-40, Section 4.4: Geophysical surveys: Areas to be surveyed and proposed survey transects should be indicated on an appropriate figure at the Work Plan stage. It is also noted that both the methods discussed here (GPR and GEM-300) rely, in this application, on the presumption of a moisture contrast between the drainage layer above the liner and the presumably dry waste materials below it. The recurrent presence of large areas of standing water at the site, suggests that, at a minimum, the geophysical work will need to be scheduled at a time which will optimize the chances of encountering the presumed conditions. A GPR survey may be useful to identify the different underlying soil layers, but EPA questions whether it will be capable of identifying the 30 mil PVC geomembrane. The

factors which will lead to a successful implementation of the GEM-300 technique, as proposed here, is in need of clarification.

Response:
The design and anticipated outcome of the geophysical investigation will be discussed in detail in the CSA Scope of Work. Briefly, the GPR signal is unlikely to be significantly affected by the landfill liner membrane itself. However, the anticipated moisture contrast above versus below the liner is an appropriate target for the GPR method. We expect therefore that the depth and lateral extent of the liner will be indirectly imaged.

71. <u>Figure 3-5</u>: Are the hotspots connected? Additional well control is needed to assess this important CSM issue. The central portion of the landfill (e.g., west of Red Cove) is generally devoid of monitoring well control. Similarly, the extensive western boundary of the landfill has only limited monitoring. The limits of the arsenic plume has not yet been delineated in the southwestern corner of the landfill.

Response:
The isoconcentration contours may or may not be connected; the Army concurs that the data to definitively answer this question do not exist. However, understanding the continuity of the isoconcentration contours does not appear to be of first-order importance to fulfilling the Technical Objectives for this project.

72. <u>Table 1-2 and 5-1</u>: The last sentence of Table 1-2 indicates that the "…CSA and CAAA reports will be incorporated within the second Five Year Review for Shepley's Hill by reference…" The last sentence of Table 5-1 indicated that: "The combined CSA and CAAA reports will be incorporated within the second Five Year Review for Shepley's Hill Landfill by reference." In both these tables, it is more accurate to state: "A protectiveness determination of the remedy for SHL was deferred in the 2005 Five Year Review until further information is obtained through the completion of the CSA and CAAA. The CSA and CAAA reports will meet a critical milestone obligation set forth in the 2005 Five Year Review."

Response:
The text will be revised to reflect this comment.

Comments:

1. Stakeholders Technical Objectives – please incorporate the following DQOs:
   a. Develop a final corrective action alternative for all Operable units that will minimize future O & M.
   b. Appropriately close the landfill (as a source control for landfill waste), address contaminant migration from the landfill and ensure that any migration is addressed for sensitive resources in the flowpath of groundwater leaving SHL in the northern plume and Nonacoicus Brook (NB), Red Cove (RC) and towards Willow Brook (WB).
   c. Evaluate the need remediation of ecological risks at RC, NB system and WB using a quantitative risk assessment as requested in previous MassDEP correspondence.
   d. The GW modeling tool will need to be refined because it is not consistent with ground water flow at SHL as developed EPA in June 2005.
   e. Determine the benefits and feasibility of consolidating portions of SHL Phase I to eliminate waste in contact with groundwater and minimize the SHL footprint.

   The CAAA will need to evaluate alternative remedial measures and compare their effectiveness to meeting performance standards of a source control and risk reduction remedy for offsite impacts. Comparing the costs of alternative remedial measures to the long-term pump and treat system operation and maintenance costs is not appropriate. Please refer to a MassDEP letter dated August 24, 2004, it was stated that we believe the source control remedy for SHL had failed and the Pump and Treat System implementation was appropriate to assist in controlling the plume migrating from SHL but additional measure needed to be taken to reduce the generation of leachate. Additionally, please refer to the Solid Waste Regulation 310 CMR 150 (6) and Chapter 5 of the MassDEP Landfill Technical Guidance Sect V, C Objectives of the CAAA.

   Response:
   Section 1.2 of the DGA Report reflects the Technical Objectives that the BCT discussed and specified in the Performance Work Statement for this project. Additionally, Section 1.2 provides overall objectives with reference to applicable or relevant and appropriate regulatory requirements, including the regulations and guidance cited in the comment (Solid Waste Regulation 310 CMR 150 (6) and Chapter 5 of the MassDEP Landfill Technical Guidance). The new objectives provided in the comment will be addressed within the context of the Performance Work Statement as follows.

   The CAAA will evaluate corrective action alternatives necessary to address unacceptable risks, if any, according to the protocols specified in the Landfill Technical Guidance Manual and under the National Contingency Plan (40 CFR 300.430(e)(9) and related guidance). Those criteria are summarized below.

Criteria for Evaluating Corrective Action Alternatives

Landfill Technical Guidance Manual	CERCLA / NCP (40 CFR 300.430(e)(9))
Overall protectiveness – risk reduction	Overall protection of human health and the environment

Criteria for Evaluating Corrective Action Alternatives

Landfill Technical Guidance Manual	CERCLA / NCP (40 CFR 300.430(e)(9))
Compliance – ability to comply with all state and federal environmental laws and local zoning considerations	Compliance with ARARs
Long and short term effectiveness, considering 1. Reliability 2. Permanence 3. Useful life 4. Adverse and beneficial effects	Long-term effectiveness and permanence Short term effectiveness
Reduction of Toxicity and Volume	Reduction of toxicity, mobility, or volume through treatment
Implementability, considering 1. Technical feasibility 2. Availability 3. Demonstrated performance 4. Support and installation requirements 5. Time to implement 6. Safety 7. Operation, maintenance, and monitoring	Implementability
Cost	Cost
Community acceptance	Community acceptance
	State acceptance

A range of possible corrective actions will be considered as appropriate based on the outcome of the risk assessment and landfill cap assessment. Those corrective actions will reflect various levels of operation and maintenance (O&M). The level of O&M required will be assessed under the regulatory criterion of implementability, as indicated in the table above, and the related criterion of cost-effectiveness. Thus, a separate objective of minimizing O&M is not necessary.

The landfill has been closed under capping plans approved by the MassDEP and a Record of Decision (ROD) and contingency remedy approved by both the MassDEP and EPA. Thus, source control measures have been taken, as have measures to address migration. The CSA/CAAA will evaluate the efficacy of those measures and determine whether they should be supplemented to protect human health and the environment from an unacceptable level of risk. Thus, the proposed DQO (b) is implicitly included in the CSA/CAAA scope as defined by the Performance Work Statement.

The commenter also suggested a DQO of "evaluate the need remediation of ecological risks [sic] at RC, NB system and WB using a quantitative risk assessment". Please see the response to EPA comment 13.

The groundwater model will be updated to reflect the data collected in the CSA, to a level of sophistication appropriate for a CSA/CAAA. The CSA Scope of Work will discuss groundwater modeling further.

The commenter suggested that "The CAAA should determine the benefits and feasibility of consolidating portions of SHL Phase I to eliminate waste in contact with groundwater and minimize the SHL footprint." In keeping with the Technical Objectives in the Performance Work Statement for this project, "This CAA Analysis shall review all prior Feasibility Study alternatives, revise and/or validate these alternatives based on new data and develop any new alternatives as necessary." The Supplemental Groundwater Investigation included a feasibility study of remedial actions, among which was the option of excavating and consolidating the landfill waste at the landfill site. Thus, this alternative will be assessed in light of current conditions, if the conclusions of the CSA indicate that it could be necessary to respond to an unacceptable level of risk to human health or the environment. No additional data quality objectives must be added to the DGA Report in order for this alternative to be evaluated.

The CAAA will evaluate alternative remedial measures and compare their effectiveness to address unacceptable risks to human health and the environment, as specified by the Technical Objectives and required by applicable or relevant and appropriate regulations. Neither the Landfill Technical Guidance nor the NCP explicitly address a CAAA/FS at a site where remedial actions have already been taken, so the regulations do not stipulate whether remedial action alternatives should be compared to maintaining and monitoring the existing system. The "no action" alternative could be carried through the CAAA evaluation. Logically, maintenance and monitoring of the existing cap and groundwater extraction and treatment system should also be considered in the evaluation so that stakeholders can understand the incremental costs of incremental risk reduction from implementing additional remedial actions. Those costs will be evaluated on the following basis: capital investment, annual O&M, and present worth O&M based on the estimated life of the project. The estimated life of the project will depend on the nature of the alternative under consideration.

Additional remedial actions would only be warranted if the CSA/CAAA negated the conclusions in the ROD and Explanation of Significant Differences (ESD) that the current remedy is an appropriate means to address the potential risks at the site.

The details of the CAAA methodology will be described in the CAAA Work Plan, rather than in the DGA Report. Thus the DGA Report will not be revised to reflect this discussion.

2. CSM
   a. Needs to include an evaluation and determination of an actual arsenic waste source, i.e.

ash, exists in SHL and is the cause of the extremely high arsenic sample results.

b. Iron may be as great a risk driver for aquatic systems as arsenic, both sediment, water and physical issues should be evaluated for Red Cove. All contaminants identified through historical data should be evaluated for risks they may pose in different media.
c. The CSM should evaluate the length of time it would take for the plume to re-oxygenate after the SHL source is adequately controlled as a factor in the CAAA.
d. Even if the detected concentrations could be demonstrated to be naturally occurring due to the reducing conditions in the aquifer and bacterially mediated chemical reactions that might result in increased concentrations of dissolved arsenic in overburden groundwater, it would seem that the conditions created due to the landfill's existence would be considered to be "non-naturally occurring". Therefore the landfill's existence and resulting subsurface conditions would still be responsible for excess arsenic mobility above what would occur under naturally occurring conditions (i.e. oxygenated groundwater that would not result in such high concentrations of arsenic as have been observed beneath the landfill.

Response:

a. Identifying arsenic waste sources within the landfill is not consistent with the Technical Objectives in the Performance Work Statement. Further, accurately defining such materials could be extraordinarily difficult without seriously compromising the geomembrane. In summary, we believe that due to the nature of historical waste disposal practices, the size of the landfill, and the importance of maintaining the cap, it is imprudent to perform an intrusive investigation into the landfill. Please see the response to comment 1.
b. Compounds identified from previous investigations will be evaluated. For example, as stated on page 30: "However, concentrations of arsenic, barium, iron, manganese, and nickel exceeded sediment quality benchmarks."
c. Comment noted. Based on the large number of variables which affect reoxygenation and the complexity of the system, it is unlikely that this length of time can be estimated accurately.
d. Comment noted.

3. CSA/CAAA Data Quality Objectives
   a. Comprehensive evaluation of SHL impact on the environment should include Willow Brook.
   b. A quantitative ERA must be done – for both RC and NB system. A qualitative ERA can be performed for WB.
   c. Evaluate whether Clean Air Act New Source Performance Standards are applicable to SHL based on waste volume.
   d. SHL contains ash waste and incinerator disposal, the CSA should locate and evaluate the ash as a contributor of arsenic seen in landfill sampling, as well as determine its contribution the arsenic plume migrating toward NB.

   Site specific arsenic background numbers should be generated or used, as there are many areas of Devens that do not have elevated arsenic levels in soil or groundwater

Response:

a. The impact to Willow Brook will be evaluated if evaluation of the hydrogeologic data in the CSA indicates that groundwater containing arsenic from the site is reaching Willow Brook..
b. Please see response to EPA Comment 13. "Qualitative" will be changed to "quantitative."
c. The landfill contains an estimated waste volume of 1.3 million cubic yards or 1 million cubic meters. Relative to the pertinent threshold of 2.5 million cubic meters (as defined in 40 CFR 60 Subpart Cc), the Clean Air Act New Source Performance Standards are not applicable.
d. Please see response to EPA comment 3.

Background arsenic values for groundwater will be defined based on a combination of existing studies and site-specific data as appropriate for the CSA/CAAA.

4. The DGA discusses whether arsenic is released from natural materials or it comes from a source within the landfill, the landfill contributes reducing conditions in its plume, which in turn causes arsenic releases. MassDEP concurs with the DGA proposal to evaluate the contribution of arsenic contaminated fill to the leachate plume emanating from the landfill. This evaluation will help guide the CAAA evaluations for enhanced source control measures.

   Response:
   Comment noted.

5. The report discusses a data quality objective to "Support the concept that the stream/wetland is a hydraulic barrier" (Section 3.3.4.1). This raises concern that the only data to be collected is that which may support this theory and negate the collection of data that might draw doubt upon it. This would lead to only two possible results: confirmed (stream is a barrier) or inconclusive (unable to determine based on the data). The latter leaves us back at the beginning with the same data gap. The approach should be two-fold: 1) to determine whether the stream is acting as a hydraulic barrier for both shallow and deep groundwater flows or if there underflow of groundwater from either or both groundwater depths, and 2) to evaluate the groundwater/surface water interaction to determine if (and how much) groundwater discharges to the brook from either the shallow or deeper portions of the aquifer or if the deeper arsenic-impacted groundwater merely changes direction and follows the general direction of stream flow but remaining groundwater. If this latter is the case, then the possibility remains that it may discharge further downgradient (another data gap).

   Response:
   In the Data Quality Objectives list, the phrase "Support the concept that…" will be replaced with "Determine if…". The proposed near-stream piezometers installations, hydraulic monitoring, and stream sediment, and groundwater sampling will define gradient relationships with respect to the stream/wetland, and confirm or refute the hypothesis that the stream is a hydraulic barrier.

6. Section 4.2 discusses installing two shallow drive point piezeometers transects across Nonacoicus Brook and the adjacent wetlands to measure hydraulic heads. While this may be useful for the immediate shallow groundwater flow, it would be difficult to interpolate the deeper arsenic-impacted groundwater relative to these points or determine vertical gradients.

The transects should consist of multilevel piezeometers in order to overcome the uncertainties regarding vertical flows, rule out the creation of more data gaps, and confirm the hydraulic barrier concept. These could be installed during winter conditions to facilitate advantageous conditions.

Response:
The Army agrees with the recommendation that deep-shallow piezometers pairs be installed near the stream. Depth to bedrock in this area is believed to be in excess of 100 feet below ground surface based on existing boring logs. Due to the wetland conditions, use of heavy equipment to install deep monitoring wells is highly impractical. Therefore, piezometers will be emplaced to the maximum depth practical using manual installation methods. The details of the piezometer installation program (and appropriate contingencies with regard to depth of installations) will be presented in the CSA Scope of Work.

7. Underflow and Perimeter anchoring of PVC Geomembrane - The Army proposes to use nondestructive geophysical methods to "determine how much water infiltration is entering the refuse" by identifying the perimeter conditions. Without having a formal work plan, it is difficult to determine in this report exactly how this will be accomplished. Also it is not apparent the level of effort to be put into the geophysical testing (how many locations this will be done, and what kind of control to be used to confirm the results of the method). I recognize that the Army's concern is to "prevent inadvertent destruction of the existing anchoring system." However, it is recognized by all parties that the physical relationship between the perimeter end of the PVC and the soil and bedrock with an anchoring system is minimal, and that limited test pits conducted previously by others did not report an anchoring system. Given that test pits will be performed to inspect the PVC at numerous locations with precautions in place to prevent damaging the PVC, performing test pits at a landfill edge should not be of much concern. Performing a limited number of test pits to validate the geophysical results would be useful.

   Response:
   Comment noted. The CSA Scope of Work will describe the details of the field investigation.

8. Groundwater Flow Modeling has been used in numerous applications for SHL investigations and remediation. MassDEP concurs that a unless a rigorous validation of the model is undertaken results will be preliminary at best and will constitute a data gap until validation is completed, including both groundwater table and deeper aquifer information from both sides of Nonacoicus Brook

   Response:
   Validation of the model will be conducted. Comment noted.

9. The recent work undertaken by USEPA on Plow Shop and Grove Pond, among other results, it showed that there is elevated chronic toxicity of sediment in Red Cove, in addition to the investigations proposed through the CSA there is an impact already established at Red Cove and the CAAA needs to address the remediation of that impact

Response:
The EPA conducted (acute) ten-day sediment toxicity tests using *Hyalella azteca* and *Chironomus tentans*. As discussed on page 31, "Red Cove sediment toxicity testing showed growth effects to one of two test organisms (USEPA, 2005a)." These test results will be used, along with other information to be gathered, to evaluate potential impacts to Plow Shop Pond and to evaluate remedial alternatives in the CAAA as appropriate to address unacceptable risks. The text of the DGA Report will not be modified.

10. The proposed assessment for Landfill Cover Assessment needs to include, in addition to focusing on competence of the low permeability (PVC) layer, the other components of the cap, including the effectiveness of the gas collection layer and the possible moisture intrusions that could cause degraded effectiveness, the development of detailed waste volume amounts to determine if the Clean Air Act New Source Performance Standards apply, and the engineering design to ensure that all components of SHL will be effective if surcharged with the pesticide soils being removed as part of another Devens cleanup

    Response:
    The effectiveness of the gas collection system will be evaluated based on review of data from gas probes at the edge of the landfill, located between the waste and receptors. Moisture intrusion would primarily occur if the PVC had been compromised, and will therefore be considered in the assessment of the PVC layer. With respect to the New Source Performance Standards, please see the response to comment 3 above. The potential emplacement of pesticide containing soils on the landfill is being managed as a Release Abatement Measure (RAM) under the Massachusetts Contingency Plan. The loading assessment would be performed as a component of the RAM Plan.

11. While Zone IIs have been developed and approved by MassDEP for McPherson well, if information is developed during the CSA to indicate that the data upon which that determination was made was in error, specifically the Well Yield 0-100 gpm Transmissivity 0-1400 ft2/d area, the CSA will need to include the possibility that a complete pathway exists from SHL plume to McPherson Well.

    Response:
    Comment noted.

Comments from Loureiro Engineering Associates, Inc. on behalf of MassDEP

1. Section 3.1.1, "Existing CSM", pages 11 and 12, Bullet # 2 –
    - The statement is made that the "original primary source of dissolved arsenic in groundwater is probably the metasedimentary bedrock…", yet there is no documentation to support that statement. In only presenting the unsupported assertion that concentrations are due to naturally occurring concentrations in bedrock, the statement alone fails to recognize other potential sources of arsenic in that particular environment, and apparently dismisses either the existence, or effects, of excess arsenic (above concentrations in bedrock or naturally occurring overburden sediments) in the subsurface that may be due to ash or other waste in the landfill. To assume that no waste was

disposed in the landfill that might have contained arsenic or arsenic compounds seems unrealistic, without presenting solid evidence for such an assumption.

- The statement is made that "bedrock is known to contain elevated concentrations of arsenic", but the source of that statement was not provided, and no actual data was included to document whether or not concentrations in the bedrock in the vicinity are actually elevated and whether the concentrations of arsenic that are present would be high enough to result in the concentrations detected in groundwater in the overburden aquifer (i.e., no site-specific documentation of background arsenic concentrations has been provided to support the assertions that are being made).

- The CSM does not adequately present the mechanism(s) for getting arsenic from bedrock into overburden groundwater at the locations where elevated and high concentrations of arsenic in overburden groundwater have been observed and does not provide sufficient information to indicate that the concentrations in bedrock are at all "elevated" enough to result in the concentrations that have been detected in overburden groundwater. There is no documentation describing actual concentrations of arsenic in groundwater within the bedrock aquifer discharging into the overburden aquifer or in the unconsolidated sediments comprising the overburden aquifer.

Response:
Please see the response to EPA comment 24. As stated in the opening paragraph of Section 3.1, the text that follows is a summary of the *existing* CSM, which will be refined during the CSA process, and does not therefore represent new "assertions."

2. Section 3.1.1, "Existing CSM", pages 11 and 12, Bullet #'s 3 through 6 --
   - Although graphs have been provided to illustrate the respective concentrations of such constituents as iron and manganese and geochemical conditions within an aquifer that can affect the concentrations of dissolved arsenic in the subsurface, there is no documentation regarding the equilibrium of such reactions and whether conditions in the aquifer are at equilibrium or not, and whether the concentrations of naturally occurring arsenic concentrations in unconsolidated aquifer sediments are sufficient to result in the detected concentrations of arsenic in overburden groundwater. Since there are no data presented for concentrations of naturally occurring concentrations of arsenic in the aquifer solids or in the waste materials in the landfill. It is difficult to assess whether or not detected concentrations in groundwater would be "naturally occurring" in that environment.

   - Even if the detected concentrations could be demonstrated to be naturally occurring due to the reducing conditions in the aquifer and bacterially mediated chemical reactions that might result in increased concentrations of dissolved arsenic in overburden groundwater, it would seem that the conditions created due to the landfill's existence would be considered to be "non-naturally occurring". Therefore the landfill's existence and resulting subsurface conditions would still be responsible for excess arsenic mobility above what would occur under naturally occurring conditions (i.e. oxygenated groundwater that would not result in such high concentrations of arsenic as have been observed beneath the landfill.

- Although it was stated that the reducing conditions seen beneath the Shepley's Hill landfill are observed at other landfills, the source of the document cited in Section 3.2.1.3 regarding landfills in Massachusetts and New Hampshire was not provided. The information that was provided on other landfills (also in Section 3.2.1.3) was insufficient to support an assertion that conditions observed at the Shepley's Hill Landfill were similar to those reported for other landfills, and the applicability of those studies to the Shepley's Hill Landfill was not demonstrated. Without documenting the applicability of the reported studies to the conditions observed at Shepley's Hill Landill using actual data from Shepley's Hill on naturally occurring concentrations of arsenic in bedrock and unconsolidated deposits, groundwater quality in bedrock, and a direct connection between the naturally occurring conditions to the high concentrations of arsenic in groundwater in a limited portion of the aquifer beneath the landfill, it is inappropriate to assume that the what was observed at other locations is occurring at Shepley's Hill. Such a comparison would also require documentation of applicable conditions at each of the other sites, including documentation that no waste containing arsenic was present at those landfills.

- The fact that groundwater beneath several areas of the Shepley's Hill Landfill appears to exhibit reducing conditions without such high arsenic concentrations as have been detected in specific locations beneath the landfill would suggest that it may not be the reducing conditions alone that result in high arsenic in groundwater. Rather, it would appear that the high arsenic in groundwater emanates from a relatively limited area and could certainly be due to another source of arsenic than naturally occurring dissolution of arsenic in either bedrock or overburden materials.

- The limited area in which high arsenic concentrations have been detected also makes it difficult to assume that the high arsenic is due primarily from a bedrock source, unless such a link can be demonstrated with actual data on groundwater quality in bedrock entering the area of high arsenic in overburden groundwater. If the actual intent of statements made regarding the bedrock being the primary source of the arsenic in groundwater at specific locations is that the bedrock is the source of the arsenic in the overburden materials that is then mobilized by reducing conditions in groundwater beneath the landfill, actual site-specific data should be provided to support such assertions.

  One would also expect, in the absence of actual data to the contrary that arsenic concentrations in overburden materials would be well distributed throughout the overburden aquifer and not restricted to the limited area in which elevated arsenic concentrations are found in groundwater. Without documentation that the background concentrations in bedrock itself and the overburden sediments are high enough to produce the observed concentrations of dissolved arsenic even under reducing conditions, and that such concentrations are limited to the area where high concentrations of arsenic are observed in the overburden groundwater, it is difficult not to consider a more localized source of arsenic in the vicinity of the elevated concentrations in groundwater to explain the observed pattern of arsenic distribution in groundwater.

- Although it is stated that iron manganese and arsenic will be re-deposited in a solid phase once oxygenated conditions are re-established in the aquifer, it is necessary to provide documentation of that hypothesis to validate that portion of the CSM.

Response:
See response to comments 1 and 4, EPA comment 36, and MassDEP comment 2d.

3. Section 3.1.3 "DGA Focus With Respect to Groundwater Flow and Surface Water Interactions" Page 13 – In addition to performing an investigation to establish the potentiometric relationship between groundwater and surface water on either side of Nonacoicus Brook, the investigation should not only focus on shallow groundwater, but also include multi-level wells that can be used to establish both the potentiometric relationships and groundwater quality in deeper groundwater (intermediate and deep zones) on either side of the brook. Depending on conditions in the immediate vicinity of the stream, it may be appropriate to place the shallow wells closer to the stream because smaller drilling equipment can be used to install the wells, while the deeper wells may need to be installed using larger drilling equipment, which could be placed as slightly further away to minimize disturbance in wetland areas.

   Water levels should be measured and groundwater samples collected from these locations on a quarterly basis for at least one year to establish seasonal variability in both hydraulic relationships and groundwater quality. Soil samples should be collected during drilling and analyzed for relevant chemicals and geochemical parameters to validate assumptions made regarding the geochemical fate and transport of arsenic, iron, and manganese. Description of subsurface materials encountered during drilling and other hydraulic and geochemical information obtained from these wells should be incorporated into the groundwater model, and the model should be revised accordingly if necessary.

   To further establish the hydraulic relationship between stream water and shallow groundwater along the portion of the brook downgradient of the landfill, in-stream piezometers should be installed and screened approximately two feet below the stream bed to measure water levels in both groundwater beneath the stream and in the stream itself using the piezometer as a staff gauge. The piezometers should also be constructed of materials that would permit sampling of groundwater from that zone to again, further evaluate the geochemical fate and transport of arsenic, iron, and manganese, and water samples should be collected from those piezometers on a quarterly basis for a minimum of one year to evaluate seasonal changes. Water-level measurements could be collected more frequently to address varying hydrologic conditions. Sediment samples should be collected at the piezometer locations and analyzed for specific chemicals and geochemical parameters to validate assumptions made regarding the geochemical fate and transport of arsenic, iron, and manganese and to assess ecological exposure if appropriate given the concentrations detected.

   It is expected that at least three to four in-stream piezometers and at least two well clusters on each side of the brook would be installed to provide a more comprehensive understanding of hydraulic relationships and geochemical conditions. The hydrologic data collected should then be included in an updated version of a groundwater model that could be developed to more accurately simulate actual conditions throughout the three-dimensional extent of the overburden aquifer in this area. The geochemical data should be used to refine the understanding of geochemical conditions in the aquifer, particularly in terms of arsenic concentrations and mobility. Both the refined groundwater flow model and the chemical transport model can be used to better assess the risk.

Response:
See response to MassDEP comment 6. The Army agrees with the recommendation that deep-shallow piezometers pairs be installed near the stream. Depth to bedrock in this area is believed to be in excess of 100 feet below ground surface based on existing boring logs. Due to the wetland conditions, use of heavy equipment to install deep monitoring wells is highly impractical. Therefore, piezometers will be emplaced to the maximum depth practical using manual installation methods. The details of the piezometer installation program (and appropriate contingencies with regard to depth of installations) will be presented in the CSA Scope of Work.

As a drivepoint installation method is proposed, no sediment samples will be collected from near-stream borings. The Army believes that the combination of the proposed stream-sediment samples, and soil samples from borings upgradient of the stream, will be adequate.

The Army believes believe that the two proposed rounds of piezometer sampling will be adequate to evaluate seasonal changes for the purpose of the CSA/CAAA. Further, utilizing two rounds of data, rather than four, will enable the project to proceed as quickly as possible.

All pertinent data will be considered for incorporation into the numerical groundwater model. However, no chemical transport modeling is proposed. Given the complexity of arsenic geochemistry, we believe that such modeling would be difficult to calibrate and would therefore provide little value.

4. Section 3.2 "Arsenic Geochemistry" Pages 13 and 14 - The discussion of the current CSM regarding arsenic geochemistry makes many statements that are not supported by any actual data from the site itself. This represents a significant data gap that must be addressed to continue the assumption on which much of the presentation and rationale for remedial actions is based that the primary source of the high arsenic concentrations detected in groundwater in specific locations beneath the landfill is the result of naturally occurring, elevated concentrations of arsenic in the bedrock. The statement that "some of the groundwater plume may be in contact with minerals in the bedrock … that may (emphasis added) have naturally elevated concentrations of arsenic" is not supported either with respect to the actual concentrations in bedrock in the vicinity of the site or by any indication of where the plume is in contact with bedrock or where the portion of the arsenic plume would have come into contact with bedrock to the exclusion of other areas of groundwater beneath the landfill that do not exhibit such elevated arsenic concentrations. Similarly, there is no discussion that addresses the contact time of groundwater with the bedrock containing

elevated concentrations of arsenic, what the equilibrium concentration of arsenic in groundwater would be given the likely exposure time and limited surface area to which groundwater in the bedrock aquifer would be exposed, or how the observed high concentrations of arsenic in groundwater at the site compare to other groundwater in contact with similar bedrock, even assuming that the arsenic concentration in local bedrock were known).

In this context, it is important to consider that a significant portion of the groundwater does not exhibit the very high concentrations of arsenic that are reported in specific areas. If arsenic is to be derived from the bedrock aquifer at concentrations that high, the conditions that mobilize arsenic would have to be present in the bedrock aquifer and the concentrations in bedrock would have to be high enough to result in the observed high arsenic concentrations under equilibrium conditions. None of the data to support these conditions has been presented.

It should be noted, in fact, that the studies on arsenic in groundwater from bedrock wells in what has been reported to be a defined "arsenic belt" indicated that only 29% of the wells indicated arsenic concentrations greater than 10 ug/l, which is many orders of magnitude below the concentrations that have been observed in groundwater beneath the landfill. No upper limit was given for wells in this study in the Data Gaps Analysis Report, but it does not seem likely that results were in the range of those reported fro the landfill. It is unclear, therefore, how the assumption can be made that it is the bedrock aquifer or groundwater from the bedrock aquifer that is the primary source of arsenic detected in groundwater beneath the landfill, and no connection between the information reported in Section 3.2.1.1 and the detected concentrations at the landfill was provided.

Response:
The discussion of arsenic on pages 13 and 14 was intended as introductory material to the discussion of site-related data on pages 16 – 19.

Both the correlation of arsenic with manganese and iron and the presence of elevated arsenic within a particular range of ORP (0 to –200 mV) is consistent with the mechanisms of mobilization of naturally occurring arsenic at other landfills (e.g., see Delemos et al., 2006 and USEPA website cited in EPA comment 26). The Army is therefore confident that a more detailed statistical analysis will reveal a stronger relationship (due to the weight of additional data points) between dissolved arsenic and iron, manganese and ORP. The collection of additional monitoring data in 2006 may also lend more support to the supposition that naturally occurring arsenic is being mobilized from amorphous iron oxyhydroxides that may be present within native subsurface geologic materials.

The commenter cites a literature report, i.e., "It should be noted, in fact, that the studies on arsenic in groundwater from bedrock wells in what has been reported to be a defined "arsenic belt" indicated that only 29% of the wells indicated arsenic concentrations greater than 10 ug/l, which is many orders of magnitude below the concentrations that have been observed in groundwater beneath the landfill. " Please provide the reference for this report.

Remaining points within this comment are noted.

5. Section 3.2 "Arsenic Geochemistry" Page 19 – The text includes the statement that "an upper limit for iron or manganese… also infers an upper limit for arsenic since all three elements are derived from the same parent material". There are numerous assumptions that must have been made to present such a statement, including the assumption that iron, manganese, and arsenic, are all derived from the same parent material, which has certainly not been demonstrated. There are numerous iron-bearing minerals that do not necessarily contain arsenic, even in naturally occurring situations. In this case (deposition in a landfill setting), one would assume that there are other sources of iron that would not contain arsenic, as the fairly wide distribution of arsenic vs. iron on Figure 3-3 illustrates. Both the graphs of iron vs. arsenic and manganese vs. arsenic also indicate that while there seems to be an upper limit to the concentrations of both iron and manganese, the concentration of arsenic does not seem to indicate and upper limit (as arsenic values seem to increase over at least an order of magnitude, while both iron and manganese concentrations seem to level off. This assessment of continued increase in arsenic concentration also appears to be supported by the graph in Figure 3-1, in which arsenic concentration is plotted against ORP. The arsenic concentration appears to still be increasing as ORP decreases. With no evidence of a maximum concentration, other than a concentration that might be limited by the ORP values in the aquifer.

   It should also be noted that the statistics report indicates that the assumption of normality is rejected for arsenic concentrations in groundwater. However, including all of the results into the normality test is based on an assumption that all arsenic detected is due to naturally occurring concentrations. Rather, one should have considered, especially once the assumption of normality was rejected, that more than one separate population might exist. Presumably, this could be a naturally occurring population and a population derived from another source, presumably not naturally occurring.

   If the statistical analysis were re-run to separate out the much larger population at the lower concentration ranges or to de-design the histogram to illustrate more effectively that lower concentration range, it is likely that the lower-range concentrations might be normally distributed and the elevated and high concentrations would stand out as outliers, probably derived from another source. While those elevated concentrations could be the result of that other source or the result of naturally occurring arsenic being exposed to the reducing conditions in the overburden aquifer that developed as a result of the landfill, it would still suggest the landfill as the cause of the contamination. This could either be due to a source of arsenic above that which would exist under natural conditions or because the geochemical conditions that developed in the aquifer due to the characteristics of landfill leachate mobilized additional naturally occurring arsenic. If that latter scenario were actually the case, it would have to be demonstrated that the naturally occurring arsenic concentrations were high enough to result to result in the dissolved concentrations that have been observed. Such information has not to date been provide, and that data must be generated to support the latter assumption.

   Response:

Comment noted. A more rigorous statistical evaluation will be performed as part of the CSA. Please see response to LEA comment 4.

6. Section 3.3.2 – "Groundwater Flow Modeling" Page 22 – The text states that "While a rigorous validation of the model has not been completed, this preliminary result suggests …". It is very important that rigorous validation of any groundwater model be performed before any final decisions are made that are based on that model if those decisions would be affected by the model results. Not only should all newly acquired data be incorporated into a new model that will be subjected to rigorous validation, but the model itself should be re-evaluated to demonstrate how accurately model assumptions and input parameters reflect actual conditions. Model validation should be performed using both older and newly acquired data, and the rationale for model input parameters and assumptions should be provided.

   The detail included in developing the newly refined model should be appropriate for the level of detail that is needed with respect to the decisions that will be made based on the output from the model (i.e. the level of detail included in the model should result in a model that can be demonstrated to accurately reflect site-specific conditions with the level of confidence necessary to meet the Data Quality Objectives for the decision-making that will be based on the model). It is necessary to demonstrate through the model evaluation and validation processes that the results from the modeling effort can be relied on with the requisite level of confidence that is needed by each of the stakeholders for every decision that will be made based on the model.

   Response:
   Comment noted.

7. Section 4.4 "Geophysical Studies" Page 39 -- It is unclear how the GPR survey will be used to assess the magnitude and rate of influx of shallow groundwater to the landfill. This should be address. If the GPR survey cannot produce that information, such information should be obtained using another method

   Response:
   Using profiles that cross the liner edge, we expect GPR to disclose the liner's lateral limit. Using one or more profiles parallel to and vertically above the liner edge, we expect to estimate the thickness of saturated, unconsolidated sediment above bedrock. This saturated thickness is what limits the potential groundwater influx from the hill slope into the waste. Conversely, the GPR may show that the liner is keyed nearly into bedrock along the liner's entire upgradient edge - in which case there would be little opportunity for hill slope groundwater to enter the landfill except via fracture flow.

8. Section 5 – "Conclusions" Page 42 – In addition to the key data gaps that were identified for the Shepley's Hill Landfill, LEA believes that additional critical data gaps to be filled include those associated with documentation for assertions that the primary source of arsenic in groundwater is the elevated concentrations in bedrock. Specifically, a comprehensive investigation should be performed to document:

- background concentrations of arsenic in bedrock surrounding and beneath the landfill
- background concentrations in unconsolidated materials at multiple locations and depths in the vicinity of and beneath the landfill
- background concentrations in groundwater in bedrock entering the overburden aquifer, especially in areas where elevated and high concentrations of arsenic have been detected in the overburden aquifer
- concentrations of arsenic in waste materials in the landfill
- locations where waste material is in contact with groundwater and nature of that waste material.

Information should also be presented to document that the waste material placed in the landfill does not contain materials with elevated concentrations of arsenic, such ash or arsenic-containing pesticides. If information is found indicating that such materials were disposed of in the landfill, efforts should be made to document the volumes of such materials, as well as probable location and timing of such placement, to the extent possible. Although it was noted on page 13 that "it is important to investigate the possibility that arsenic is being mobilized by bacterial methylation of inorganic arsenic, that may be present as a result of contaminated fill material", such an investigation is not identified in the conclusion as a key data gap or in Table 5-1.

Response:
See responses to EPA comments 1, 3, 8, 12, 18, 24, 42 and 51.

Comments from Mass Development (12/15/05)

1. On page 13, under Section 3.2, Arsenic Geochemistry, AMEC acknowledges that reducing conditions contribute to the mobilization of arsenic, and state that arsenic is likely concentrated within the pyrite-bearing bedrock. AMEC further speculates that peat underlying the landfill may be causing reducing conditions that leach arsenic from the natural bedrock substrate. These statements de-emphasize the more likely mechanism for dissolution and transport of dissolved arsenic downgradient of the landfill – reducing conditions generated by oxygen demand in the landfill leachate (as described by AMEC on page 12).

   Section 3.2 sets the stage for numerous subsequent references in the text to arsenic as a possible background condition. While arsenic is likely concentrated in the bedrock, as stated by AMEC, the distribution of dissolved arsenic at the site indicate the plume of arsenic is largely the result of reducing conditions created by contamination of the groundwater by landfill leachate. For example, as shown in Figure 3-5, arsenic concentrations exceeding 4,000 ug/L were detected beneath the landfill and in the plume downgradient of the landfill. Secondly, the concentrations are not random, but instead are highest along a longitudinal axis of the plume, parallel to the model-generated hydraulic gradients (Figure 3-6), and the concentrations decrease laterally (cross-gradient) to the plume. Lastly, maximum concentrations detected in the plume exceed by a factor of four to 400 the maximum concentrations reported in Ayotte, et al (1999), a published reference that evaluated background arsenic concentrations in the New England region, including eastern Massachusetts. Similarly, the reference cited by AMEC on page 14, Section 3.2.1.1, cites concentrations (0.74 – 6.1 ug/L) that are well below the maximum levels detected at the site. Regardless of whether the source is landfill waste or natural arsenic in soil and bedrock, the groundwater concentrations are well above typical background concentrations principally due to changes in aqueous geochemistry resulting from contamination by landfill leachate.

   Response:
   The Army agrees that observed groundwater concentrations are well above typical background concentrations. Comment noted.

2. In Section 3.3.4.1, Nonacoicus Brook and Adjacent Wetlands, AMEC proposes to evaluate contaminant plume extent and pathways by installing piezometers, monitoring the stream stage and groundwater levels, stream gauging, and surface water, groundwater, and sediments (AMEC provides additional details on these tasks in Section 4). The following additional tasks, which are fairly standard in landfill investigations, would be very helpful in delineating the contaminant plume extent:
   - Installing seepage meters, which can be used to estimate groundwater baseflow through streambed materials
   - Systematic mapping of leachate breakouts (assuming the leachate can be readily distinguished in the field, based on discoloration of sediments and vegetation by iron and manganese oxides, and iron bacteria)
   - Surface geophysics to identify high-conductivity/low resistivity zones (indicative of landfill leachate) at various depths in the subsurface. This would also be useful in addressing

the objective applicable to the McPherson well (Section 3.3.4.2) – to better delineate the leachate plume north and west of Shepley's Hill

These tasks are particularly useful in wetland areas and surface waters because they do not require machinery or heavy equipment.

Response:
It is AMECs experience that seepage meters sample a very limited area of streambed and can therefore be unreliable. Therefore, comparative stream gauging, which provides a bulk measure of groundwater discharge, is the proposed method for quantifying base flow contribution over the target reach of Nonacoicus Brook.

If leachate breakouts are noted, they will be mapped.

With respect to the comment about surface geophysics, it is possible for surface resistivity methods to define areas of high-conductivity groundwater where it is in sharp contrast and close proximity to low-conductivity groundwater. However, for this to succeed, ionic strength of the groundwater must be very high, and other variables relatively constant. The highest TDS levels observed in the project area (<1000 mg/L) do not typically cause water resistivities low enough for the groundwater itself to constitute a likely geophysical target. The downgradient edge of a solute-bearing plume – where it effectively grades into unimpacted groundwater – is a particularly unlikely geophysical target.

3. Under Section 3.5.1, Data Gaps for the Human Health Risk Assessment, page 30, AMEC states that groundwater areas beneath and downgradient of the landfill "are likely to be classified as non-potential drinking water sources areas (NPDWSAs) in accordance with MassDEP policy (#WSC-97-701)." According to the Massachusetts Geographic Information Systems (MAGIS) On-Line Viewer, the groundwater areas referenced by AMEC are classified as NPDWSAs. In addition, the Devens Bylaws should be reviewed to determine whether the plume falls within a Potential Drinking Water Sources Area (PDWSA), as defined under 310 CMR 40.0006 as "an area designated by a municipality specifically for the protection of groundwater quality to ensure its availability for use as a source of potable water supply." If additional work indicates the plume encroaches on a Current Drinking Water Source Area (the McPherson well Zone II) or a PDWSA, then the Risk Assessment must consider a groundwater exposure pathway for drinking water.

Response:
The information reviewed through the MAGIS On-Line Viewer indicates that the actual landfill is noted as a "Solid Waste Site" and the area immediately surrounding the landfill boundary is designated as a medium or high yield aquifer. Neither the landfill nor the area immediately surrounding the landfill is designated as an NPDWSA. A NPDWSA is located as a narrow band adjacent to the railroad right-of way located to the east (bisecting Plow Shop Pond), continuing to follow the railroad right-of way north of the landfill (along Shirley Street) and then continues along West Main Extension to Good Blood Drive, as a narrow strip to the west and south of Shepley's Hill and the landfill (along roadways including Kyle Avenue, Antietam Street, Cooke Street, Sarratoga Street), ultimately rejoining the railroad-right of

way. As indicated in the response to EPA Comment 63, additional research is being conducted regarding the potential for the drinking water exposure pathway to exist. The HERA will evaluate this exposure pathway should the pathway be found to be complete.

Comments from PACE (12/6/05)

1. We agree with the Draft report's conclusions that additional investigation of arsenic impacts is needed in areas north and northwest of the landfill and in the Red Cove area of Plow Shop Pond. We also agree with the conclusion that potential impacts on the MacPherson well should be more fully evaluated.

   Response:
   Comment noted.

2. We strongly believe that the Corrective Action Alternatives Analysis (CAAA) should include an evaluation of consolidating the footprint of this landfill, which is among the largest in New England. The landfill currently appears to have insufficient slopes in some areas, and it is our understanding that the Army is considering using soils excavated from other areas to provide increase slopes. An alternative (or perhaps complementary) approach would be to increase slopes by drawing in existing wastes from the fringes of the landfill. Decreasing the footprint of this large landfill would provide an environmental benefit and make future management of the landfill less burdensome. To evaluate the feasibility of this alternative, information will be needed on the extent of the waste in the landfill, and the approximate thickness of the waste on the fringe areas of the landfill. This information could be readily obtained by conducting a series of test pits around the perimeter of the landfill. We believe that this is a key data gap that needs to be identified in the Data Gaps Analysis Report.

   Response:
   Please see the response to MassDEP's comment 1.