PUBLIC REVIEW DRAFT

Hansville Landfill

Remedial Investigation/ Feasibility Study

Remedial Investigation Report

Prepared for

Kitsap County
614 Division Street
Port Orchard, Washington 98366

and

Waste Management of Washington, Inc.
801 Second Avenue, Suite 614
Seattle, Washington 98104-1502

Prepared by

Parametrix
411 108th Avenue NE, Suite 1800
Bellevue, WA 98004-5571
425-458-6200
www.parametrix.com

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CERTIFICATION

The technical material and data contained in this document were prepared under the supervision and direction of the undersigned.

Approved by Michael R. Warfel, LHG

Approved by Stephen M. Emge, P.E.

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EXECUTIVE SUMMARY

This document describes the results of a Remedial Investigation (RI) conducted for the Hansville Landfill, a municipal solid waste disposal site that operated from 1962 through 1989 near the community of Hansville in northern Kitsap County, Washington. The RI was conducted in accordance with a Consent Decree by the Washington Department of Ecology (Ecology), Kitsap County (the property owner), and Kitsap County Sanitary Landfill, Inc., (the facility operator), now known as Waste Management of Washington, Inc.

REMEDIAL INVESTIGATION PURPOSE AND SCOPE

The Hansville Landfill RI was conducted in accordance with the Project Work Plan (Parametrix 1995) that was approved by the Department of Ecology and incorporated into the Consent Decree. The purpose of the RI is to determine the nature and extent of hazardous substances in groundwater, surface water, and sediment attributable to the waste disposal areas at the Hansville Landfill, in a manner sufficient to support evaluation of various remedial actions and selection of an appropriate remedial alternative in the Feasibility Study.

The Hansville Landfill RI included the following investigations and evaluations:

- Waste source investigation,
- Landfill gas investigation,
- Groundwater investigation,
- Surface water investigation,
- Sediment investigation,
- Fish habitat assessment (including finfish), and
- A site-specific chemical screening and chemical fate and transport evaluation.

REMEDIAL INVESTIGATION RESULTS

1. The uppermost zone of groundwater beneath the Hansville Landfill occurs in a sand unit and forms the upper aquifer, which is 80 to 120 ft thick beneath the Landfill Property. Depths to groundwater range from 50 to 100 ft below ground surface, approximately 45 to 55 ft below the lowest depth of solid waste.
2. Groundwater in the upper aquifer flows to the west and southwest and discharges along the outcrop of the upper aquifer, on the hillside west of the Hansville Landfill. This discharge creates the headwaters of streams that generally flow westward to Port Gamble Bay.
3. The upper aquifer is underlain by a low-permeability clay unit known as the Kitsap Formation, a regionally extensive aquitard that greatly restricts downward vertical migration of groundwater to the Salmon Springs formation, a regional aquifer used for water supply. The Kitsap Formation is approximately 150 ft thick beneath the Hansville Landfill.

4. Landfill gas migration into the soils surrounding the solid waste disposal area at the Hansville Landfill was documented in 1991. The installation of an active landfill gas extraction and flaring system in November 1991 and system upgrades completed in 1993 proved effective in controlling landfill gas migration from the solid waste disposal area and in removing gas that had previously migrated into the surrounding soils.
5. The nature and extent of chemicals attributed to impacts from the disposal areas of the Hansville Landfill have been characterized by the RI.
6. Based on the analysis conducted within the RI, the following chemicals are recommended for further evaluation in the Feasibility Study (FS):

Chemicals	Groundwater	Surface Water	Sediment
Antimony			X
Arsenic	X	X	X
Bis(2-ethylhexy)phthalate	X		
Chromium			X
Copper	X	X	
Lead	X		
Manganese	X		X
Nickel	X		X
Nitrate	X		
Silver	X		X
Vinyl Chloride	X	X	
Zinc	X	X	

7. The highest measured concentrations of chemicals to be evaluated in the FS occur immediately adjacent to the waste disposal areas at the Hansville Landfill, with decreasing concentrations detected with increasing distance from the disposal areas and outside the Hansville Landfill boundary. The concentrations of these chemicals in onsite and offsite monitoring wells have been stable or declining over time, as the previously implemented source control/remedial actions (landfill closure, engineered cap/cover system, and active landfill gas extraction and flaring system) continue to function as designed.
8. Impacts of these chemicals to the groundwater beneath the waste disposal area should continue to decrease over time, as the engineered cover system and active landfill gas extraction and flaring system continue to function as designed, and residual leachate and landfill gas dissipate.

Results of this RI will be used in the Feasibility Study to assess potential risks posed by these chemicals to human health and the environment, and to determine the benefit and cost of remedial actions in addition to those already implemented on the Landfill Property, which include capping, surface water drainage control, and landfill gas control measures.

ACRONYMS

ARARs	Applicable or Relevant and Appropriate Requirements
BKCHD	Bremerton-Kitsap County Health District
BTU	British Thermal Unit
DCE	dichloroethylene
DOH	Washington State Department of Health
Ecology	Washington Department of Ecology
FS	Feasibility Study
FSQVs	freshwater sediment quality levels
HDPE	high-density polyethylene
KCHD	Kitsap County Health District
KCSL	Kitsap County Sanitary Landfill, Inc.
LAETs	lowest apparent effects thresholds
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
MFS	Minimum Functional Standards
MSL	mean sea level
MTCA	Model Toxics Control Act
NAVD	North American Vertical Datum
NGVD	National Geodetic Vertical Datum
ORNL	Oak Ridge National Laboratory
OVSL	Olympic View Sanitary Landfill, Inc
PAC	Policy Advisory Committee
PCBs	polychlorinated biphenyls
PCE	tetrachloroethylene
PCL	Preliminary Cleanup Level
PGST	Port Gamble S'Klallam Tribe
PLP	Potentially Liable Party
PSCAA	Puget Sound Clean Air Agency
REDOX	oxidation-reduction potential
RI	Remedial Investigation
SAP	Sampling and Analysis Plan
SCS	Soil Conservation Service
SVOCs	semi-volatile organic compounds
SWQS	Surface Water Quality Standards
TCE	trichloroethylene
TDEM	Time Domain Electromagnetic
TOC	Total organic carbon
TPH	Total petroleum hydrocarbons
TSS	Total suspended solids
USEPA	U.S. Environmental Protection Agency
VOCs	volatile organic compounds
WMW	Waste Management of Washington, Incorporated

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CHEMICALS AND UNITS

List of Units

C	centigrade
cfm	cubic feet per minute
cfs	cubic feet per second
cm	centimeter
ft	feet
g	gram
in	inch(es)
kg	kilogram
L	liter
m^2/s	square meter per second
m^3	cubic meter
mg	milligram
µg	microgram
µmhos/cm	micromhos per centimeter
mm	millimeter
mV	millivolt
ppbv	parts per billion by volume
ppmv	part per million by volume
sec	second
yr	year

List of Chemicals

CH_4	methane
CO_2	carbon dioxide
COD	chemical oxygen demand
DCE	dichloroethylene
H_2O	water
N_2	nitrogen gas
NH_3	ammonia
NO_2	nitrite
NO_3	nitrate
O_2	oxygen
PCE	perchloroethylene
TCE	trichloroethylene

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GLOSSARY

Aerobic— A condition where oxygen is present.

Anaerobic—A condition where oxygen is absent.

Anion—A negatively charged atom or group of atoms.

Aquifer—Rock or sediment in a formation, group of formations, or part of a formation which is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.

Aquitard—A geologic unit with low permeability (hydraulic conductivity) which restricts movement of water into or out of the aquifer.

British Thermal Unit (BTU)—A unit of energy; the quantity of heat required to raise the temperature of one pound of water 1 degree Fahrenheit.

Capillary Fringe—The zone above the water table in which water is drawn up and held by surface tension.

Carcinogen—Any substance or agent that produces or tends to produce cancer in humans. The term carcinogen applies to substances on the United States Environmental Protection Agency list of A (known human) and B (probable human) carcinogens, and any substance which causes a significant increased incidence of benign or malignant tumors in a single, well-conducted animal bioassay, consistent with the weight of evidence approach specified in the United States Environmental Protection Agency's Guidelines for Carcinogen Risk Assessment as set forth in 51 FR 33992 et seq. as presently published or as subsequently amended or republished.

Cation—A positively charged atom or group of atoms.

Cleanup Action—Any remedial action, except interim actions, taken at a site to eliminate, render less toxic, stabilize, contain, immobilize, isolate, treat, destroy, or remove a hazardous substance that complies with WAC 173-340-360.

Cleanup Level—The concentration of a hazardous substance in soil, water, air, or sediment that is determined to be protective of human health and the environment under specific exposure conditions.

Cleanup Standards—The standards promulgated under RCW 70.105D.030 (2)(e). Establishing cleanup standards requires specification of the following:

- Hazardous substance concentrations that protect human health and the environment ("cleanup levels");
- The location on the site where those cleanup levels must be attained ("points of compliance"); and
- Additional regulatory requirements that apply to a cleanup action because of the type of action and/or the location of the site. These requirements are specified in applicable state and federal laws and are generally established following the selection of a specific cleanup action.

Conceptual Site Model—A diagrammatic method of describing a hazardous waste site that identifies routes of contaminant migration, from contamination sources to human or environmental receptors.

GLOSSARY (CONTINUED)

Confined Aquifer—An aquifer overlain by low-permeability strata, such that the water level in a well drilled into the aquifer rises above the top of the aquifer.

Discharge Area—The location at which groundwater moves from an aquifer to the land surface or to a surface water body.

Downgradient—In a direction of decreasing groundwater flow potential, from an area of higher groundwater elevation to an area of lower groundwater elevation.

Driller's Log—A record of the geologic and aquifer conditions encountered by a driller during drilling of a water supply well. The State of Washington requires that a log be completed for each well.

Evapotranspiration—Loss of water due to the combined effect of evaporation and transpiration, the process by which plants give off water vapor through their leaves.

Feasibility Study (FS)—An evaluation of cleanup technologies and alternatives for a contaminated waste site, conducted in accordance with State or Federal regulations and guidelines; follows a Remedial Investigation (RI).

Geomembrane—A plastic sheet, typically made of high-density polyethylene (HDPE) or polyvinyl chloride (PVC), used as a hydraulic (water) or vapor/air barrier in environmental containment structures.

Geotextile—A permeable fabric sheet made of either woven or non-woven synthetic fibers, used as a protective cover for a geomembrane, a separation fabric between two soil layers, or a foundation layer to stabilize soft soils.

Groundwater Divide—A line separating two regions of diverging groundwater flow.

Groundwater Gradient—The change in total head with a change in distance in a given direction. The direction is that which yields a maximum rate of decrease in head.

Hydraulic Evaluation of Landfill Performance (HELP) Model—A computer model developed by the U.S. Environmental Protection Agency that simulates water balance conditions and predicts leachate volumes generated at landfills and other waste sites. Variables such as precipitation, runoff, percolation, and evapotranspiration can be modified to depict site-specific conditions.

Hydraulic Conductivity—A coefficient of proportionality describing the rate at which water can move through a permeable medium.

Indicator Hazardous Substance—The subset of hazardous substances present at a site selected under WAC 173-340-708 for monitoring and analysis during any phase of remedial action for the purpose of characterizing the site or establishing cleanup requirements for that site.

Landfill—The solid waste disposal area, the demolition waste disposal area, and the septage disposal area located on the Hansville Landfill Property.

Landfill Property—The area encompassed by the Landfill Property boundary, including the Landfill, the transfer station, and all other facilities and features within the Property boundary.

Model Toxics Control Act (MTCA)—Washington State's laws governing the identification, investigation and assessment, and the cleanup and monitoring of hazardous substance release sites. Ecology's authority to take action is defined by

GLOSSARY (CONTINUED)

Chapter 70.105D RCW, and the rules describing when and how Ecology exercises that authority are published under Chapter 173-340 WAC.

"on-site" and "off-site"—Areas on the Landfill Property and off the Landfill Property, respectively, as convenient references to areas of Landfill impacts. These terms should not be confused with "Site" as defined below.

Organic Chemicals—Generally compounds containing hydrogen and carbon, i.e., hydrocarbons.

Partitioning—Separation of the molecules of a chemical in the presence of other chemicals.

Permeability—The relative ease with which a porous medium can transmit a liquid under a hydraulic gradient. It is a property of the porous medium and is independent of the nature of the liquid.

pH—A measure of the acidity or alkalinity of a substance, defined as the negative logarithm of the hydrogen ion activity at 25° C.

Potential Liable Party (PLP)—A person with potential liability for cleanup of a contaminated site in Washington State, by virtue of a past or present relationship the site, per Chapter 173-340 WAC (Ecology 2001). Ecology is required to notify PLPs of their potential liability, conduct research to assess the degree of liability, and render a determination of the liability.

PLP Group—The group of PLPs for the Hansville Landfill Property that consists of : Kitsap County, Washington; Waste Management, Inc.

Polychlorinated Biphenyls (PCB)—Those aromatic compounds containing two benzene nuclei with two or more substituted chlorine atoms.

Potentiometric or Piezometric Surface—A surface that represents the level to which water will rise in tightly cased wells. If the head varies significantly with depth in the aquifer, then there may be more than one potentiometric surface. The water table is a particular potentiometric surface for an unconfined aquifer.

Preliminary Cleanup Level (PCL) —A cleanup level established for individual chemicals as part of the chemical screening process described in Chapter 8 of this RI report. The term "preliminary" is used at the screening stage to acknowledge that "final" cleanup levels will be established in the Feasibility Study, and is consistent with correspondence from Ecology (2002).

Property—The area encompassed by the Landfill Property boundary, including the Landfill, the transfer station, and all other facilities and features within the Property boundary.

Putrescible—Comprised of material that can be decomposed by bacteria.

Remedial Action—Any action or expenditure consistent with the purposes of Chapter 70.105D RCW to identify, eliminate, or minimize any threat posed by hazardous substances to human health or the environment including any investigative and monitoring activities with respect to any release or threatened release of a hazardous substance and any health assessments or health effects studies conducted in order to determine the risk or potential risk to human health.

Remedial Investigation (RI)—An investigation of the sources, type, extent, and potential impacts to human health and the environment from contamination at a

GLOSSARY (CONTINUED)

hazardous waste site. An RI is conducted in accordance with State or Federal regulations and guidelines, and precedes a Feasibility Study (FS).

Sampling and Analysis Plan (SAP)—A plan, developed in accordance with State or Federal regulations and guidelines, that specifies the objectives, rationale, methods, and procedures for collecting and analyzing samples at a hazardous waste site. The SAP is usually organized by media to be sampled (such as waste, soil, groundwater, surface water, sediments, and air).

Saturated zone—The zone beneath the land surface in which water fills all pores at a pressure greater than or equal to atmospheric pressure.

Semi-Volatile Organic Compound (SVOC)—Organic chemicals that do not readily evaporate under atmospheric conditions and generally exhibit low solubility in water.

Site—The Hansville Landfill Property plus the estimated off-site extent of groundwater, surface water, and sediment impacts from Hansville Landfill on Port Gamble S'Klallam Tribal property.

Study Area—Areas within and beyond the Site that were examined as part of this RI, generally including areas north of Little Boston Road NE and west of Hansville Road NE.

Total Petroleum Hydrocarbons (TPH)—Any fraction of crude oil that is contained in plant condensate, crankcase motor oil, gasoline, aviation fuels, kerosene, diesel motor fuel, benzol, fuel oil, and other products derived from the refining of crude oil.

Tribe—Port Gamble S'Klallam Tribe

Upgradient—In a direction of increasing groundwater flow potential, from an area of lower groundwater elevation to an area of higher groundwater elevation.

Unconfined (Water Table) Aquifer—An aquifer which is only partially filled with water and in which the water table, or a surface in equilibrium with atmospheric pressure, forms the upper boundary.

Unsaturated Zone—The subsurface zone containing both water and air. The lower part of the unsaturated zone (capillary fringe) does not actually contain air, but is saturated with water held by suction at less than atmospheric pressure.

Vadose Zone—See "Unsaturated Zone".

Volatile Organic Compound (VOC)—Organic chemicals that readily evaporate under atmospheric conditions and are generally highly soluble in water.

Water Table—The level of underground water at which the hydraulic pressure equals atmospheric pressure.

1. INTRODUCTION

This Remedial Investigation (RI) report for the Hansville Landfill Site has been prepared in accordance with the Consent Decree entered into among the Washington State Department of Ecology (Ecology), Kitsap County, and Kitsap County Sanitary Landfill, Inc. (KCSL) in October 1995. The work required to be completed in preparation of the RI report was described in the Project Work Plan (Parametrix 1995) that was approved by Ecology. This chapter provides an overview of the RI including regulatory authority, site background information, purpose and objectives, and an overview of the report organization.

The Hansville Landfill is located in northern Kitsap County (Figure 1-1), east of Port Gamble Bay (Figure 1-2). The Landfill consists of three former waste disposal areas: the solid waste, demolition waste, and septage waste disposal areas (Figure 1-3).

The following terminology is used throughout this report when referring to properties and areas associated with the Hansville Landfill:

- **Hansville Landfill (also referenced as "the Landfill")**: Refers to the solid waste disposal area, the demolition waste disposal area, and the septage disposal area (see Figure 1-3).
- **Hansville Landfill Property (also referenced as "the Property")**: Refers to the area encompassed by the Landfill Property boundary (see Figure 1-2) which includes the closed disposal areas (solid waste disposal area, demolition waste disposal area, and septage disposal area), the transfer station, and all other facilities and features within the Property boundary. The closed disposal areas are generally defined by the limits of the final cover system constructed in 1989.
- **Hansville Landfill Site (also referenced as "the Site")**: Refers to the Hansville Landfill Property plus the estimated off-site extent of groundwater, surface water, and sediment impacts from the Hansville Landfill on Port Gamble S'Klallam Tribal property. This definition is consistent with the definition of "Site" in the consent Decree and Chapter 173-340 WAC (Ecology 2001).
- **Study Area:** Refers to the Site and areas beyond the Site that were examined as part of this RI, generally including areas north of Little Boston Road NE and west of Hansville Road NE.
- **"on-site"** and **"off-site"**: Refers to areas on the Landfill Property and off the Landfill Property, respectively, as convenient references to areas of Landfill impacts. These terms should not be confused with "Site" as defined above.

1.1 PURPOSE AND OBJECTIVES OF THE REMEDIAL INVESTIGATION

As stated in Chapter 173-340 WAC, the purpose of a remedial investigation/feasibility study is to collect, develop, and evaluate information on a site sufficient to support an assessment of the need for, and selection of, a cleanup action under Chapter 173-340-360 WAC. The use of the word "sufficient" in this statement of purpose recognizes that a complete characterization of a site and a full determination of the extent of chemical impacts to environmental media is not achievable due to the complex structure dynamics of these natural systems. The extent and magnitude of any chemical release are to be determined along with the potential pathways and receptors.

The purpose of this RI report is to present the results of the investigations conducted to date at the Site, as outlined in the Project Work Plan (Parametrix 1995) and subsequent modifications to the Work Plan. A Feasibility Study (FS) evaluating the necessity for additional site remedial actions to reduce unacceptable human health or ecological risk will be prepared using data from the RI, in addition to information about historical and current site conditions.

The specific objectives of this RI are summarized as follows:

- Characterize the physical features of the Study Area including topography, geology, hydrogeology, hydrology, and ecology.
- Characterize the nature and extent of chemicals in the groundwater of the Study Area that may be attributed to the waste disposal areas of the Landfill.
- Characterize the nature and extent of chemicals in the surface water and sediments of the Study Area adjacent to and downstream from the Landfill that may be attributed to the waste disposal areas of the Landfill.
- Characterize the human populations potentially exposed to chemicals from Landfill disposal areas, native soils, or other sources through groundwater or surface water pathways.
- Characterize the source of chemicals that may pose risks to human health and the environment.
- Identify which chemicals in which media will be addressed in the FS.

The following work was completed to meet the RI objectives:

- Further characterization of the Site hydrogeology with respect to groundwater depth and flow paths within the upper aquifer beneath the Site.
- Characterization of the extent and concentrations of Landfill-derived chemicals within the upper aquifer.
- Estimation of the rates of groundwater movement within the upper aquifer.
- Characterization of surface water quality and sediment characteristics of the creeks downgradient and in the Study Area, to assess the presence or extent of impacts from the Landfill disposal areas.
- Evaluation of the effectiveness of the active landfill gas extraction and flaring system to control landfill gas migration from the waste disposal areas of the Landfill and landfill gas chemical transport to the groundwater.
- Assessment of the waste disposal area cover system effectiveness in reducing leachate production from the disposal areas of the Landfill, and evaluation of future potential for continued chemical release from the waste disposal areas of the Landfill.
- Collection of data necessary to identify and evaluate remedial action alternatives in the FS.

1.2 REGULATORY AUTHORITY

This RI report is prepared in compliance with a Consent Decree (No. 95-2-03005-1, Kitsap County Superior Court) entered into among Kitsap County, KCSL, and Ecology in October 1995. The work required to be performed as part of the Consent Decree is described in the

Ecology Scope of Work and the Project Work Plan, both of which are incorporated into the Consent Decree as Exhibits C and D, respectively. The regulatory authority for oversight of the remedial investigation and feasibility study for the Site is set forth in the Model Toxics Control Act (MTCA), Chapter 70.105D RCW, as implemented by Ecology via Chapter 173-340 WAC as amended (Ecology 2001). Subsequent correspondence from Ecology (2004) confirmed that the most recent update of the MTCA regulations (Ecology 2001) would be applied to the Hansville Landfill RI/FS.

Throughout the process of developing the Ecology Scope of Work and Project Work Plan, Ecology received review and advisory input from the Port Gamble S'Klallam Tribe (the Tribe) and the Bremerton-Kitsap County Health District (BKCHD), now known as the Kitsap County Health District (KCHD). This review and advisory input continued throughout the RI.

1.3 PROPERTY BACKGROUND INFORMATION

1.3.1 Facility Description

The Landfill Property is located about 4 ½ miles south of the community of Hansville on the northernmost reach of the Kitsap Peninsula (Figure 1-1). The Property is a 73-acre parcel in the northeast quarter of Section 9, Township 27 North, Range 2 East. Bordering the Property to the south and west is land owned by the Port Gamble S'Klallam Tribe. Surrounding areas to the north and south are zoned low-density residential, rural wooded, or light industrial and are sparsely developed. The area directly east of the Property was recently cleared and is under development for light industrial use. The nearest permanent residence is located approximately 1,500 ft east of the solid waste disposal area of the Landfill. The Property is positioned on the western slope of the Kitsap Peninsula near the crest, approximately 4,000 ft east of Port Gamble Bay (Figure 1-2).

Three separate disposal areas were formerly operated within the 73-acre Property (Figure 1-3). These include a 13-acre municipal solid waste disposal area in the central portion of the Property which accepted mixed municipal solid waste; a 4-acre demolition disposal area in the northeast corner of the Property, which accepted construction, demolition, and land clearing wastes; and a 1/3-acre septage lagoon located southwest of the demolition disposal area, which accepted residential septic tank waste from the north county area until 1982, when other disposal options became available. A second septage disposal area was located in the northeast corner of the demolition disposal area. This area stopped receiving septage waste when the septage lagoon was opened. The remaining area of the Property is comprised of access roads, a solid waste transfer station, a soil borrow area, and wooded land.

1.3.2 Legal Description

The following is the legal description for the Property as listed in the Kitsap County Auditors records:

The South ½ of the N.W. ¼ of the N.E.¼, together with the North½, of the S.W.¼, of the N.E.¼, all located in Section 9, Township 27 North, Range 2 East, Western Meridian, Kitsap County, Washington.

1.3.3 Property Ownership

The Property on which the Landfill is located is owned by Kitsap County. Prior to development of the Landfill, the Property was undeveloped forested land.

1.3.4 Landfill Operators

Operation of the Landfill began in 1962 under lease from Kitsap County by Hudson Disposal Company. The Washington State Department of Health (DOH) investigated the Landfill in 1962 and advised the BKCHD that the Property was appropriate for use as a landfill and for burning of waste. The DOH set out conditions under which the Landfill should be operated. (Washington State Department of Health 1962).

Hudson obtained its first annual operating permit for the Landfill in 1962 and renewed it annually until 1972. For at least the latter portion of operation, Hudson leased the property from Kitsap County.

On August 17, 1972, Brem-Air Disposal, Inc. and Hudson Disposal Co., Inc. entered into an agreement under which Brem-Air would acquire all the stock in Hudson as of January 2, 1973. A new corporation, North Sound Sanitation, Inc., was formed. North Sound Sanitation collected solid waste throughout the northern part of unincorporated Kitsap County, used the Landfill for disposal of this waste from January through April 1973, and also operated the Landfill after taking over operations from Hudson Disposal.

In April 1973, the Landfill lease expired and was subsequently put out for bid. North Sound Sanitation signed a lease for the use of the property on May 7, 1973. North Sound Sanitation operated the Landfill under annual permits issued by BKCHD from 1973 to 1976. Between 1973 and 1976, KCSL was created as an affiliated corporation to North Sound Sanitation. The Landfill operations conducted by North Sound Sanitation were conveyed to the new corporation in 1975. The lease was renewed on May 10, 1976, with KCSL as the lessee. It was renewed again in 1979, and expired by its terms in 1994.

In the summer and fall of 1989, the three disposal areas at the Landfill were closed and KCSL constructed a final cover consistent with the Minimum Functional Standards for Solid Waste Handling, Chapter 173-304 WAC (Ecology 1986). Concurrent with the closure of the Landfill in 1989, KCSL entered into lease termination and transfer station operation negotiations with Kitsap County. No agreement was reached and the lease terminated under its original provisions in 1994. In the fall of 1993, all shares of KCSL, Inc. were sold to Envirofil, Inc., which has subsequently merged with USA Waste Services, Inc., a national waste management corporation. USA Waste Services continued to provide waste disposal services in Kitsap County under the name KCSL until 1996, when the name was changed to Olympic View Sanitary Landfill, Inc (OVSL). In 1998, USA Waste Services, Inc. acquired Waste Management. The current company name is Waste Management of Washington, Incorporated (WMW).

1.3.5 Landfill Operations History

The Landfill began operations as a solid waste disposal site for north Kitsap County in approximately 1962. The facility was operated by Hudson under a BKCHD permit as an open dump from 1962 until 1972. In 1972, the state regulations concerning landfill operations were revised. Further, the new lease from the County required upgraded operations for operation as a sanitary landfill, including routine covering of solid wastes and prohibition of open burning.

The 1975 Comprehensive Solid Waste Management Plan Update for Kitsap County identified the Landfill as the disposal site for all refuse from Bainbridge Island, Poulsbo, and all other communities and rural areas in the northern portion of the County. It also outlined necessary improvements at the Landfill to convert it to a sanitary landfill operation, consistent with the then recently adopted Minimum Functional Standards for Solid Waste Handling (Chapter 173-301 WAC, 1972). Improvements at the Property were made to include the use of cover soil, access road improvements, a drinking water supply well, and construction of a toll booth.

The 1982 Comprehensive Solid Waste Management Plan for Kitsap County (Parametrix 1982) recommended that "the County continue the present collection and disposal operations in the north county area unchanged through 1990," and that "the County urge the expeditious completion of the proposed development plan being prepared by the site operator." The Plan also recommended the elimination of septage disposal; however, the Landfill ceased receiving septage waste in May 1982 prior to adoption of the Comprehensive Solid Waste Management Plan.

Three groundwater monitoring wells were installed in 1982 on the Property to monitor potential landfill impacts on the upper aquifer. Monitoring of these wells commenced in 1982 and continues through the present. These wells, designated MW-1 through MW-3, are shown in Figure 1-3. Additional monitoring wells were installed in 1988 (MW-4 and MW-5) and 1990 (MW-6). The frequency of monitoring and the number of parameters have varied. The history of groundwater monitoring is described in Chapter 2, Current Property Features and Conditions, and Chapter 5, Groundwater Investigation, of this RI report.

In 1988, the U.S. Environmental Protection Agency (USEPA) performed a Potential Hazardous Waste Site Preliminary Assessment of the Site. While noting the presence of elevated chemicals in the upper aquifer downgradient of the Site, the assessment report ranked the Site a low priority and did not identify it for inclusion on the National Priority Sites List (Ecology and Environment 1988).

In June 1989, waste disposal operations ceased and construction of the final cover system started, in accordance with construction plans prepared by KCSL and approved by BKCHD and Ecology. By the summer and fall of 1989, the majority of construction on the final cover system was completed, including the installation of a high-density polyethylene (HDPE) liner over all three disposal areas. This provided a low-permeability cap that met the performance requirements of Chapter 173-304 WAC over the disposal areas, thus reducing leachate generation beginning with the winter of 1989/90. The remainder of the cap was constructed in 1990. Final as-built drawings were prepared and submitted to BKCHD in the fall of 1990. The configuration of the cover system is shown on Figure 1-3.

Concurrent with the closure of the disposal areas at the Landfill, Kitsap County constructed a solid waste transfer station on the Property to allow for continued service for north county residents. The transfer station initially accepted waste from self-haulers and commercial haulers in the North Kitsap County area. Commercial haulers are no longer allowed to use the Hansville Transfer Station, however, and the facility continues to operate as a drop box facility for only North Kitsap County residential self-haulers.

In 1990, downstream surface water station monitoring began at locations on and off the Property. The history of surface water sampling in the Study Area is described in Chapter 6, Surface Water Investigation, of this RI report.

In 1991, Ecology performed a Site Hazard Assessment under the Model Toxics Control Act (SAIC 1991), which resulted in an initial ranking of 3 for the Site by Ecology. This ranking was subsequently changed to a 1 in 1992, based on changes in the state ranking model. The Ecology ranking scale classifies highest priority sites as "1" and lowest priority sites as "5". Throughout this period, KCSL conducted additional investigations, continued environmental monitoring, and implemented additional improvements at the Site as part of a corrective action program planned in conjunction with and approved by BKCHD.

1.3.6 Current Status

The disposal areas at the Landfill have been closed to the receipt of refuse since June 1989. All disposal areas are capped with a cover system that is compliant with Chapter 173-304 WAC, and an active gas extraction system operates to remove refuse-generated landfill gas from the Landfill and combusts it in a flare. Regular (twice per month) monitoring and maintenance of the landfill gas extraction and flaring system were conducted during the four initial RI sampling events and continues during the Ecology-directed monitoring period on a monthly schedule. Routine post-closure quarterly (or more frequent) groundwater and surface water monitoring was replaced with four initial RI comprehensive quarterly monitoring events during the months of March 1996, November 1996, March 1997, and May 1997. Quarterly post-closure monitoring, as directed by Ecology, resumed in March 1998 and continues through the present.

Two studies were conducted after the Site was ranked, one by Ridolfi Engineers, and one by the U.S. Environmental Protection Agency (USEPA). Ridolfi Engineers (2001) conducted an independent investigation of the Hansville Landfill for the Port Gamble S'Klallam Tribe. This study was developed and implemented without input from Ecology or the PLPs and included collection and analysis of samples from some of the pre-existing RI sampling stations as well as other additional locations.

The second study was conducted by USEPA (2004b) to determine if arsenic is adversely impacting the health of the residents on the Tribal reservation since the Kitsap Peninsula is known to have naturally occurring elevated levels of arsenic. The study analyzed urine, blood, and shellfish tissue, but did not involve collection of samples at RI sampling stations.

The transfer station (now a drop box facility, since it no longer receives commercial compactor trucks) continues to operate and receive waste from local residential self-haulers. A recycling drop-off area is established adjacent to the drop-box station and a toll-booth attendant is on-site during normal hours of operation. The drop-box station does not add any contamination to the Property.

1.4 RI REPORT ORGANIZATION

This RI report is organized into 11 chapters to present the results of the investigations conducted under the Project Work Plan. This report is prepared as a "stand alone" document, incorporating results of interim reports and technical memoranda. The chapters of this report are briefly described as follows:

EXECUTIVE SUMMARY

Provides a brief description of the purpose, scope, methods, and results of the RI report.

Chapter 1: INTRODUCTION

Provides an overview of the RI report, describes regulatory authority, presents site background information, and outlines the purposes and objectives of the remedial investigation.

Chapter 2: CURRENT PROPERTY FEATURES AND CONDITIONS

Includes a more detailed description of the Property, outlines actions implemented at the Property to date, describes the Site topography and drainage, discusses the boundaries of the investigation, describes adjacent properties and land use, and describes ecological resources in the Study Area.

Chapter 3: WASTE SOURCE INVESTIGATION

Describes the history of waste disposal at the Landfill, including types of wastes, areas of disposal, dates of disposal, and characteristics of the wastes.

Chapter 4: LANDFILL GAS INVESTIGATION

Describes the evolution of the landfill gas extraction and flaring system at the Landfill, including a description of the existing active gas control system and its performance. It also includes a description of the gas monitoring program, summarizes monitoring results, and provides an assessment of the gas control system effectiveness in reducing landfill gas migration.

Chapter 5: GROUNDWATER INVESTIGATION

Describes the groundwater investigations conducted at the Site as part of the RI, including the history of groundwater and hydrogeologic investigations, a description of the hydrogeology of the Site, estimates of leachate generation, and the results of groundwater quality monitoring.

Chapter 6: SURFACE WATER INVESTIGATION

Describes the surface water investigations conducted in the Study Area as part of the RI, including the history of surface water monitoring, a description of the regional surface water system, and the results of the surface water sampling program.

Chapter 7: SEDIMENT INVESTIGATION

Describes the sediment investigations conducted in the Study Area as part of the RI, including sampling station selection and sediment investigation findings.

Chapter 8: CHEMICAL SCREENING

Presents the process of chemical screening used to select chemicals for further consideration in the Feasibility Study and the results of the screening process for groundwater, surface water, and sediment.

Chapter 9: CHEMICAL FATE AND TRANSPORT EVALUATION

Introduces the conceptual site model incorporating primary and secondary contaminant sources, transport mechanisms, and chemical fate for contaminants in the groundwater, surface water, and sediments.

Chapter 10: FINDINGS AND CONCLUSIONS

Summarizes the results of the RI and identifies important conclusions that will be used in the preparation of the FS.

Chapter 11: REFERENCES

Lists references used in the preparation of the RI report.

APPENDICES

The appendices to the RI report include details of the RI investigations, laboratory reports, data plots and summaries, RI technical memoranda, and other data that are important to the RI but are too detailed to include in the main body of the report. The appendices are presented in PDF format on the enclosed CD.

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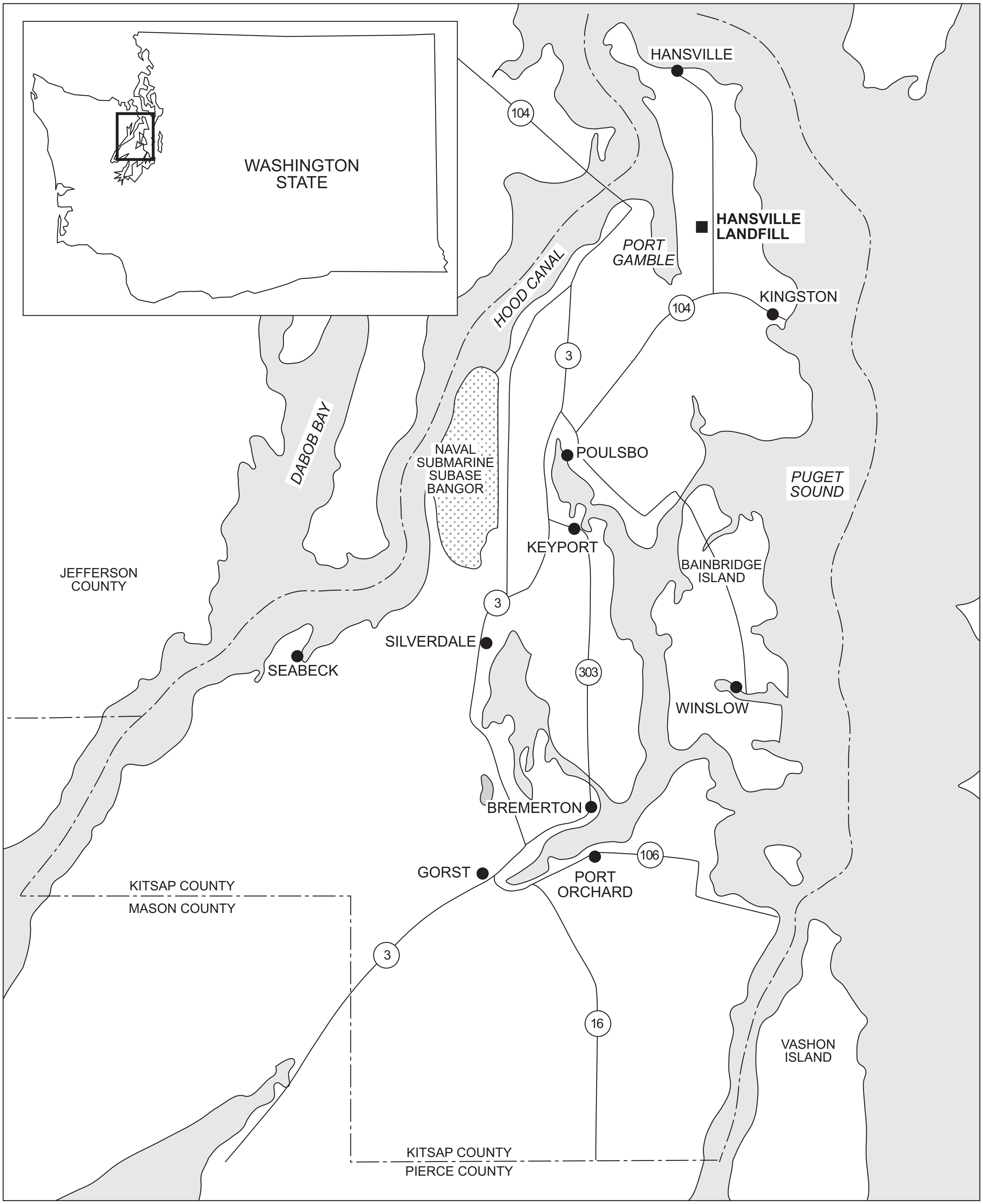

Parametrix Hansville Landfill FS 555-2966-002/02(01) 11/05 (B)

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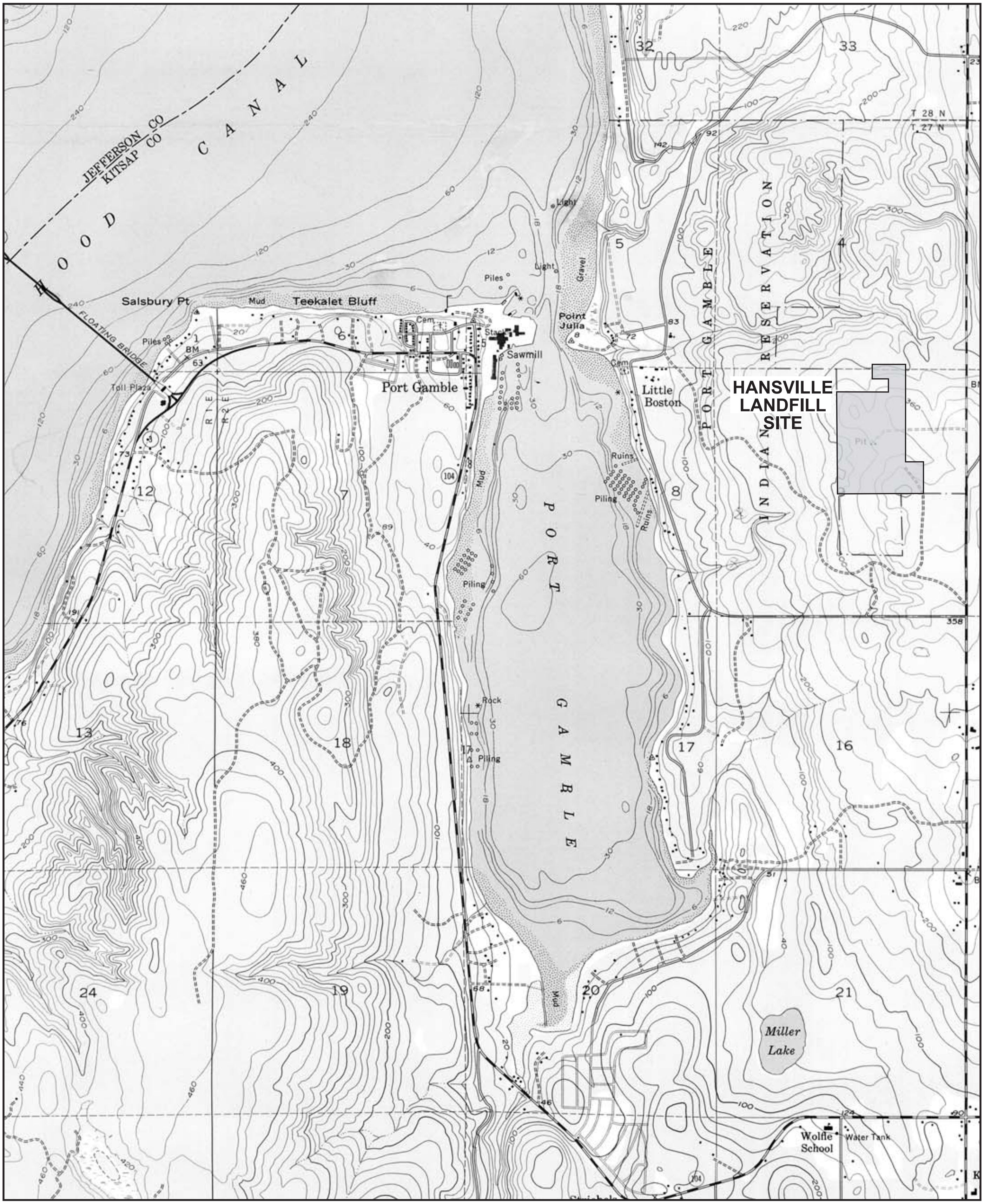
Figure 1-1
Site Location Map
Hansville Landfill RI/FS



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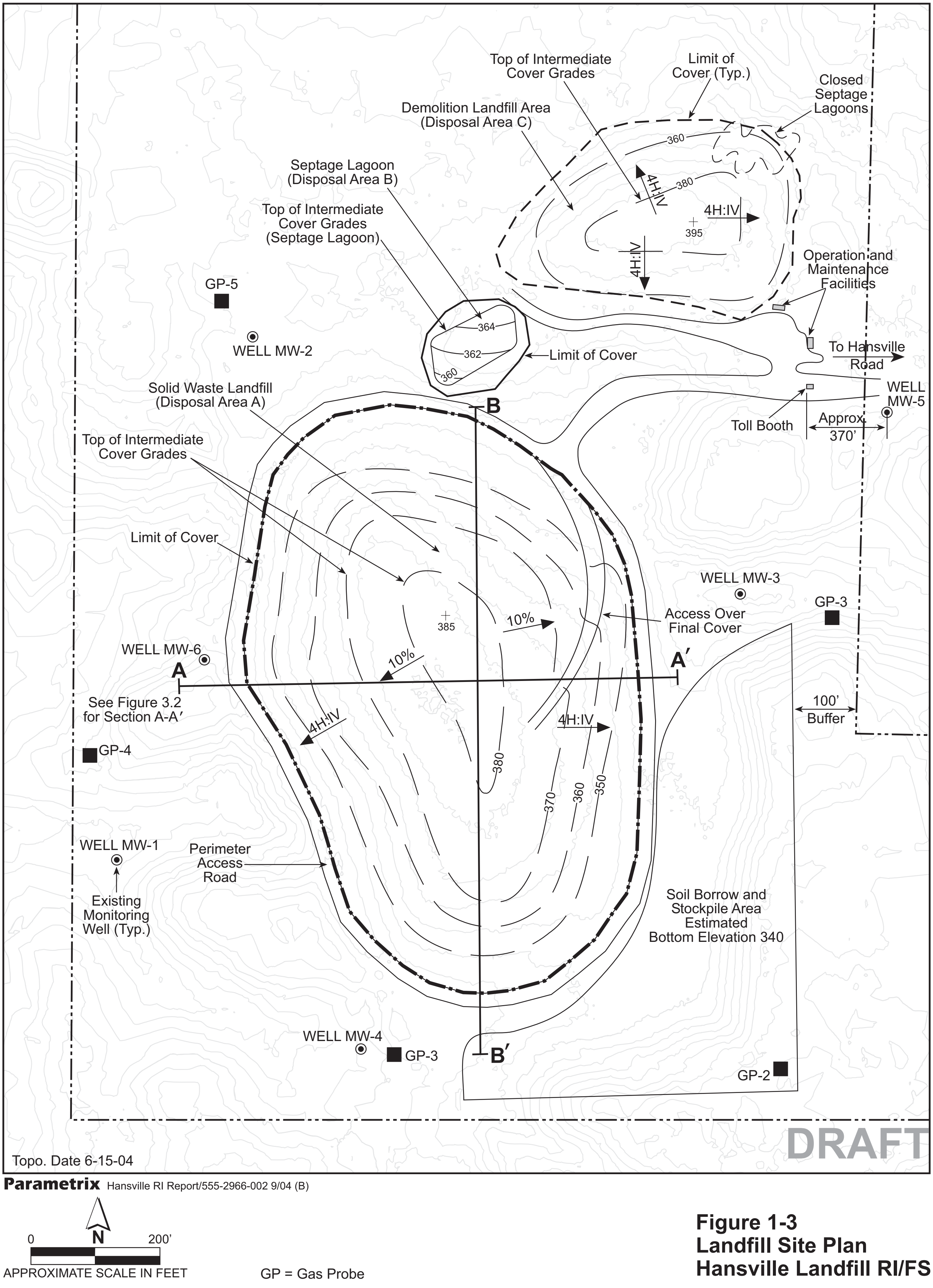
NO SCALE

Figure 1-2
Site Vicinity Map
Hansville Landfill RI/FS



Parametrix Hansville RI Report/555-2966-002 9/04 (B)

GP = Gas Probe

Figure 1-3
Landfill Site Plan
Hansville Landfill RI/FS

2. CURRENT PROPERTY FEATURES AND CONDITIONS

2.1 LANDFILL PROPERTY DESCRIPTION

This chapter provides information characterizing the past and present activities at the Landfill, including a description of the Landfill Property features and facilities, actions implemented to date, topography and drainage, and adjacent properties and land uses.

2.1.1 Property Boundary Description

The Hansville Landfill Property is located approximately 4 miles south of the community of Hansville in northern Kitsap County, Washington. Approximately 17-1/3 acres of the 73-acre Property were used for waste disposal (see Sections 2.1.2, 2.1.3, and 2.1.4 that follow). The Property is positioned on the western slope of the Kitsap Peninsula near the crest, approximately 4,000 ft east of Port Gamble Bay.

The Property is located approximately 1,500 ft due west of the Hansville Road NE and is accessed via an easement across adjacent property between the Property and the Hansville Road. The south boundary of the Property is approximately ½ mile north of the Little Boston Road NE. The legal description of Property is provided in Section 1.3.2, Legal Description. The parcel is described as a subdivision of Section 9, Township 27 North, Range 2 East.

As described in Section 1.3.1 (Facility Description), and shown in Figure 1-3, there are three separate inactive disposal areas on the Property and an operating solid waste transfer station. These facilities are described below in more detail.

2.1.2 Solid Waste Disposal Area

The solid waste disposal area consists of approximately 13 acres in the south central portion of the Property. Mixed municipal solid waste from solid waste collection companies and self-hauled waste from individuals was accepted at the solid waste disposal area from 1962 through June 1989. A description of waste received at the solid waste disposal area is included in Section 3.2.1 as part of the waste source investigation.

The solid waste disposal area received the majority of the estimated 600,000 tons of waste received at the Landfill over its operating life. Since waste stream records are not available for the complete history of the Landfill and no weighing of wastes occurred, the estimate of 600,000 tons of waste is based on an evaluation of the available waste-stream data and projected estimates of the waste stream from 1962 to 1983 (the first year for which data are available).

According to the Landfill operator (KCSL), filling in the solid waste disposal area through the early 1980s occurred in the north and central portions of the solid waste disposal area, in a natural valley that originally traversed the area from east to west (from approximately the location of MW-3 on the east to MW-1 on the west). The elevation of the valley, based on a study of a series of historical topographic maps, was approximately 340 ft mean sea level (MSL) on the east to 310 ft MSL on the west. There is no indication that excavation or placement of waste occurred below an elevation of 310 ft (Parametrix 1994). Historical documents do not reveal whether or how frequently soils were used to cover the wastes; there was no regulatory requirement for the interim cover prior to 1972.

In 1979, the top of refuse elevation in the north and central portions of the solid waste disposal area was approximately 340-360 ft MSL. Filling continued in this area to an elevation of approximately 370 ft MSL by 1983. To extend the capacity of the solid waste disposal area, the southern portion of the area was excavated to 330 ft MSL, then filled through about 1987.

In establishing the final grades for the solid waste disposal area, the existing footprint as of 1988 was filled at a 25% side slope to elevation 370 ft MSL. At this level, the disposal area grade was continued at a 10% slope to a maximum elevation 385 ft MSL. The solid waste disposal area ceased waste disposal operations in June 1989. Cross sections of the solid waste disposal area are shown on Figures 2-1 and 2-2.

A plan was prepared for the closure of the Landfill in 1988. Some initial tasks to support closure were performed in 1988, with the majority of closure construction occurring in 1989 and completed in 1990. The closure of the waste disposal areas is described in more detail in Section 2.2, Remedial Actions Implemented to Date. The work completed in 1988 included the placement of a 3-mil mesh, reinforced, polyethylene-plastic temporary cover to reduce leachate generation. This was placed over all three disposal areas of the Landfill, except that portion which was actively receiving waste. The temporary plastic cover was removed prior to construction of the final cap in 1989.

2.1.3 Demolition Waste Disposal Area

The demolition waste disposal area at the Landfill is an area approximately 4 acres in size that accepted construction, demolition, and land-clearing wastes throughout the life of the Landfill. Demolition waste placement was limited to the northeast area of the Landfill, approximately 250 to 300 ft northeast of the solid waste disposal area. Demolition waste was also used to cover former septage lagoons (see Section 2.1.4, Residential Septage Disposal Area).

The demolition waste disposal area was filled to a maximum grade of 25% on all sides. The maximum elevation of the demolition waste disposal area is approximately 395 ft MSL. An evaluation of topographic maps of the vicinity of the demolition waste disposal area indicates that the original ground surface prior to filling was between 340 and 360 ft MSL; therefore, the depth of refuse in the demolition waste disposal area is probably less than 60 ft at its deepest point. It is estimated that only 10% to 15% of the estimated 600,000 tons of waste received at the Landfill was disposed of in the demolition waste disposal area. Demolition waste extends over and covers the old septage lagoons located in the northeast corner of the demolition waste disposal area.

The demolition waste disposal area ceased receiving waste in 1988 with the installation of the temporary plastic cap referred to in the previous section. The demolition waste disposal area was capped and closed in 1989 as part of the overall Landfill closure construction.

2.1.4 Residential Septage Disposal Area

Two areas at the Landfill were used for disposal of residential septic tank pumpings. Septage was deposited in small lagoons in the northeast corner of the demolition waste disposal area, where disposal of demolition waste continued until the entire site was closed in 1989. The main septage disposal area was approximately 1/3-acre in size and was located southeast of the demolition disposal area, directly north of the solid waste disposal area. This septage disposal area is believed to have been opened when the original septage lagoons were covered with demolition waste in approximately 1979. The main septage disposal area received septic tank pumpings until May 1, 1982, when other disposal options became available.

The amount of residential septage waste received at the Landfill in 1979 through 1981, as reported by KCSL, was:

1979: 1,322,500 gallons

1980: 1,884,800 gallons

1981: 2,089,200 gallons

In preparation for closure of the Landfill, the main septage lagoon was overfilled with demolition wastes and graded to an approximately 5% slope to facilitate closure and capping in 1989.

2.1.5 Transfer Station

With the closure of the three disposal areas at the Landfill in 1989, Kitsap County committed to operate a temporary transfer station in order to maintain service to north Kitsap County. The Hansville Transfer Station, placed in operation in July 1989, consisted of two bays each containing two 50-cubic yard drop-boxes. Two additional drop boxes are available as replacements.

From July 1989 to March 31, 1993, the Hansville Transfer Station was open to both the general public and commercial haulers, including Bainbridge Disposal, the City of Poulsbo, and North Sound Sanitation. One drop box was designated for general public self-haulers and the other drop box was for commercial haulers.

The Hansville Transfer Station was constructed in the summer of 1989 as a temporary facility. The County stated in the 1992 Comprehensive Solid Waste Management Plan update that it would apply to BKCHD for a variance to Ordinance No. 10-1991, to allow the Hansville Transfer Station to continue operations without modification, until the decision was made as to the role the transfer station would have in the transfer system. During discussions between the County Public Works Department and BKCHD, it was determined that the 1992 Solid Waste Handling Permit for the Hansville Transfer Station was a non-conforming permit that allowed this facility to accept residential and commercial waste. The 1993 Solid Waste Handling Permit allowed only residential waste to be accepted.

The Hansville Transfer Station has power, water, and telephone services. Until 2003, all washdown and rainwater was collected by a containment system consisting of three 1,100-gallon holding tanks. Once full, the holding tanks were pumped into a tanker and the contents transported to the Central Kitsap Wastewater Treatment Plant. In the summer of 2003, four 50-cubic yard drop boxes were added at-grade to accept additional municipal solid waste and yard waste. As part of the construction process, the stormwater system was upgraded to meet current standards.

A leveled and graveled area with recycling drop boxes is located adjacent to the Hansville Transfer Station. These boxes are provided for the general public to drop off recyclables including glass, paper, plastic, and other commodities.

2.2 REMEDIAL ACTIONS IMPLEMENTED TO DATE

2.2.1 Overview

In 1988, KCSL and BKCHD decided to close the Landfill early, in 1989, because of detected impacts to groundwater and changing regulations. A temporary plastic cap (3 mil griffolyn-reinforced plastic) was installed in November 1988 over all three disposal areas, except a small part of the solid waste disposal area actually receiving waste. The purpose of this temporary cap was to reduce leachate production during the winter months of 1988/89. In June 1989, waste disposal operations ceased and construction of the final cover system started in accordance with construction plans prepared by KCSL and approved by the BKCHD and Ecology. In addition, a closure plan was prepared and submitted to the regulatory agencies.

The decision to close the Landfill was, for the most part, attributed to groundwater impacts and implementation of Chapter 173-304 WAC, the Minimum Functional Standards (MFS) for Solid Waste Handling (Ecology 1986). Consideration was given to closing and capping the waste disposal areas of the Landfill in the summer 1988 construction season to limit leachate production. Although immediate closure would have constituted the most aggressive response to leachate production, it would also have had a significant impact on north Kitsap County residents and waste haulers.

As a result of the potential service impact to the public, the final site plan was based on Landfill operation until mid 1989, to allow for closure by the November 1989 deadline established by the MFS (without a variance). This plan utilized time available under the MFS and allowed private haulers time to redirect the waste to the Olympic View Sanitary Landfill with no disruption in service. To reduce leachate production during the remaining operating period, the temporary plastic cover described previously was installed over the solid waste, demolition, and septage disposal areas.

The closure plan was implemented with the construction of the final cover system in 1989 and finalized in 1990. Some initial closure tasks were performed in the summer 1988 construction season, and closure construction was completed in the summer of 1990. The majority of closure construction was completed in the summer and fall of 1989, including the installation of an HDPE liner over all three disposal areas and installation of most of the geocomposite drainage net. This provided an impermeable cover (50 mil HDPE) over the landfill areas, thus reducing leachate generation beginning with the winter of 1989/1990. The remainder of the cover was constructed in1990. Additional tasks completed in 1990 included topsoil placement, hydroseeding, and placement of gravel layers for access roads. As-built plans of the final cover construction and certification of closure were provided to BKCHD in October 1990. These plans are the definitive reference for actual construction completion details.

The final cover system was designed to minimize leachate production and to mitigate potential negative environmental and public health and safety impacts associated with a closed solid waste landfill. The closure concepts are consistent with the MFS regulations and include a grading plan, final cover system, surface water management system, gas management system, and access roads.

Additional construction since the placement of the final cover system includes installation of an active gas control system and additional gas extraction wells. Technical details of these closure elements are discussed below in Section 2.2.2.

The closure plan elements summarized in this section have been implemented through the development of detailed construction drawings, specifications, and a quality assurance plan. These documents were approved by the BKCHD as part of the construction permitting process and have been implemented at the Landfill.

2.2.1.1 Solid Waste Disposal Area Closure

In establishing the final grades of the solid waste disposal area, the remaining capacity in the existing footprint as of 1988 was filled at a slope of 4 to 1 (horizontal to vertical) to elevation 370 ft MSL. At this level, the solid waste disposal area grade continued at a 10% slope to a maximum elevation of 385 ft MSL.

2.2.1.2 Demolition Waste Disposal Area and Septage Disposal Area Closure

The finished cover system on the demolition waste disposal area extends over and covers the demolition waste disposal area and septage lagoon in the northeast corner of the Property. The demolition waste disposal areas are graded to a maximum 4:1 (horizontal to vertical) side slope on all sides. Maximum demolition elevation is approximately 395 ft MSL.

The septage disposal area in the north central portion of the Site was also capped with 50 mil HDPE; however, the geosynthetic drainage net was not installed in this area since the surface was graded to only a 5% slope. All other layers of the final cover system were constructed over the septage disposal area.

2.2.1.3 Description of Final Cover System

The final cover system for the solid waste disposal area, demolition waste disposal area, and septage disposal area, as constructed, conforms to the MFS regulations and consists of the following layers (Figure 2-3):

- 1-ft intermediate cover: Consists of on site material and serves as a cover for refuse.
- 6-in. cover subgrade layer: This layer was placed, graded, and smoothed to provide a suitable base for the membrane liner. The surface was verified to be free of rocks, sticks, and other materials that may damage the membrane liner.
- Geomembrane liner: Consists of a 60 mil high-density polyethylene (HDPE) geomembrane. The geomembrane was textured to provide a stable surface for the placement of subsequent layers.
- Geosynthetic drainage net: This drainage net is a composite of polyethylene net with geotextile bonded to each side. The geotextile forms a "Velcro" type bond with the underlying geomembrane that provides cover soil stability. This was installed in all areas except the septage lagoon.
- Protective soil layer: Consists of an 18-in. layer of clean sand with permeability ranging from 10^{-4} to 10^{-2} cm/sec. This layer protects the geomembrane and directs precipitation from the disposal area surface to perimeter drainage ditches. Select on-site sand was used for this layer.
- 6-in. topsoil layer: Consists of on-site material amended with biosolids to facilitate vegetation growth.
- Hydroseeding: Provides vegetative cover and erosion control.

As part of the final cover design process, a water balance calculation for a geomembrane cover cap was performed (Parametrix 1994). This water balance was used to demonstrate that leachate reduction in the range of 99% would be accomplished by installation of a geomembrane cover. Leakage past a geomembrane cover is generally assumed to occur only if there are punctures or faulty seams. If the integrity of the geomembrane is complete, the amount of leachate reduction approaches 100%.

2.2.2 Landfill Gas Control System

As refuse decomposes at the Landfill, gas is released as a by-product. Prior to closure, this gas vented through the refuse to the atmosphere. With placement of a final cover cap, gas could no longer vent directly to the atmosphere and a path had to be provided to allow the gas produced within the Landfill to escape. A passive gas system was originally installed in the solid waste disposal area of the Landfill for this purpose during closure construction in 1989. These systems are termed "passive" because they do not use mechanical energy to collect landfill gas, but depend upon pressure differences between the landfill gas and the atmosphere to induce gas flow into collection pipes.

The passive gas collection system at the Landfill consisted primarily of piping and flares installed in conjunction with the final cover system. Landfill gas was collected in the piping system, vented through the final cover, and burned at the flares. The flares supported combustion of the methane and other gases associated with landfill gas.

The piping system was installed in a filter-fabric and drain-rock envelope, and spacing was determined based on a gas production and migration model. The piping and associated drain-rock envelope were placed in refuse. Flares were placed on the solid waste disposal area at high points in the piping at an approximate spacing of one flare per 3 acres finished cover. Valves were provided to close off flares if insufficient gas was available for combustion.

In 1991, BKCHD required development of a corrective action program for the Landfill, due to vinyl chloride concentrations exceeding the Maximum Contaminant Level (MCL) in three on-site monitoring wells. As part of the response to BKCHD, the County and KCSL proposed upgrading of the passive landfill gas system to an active landfill gas extraction and flaring system to collect and control landfill gas that was accumulating under the new cover system.

Landfill gas contains Volatile Organic Compounds (VOCs) such as vinyl chloride, in addition to methane (see Section 4.2, General Characteristics of Landfill Gas); therefore, collection of gas at landfills also intercepts these VOCs before they migrate off-site through soils or come in contact with groundwater. Active landfill gas collection systems function by pumping the gas out of extraction wells drilled in or near a landfill, and routing the gas to a flare system, where the gas is burned to destroy the methane, VOCs, and other compounds present in the gas.

BKCHD concurred with the proposed upgrade of the gas collection system at the Landfill. An active landfill gas extraction and flaring system was designed and installed in the solid waste disposal area to collect and control landfill gas. The new active gas system became operational in November 1991. The active landfill gas extraction and flaring system as it currently exists is described in Chapter 4, Landfill Gas Investigation, and is shown on Figure 4-2.

The active landfill gas extraction and flaring system was designed to include both in-refuse and perimeter gas extraction wells. The in-refuse gas wells were designed to collect the gas reservoir that had built up within the solid waste disposal area, collect future gas generation, and prevent further gas migration. The perimeter gas wells, installed in the native soils, were designed to remove the gas that had previously migrated from the solid waste disposal area, provide a second line of defense should future gas escape from the Landfill, and to serve as vapor extraction wells to remove VOCs from the surrounding soils and groundwater. The in-refuse wells were installed to a depth of approximately 80% to 90% of the projected refuse depth. The native soil wells extended to depths of approximately 40 to 45 ft below the projected refuse depth.

Five gas probes were installed on the Property prior to the initial RI sampling events to monitor landfill gas migration. The probes were installed in the native soils around the perimeter of the Property to a depth approximately equal to the depth of refuse (approximately elevation 310 ft MSL). All probes were single-completion (one screened interval) except GP-2, which is a triple-completion probe (three screened intervals).

Two additional gas probes were installed for the RI. One probe was installed with new groundwater monitoring well MW-10 southwest of the solid waste disposal area. The other probe was installed in the northeastern corner of the Property near the demolition disposal area. Each monitoring probe is single-completion and is installed in the soil above the saturated zone of the upper aquifer.

All gas extraction wells are connected to the motor/blower flare facility. Condensate that forms as the gas cools in the piping system is collected by a gravity drainage system in sumps and is periodically removed.

The active landfill gas extraction and flaring system extracts landfill gas from the refuse in the solid waste disposal area as it is generated through 13 in-refuse vertical extraction wells and eight connections to shallow in-refuse gas extraction trenches (see Chapter 4, Landfill Gas Investigation, Figure 4-2). Landfill gas is further controlled by five double-completion vertical extraction wells installed in native soil at the perimeter of the solid waste disposal area. These perimeter wells establish a vacuum barrier to prevent migration in the unsaturated zone above the groundwater surface. The vacuum is established by two 7.5-horsepower motor blowers. The landfill gas is combusted in a shrouded flare. The wells/trenches, blowers, and flare are connected by PVC manifold piping.

Once the active system became operational, the gas that had previously been generated was steadily removed from the solid waste disposal area and surrounding soils and flared over the first year of operation. As the gas flow declined, the amount of BTUs combusted in the flare declined. Within the first 6 months of operation of the gas system, it became necessary to reduce the vacuum in most of the extraction wells on the Property (including the perimeter gas wells) as a result of the reduced gas flow. By June 1993, it became necessary to close the perimeter wells to ensure that the flare had enough high quality gas to burn continuously and efficiently.

Additional modifications to the gas system were completed June 8, 1994. These modifications separated the perimeter gas extraction well flow from the in-refuse gas extraction well and trench flow. The perimeter wells were intended to be operated at a stronger vacuum to improve cleanup of the groundwater. The flow from the perimeter wells was almost entirely air. The flow from the perimeter wells was piped into the flare above the landfill gas ignition point to ensure that any VOCs in the perimeter well flow were also combusted.

The perimeter gas extraction system was turned off in 1995 when it was determined that the zone of influence of the in-refuse wells was extending to the perimeter wells, as indicated by recorded vacuum levels in the perimeter wells. In 2003, a downsized flare was installed to handle the decreased volume of gas generated by the solid waste disposal area.

The active landfill gas extraction and flaring system has been demonstrated to be effective in controlling landfill gas migration and removing landfill gas from the soils surrounding the solid waste disposal area. Additional details regarding the landfill gas control system are provided in Chapter 4, Landfill Gas Investigation.

2.2.3 Environmental Monitoring Program

Monitoring of groundwater commenced in 1982 with the installation of three groundwater monitoring wells. Monitoring of surface water commenced in 1991 at two stations on Middle Creek. Gas migration monitoring commenced in 1990 with the installation of five gas probes. Three additional groundwater monitoring wells (two in 1988, one in 1990), one additional gas migration probe (1994), and additional surface water monitoring stations were added to the environmental monitoring program prior to commencing the RI. Monitoring frequency for gas, groundwater, and surface water was increased to quarterly in 1987 and monthly in 1991, with a concurrent increase in the number of parameters monitored.

The results of this historical monitoring program are documented in previous quarterly, monthly, and annual reports prepared and submitted to Ecology and the BKCHD. These historical results were discussed in the Project Work Plan (Parametrix 1995) and were used in scoping of the landfill gas, groundwater, and surface waste investigations of the RI. Four initial RI comprehensive quarterly sampling events were conducted in 1996 and 1997, followed by resumption of post-closure quarterly monitoring in 1998. Details of landfill gas, groundwater, surface water, and sediment monitoring conducted since the start of the RI study period are described in Sections 4.6.1, 5.3.3, 6.3.2, and 7.3.2, respectively.

2.3 INVESTIGATION STUDY AREA BOUNDARY

The Study Area for investigation under this RI includes the Site and adjacent areas north of Little Boston Road NE and west of the Hansville Road NE (Figure 2-4). Additional background sampling of stream surface water and sediments occurred in areas outside of the Site boundary, as discussed in Chapters 6 and 7, Surface Water Investigation and Sediment Investigation, respectively.

2.4 SITE TOPOGRAPHY, PRECIPITATION, AND DRAINAGE

2.4.1 Topography

The Hansville Landfill Site is located near the crest of the western slope of the Kitsap Peninsula. Elevations vary from 396 ft MSL at the southeast corner of the Property to 306 ft MSL along the west Property line. Natural slopes are relatively moderate, varying from less than 6% up to 25%-30% in the westernmost portions of the Property. Relatively small amounts of surface runoff and drainage occur over the Site because of its position near the crest of the watershed and the relatively high permeability of surface soils. The runoff that does occur at the Site and surrounding areas drains toward Port Gamble Bay about 4,000 ft to the west.

2.4.2 Precipitation

Precipitation estimates for the Study Area are based on isohyetal maps and other meteorological data. According to the mean annual precipitation map published by the Soil Conservation Service (SCS) in March 1965, the Study Area receives an annual rainfall of 32 in. Average monthly precipitation values were obtained from the nearest weather station and prorated to approximate the annual rainfall at the Study Area by month, using the mean annual rainfall data from the SCS. The Chimacum Station, which is the nearest weather station to the Study Area, reports an annual 29.87 in. of rainfall (Gale Research Company 1981). The prorated average monthly rainfall estimates for the Study Area are provided in Table 2-1.

Also listed in Table 2-1 are monthly potential evapotranspiration estimates. These values are the average of potential evapotranspiration estimates for the Port Townsend and Quilcene 2SW weather stations. The estimates for these weather stations are recorded in Phillips (1972).

2.4.3 Drainage

The surface water management system for the Landfill Property is shown in Figure 2-5. The disposal area cover slopes are graded to promote surface water runoff from the closed disposal areas, rather than allow buildup of runoff on the cover and possible infiltration into refuse. Grass-lined ditches are provided around the solid waste and demolition waste disposal area perimeters to carry runoff to discharge points. Ditches in the disposal areas are underlain by the final cover system.

Vegetation planted on the final slopes of the closed disposal areas helps to prevent erosion. Culvert inlets and outlets are protected with rock to prevent scouring. Selected perimeter ditches are rock-lined where required by high flow velocity and ditch slope.

A perimeter ditch around the closed solid waste disposal area (inside the perimeter access road) collects and discharges surface water into the on-site siltation basin located west of the solid waste disposal area. The siltation basin provides for settlement of solids from the surface water. During most of the year, evaporation and infiltration maintain the basin water level below the outlet structure and no runoff leaves the Property. During major rainfall events in the wet season, the siltation basin fills and surface water is discharged west of the Property where it infiltrates. An inspection of the basin during a major rainfall event on January 29, 1999, confirmed that there was no overland flow of basin discharge that entered downgradient creeks. This storm occurred during a period of record rainfall events during the early part of 1999.

Runoff from the cover systems over the demolition disposal area and septage disposal area is routed to existing drainage swales located north and west of these disposal areas, respectively. Surface water entering the Property from the east, as well as surface water from on-site forested areas east of the solid waste disposal area, is collected in an infiltration basin east of the Property. Water control facilities are sized for a 25-year, 24-hour storm. No surface water from the closed disposal areas is discharged to the east.

The Site is part of a watershed of over 5,000 acres which ultimately discharges to Port Gamble Bay. The Site is located near the watershed boundary and the crest of the ridge that bisects the Kitsap Peninsula. Less than 10 acres of the watershed contributes to drainage over the Site. Surface water east of the Hansville Road NE flows easterly to Puget Sound.

Perennial creeks flow within a mile west of the Landfill along the hillside between the Landfill and Port Gamble Bay (see Figure 2-4). These creeks originate as springs and seepage from the upper groundwater aquifer above its contact with a confining silt and clay unit. Initial base flow of these streams occurs at elevations between 210 and 290 ft MSL to the north, west and south of the Landfill Property. These creeks discharge to Port Gamble Bay.

2.5 ADJACENT PROPERTIES AND LAND USE

Figure 2-6 shows the Property and adjacent properties with current zoning. Property ownership is as indicated. The Property is currently zoned in accordance with the Kitsap County Zoning Map (amended December 8, 2003) and is designated rural protection (1 dwelling unit/10 acres). Adjacent land zoning includes rural protection to the northeast (1 dwelling unit/10 acres), interim rural forest to the north and northeast (1 dwelling unit/20 acres), and industrial to the east. The industrial land to the east includes an industrial park and inert landfill recently approved by the KCHD.

Property to the west and southeast is owned by the Port Gamble S'Klallam Tribe. No County zoning regulations are in effect for the Tribal lands; however, communication with the Tribe has indicated that this land is currently used for forestry, but the Tribe may have an interest in developing the properties in the future for either commercial or residential uses.

Lands adjacent to the Landfill Property are generally used for forestry, with some residential land use to the east.

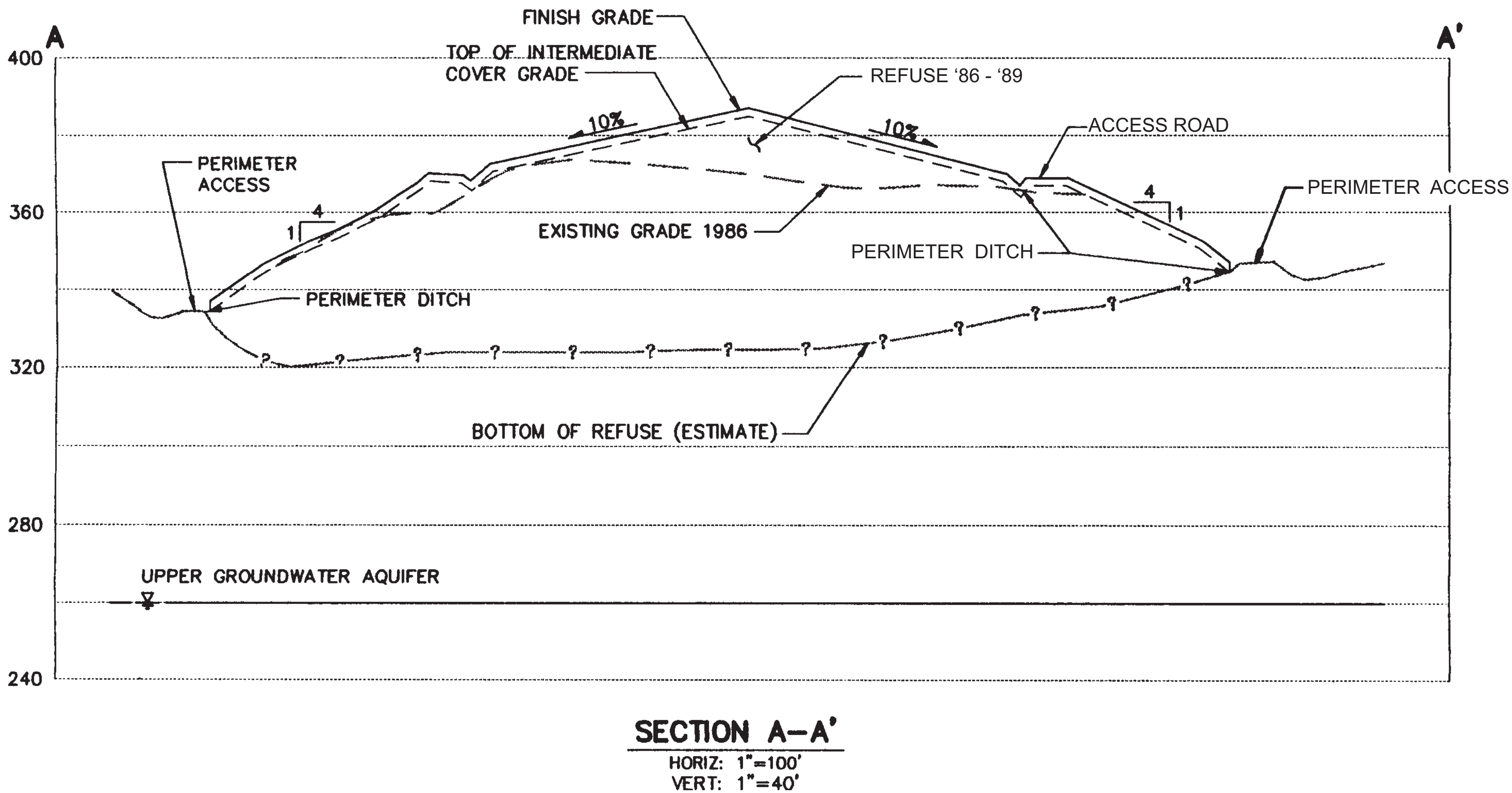
2.6 ECOLOGICAL RESOURCES IN THE STUDY AREA

Consistent with the requirements of the Project Work Plan (Parametrix 1995), an evaluation of ecological resources in the Study Area was conducted in July 1997. Ecological resources include all threatened or endangered species, all State priority habitats, unique habitat features, and ecological resources off-site that may be affected by on-site impacts. At the time of the evaluation, the Washington Department of Fish and Wildlife (WDFW) Priority Habitats and Species Database had no records of endangered, threatened or State species of concern within the Study Area (Appendix M). Freshwater wetlands and riparian areas are considered priority habitats by the WDFW, though the wetlands within the Study Area were not identified in the database. Common and disturbed on-site habitats comprise most of the habitat in the Study Area.

Table 2-1. Average Monthly Precipitation and Evapotranspiration Estimates for the Hansville Study Area[1]

Month	Average Precipitation (in)	Average Potential Evapotranspiration (in)
Oct.	2.6	1.8
Nov.	3.9	0.9
Dec.	4.8	0.6
Jan.	4.1	0.5
Feb.	3.8	0.6
Mar.	2.8	1.1
Apr.	2.3	1.9
May	2.1	2.9
Jun.	2.2	3.5
Jul.	0.9	4.1
Aug.	1.0	3.8
Sep.	1.4	2.8
	31.9	24.5

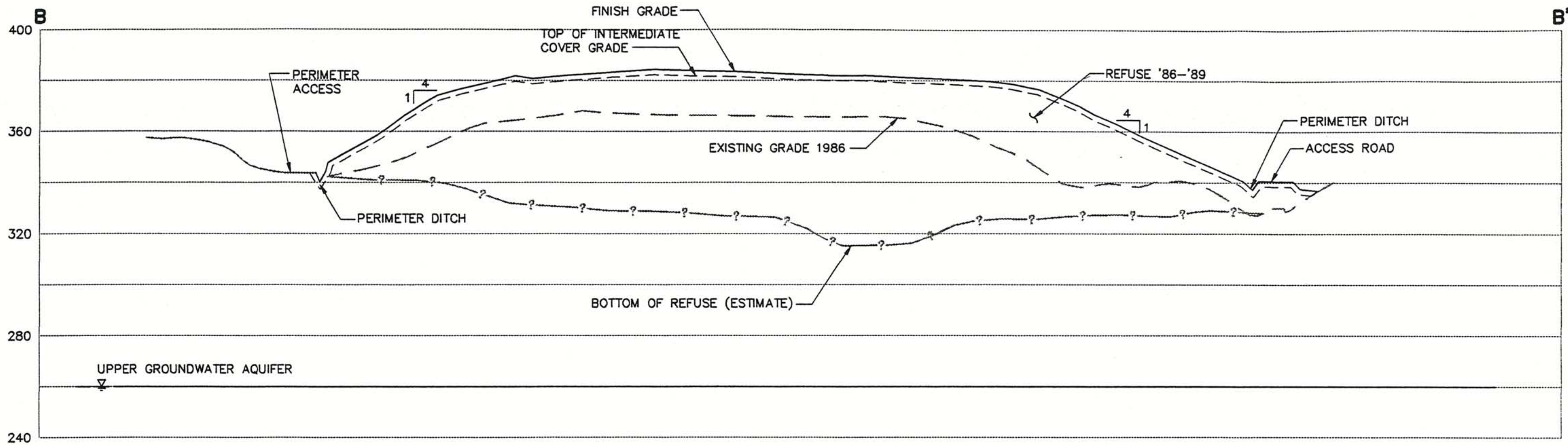
[1] Based on prorating mean annual precipitation (March 1965 Soil Conservation Service data) with average monthly precipitation values from the Chimacum weather station (Gale Research Company 1981).



Note:Line of section shown on Figure 1-3.

DRAFT

Figure 2-1
Landfill Section A-A'
Hansville Landfill RI/FS



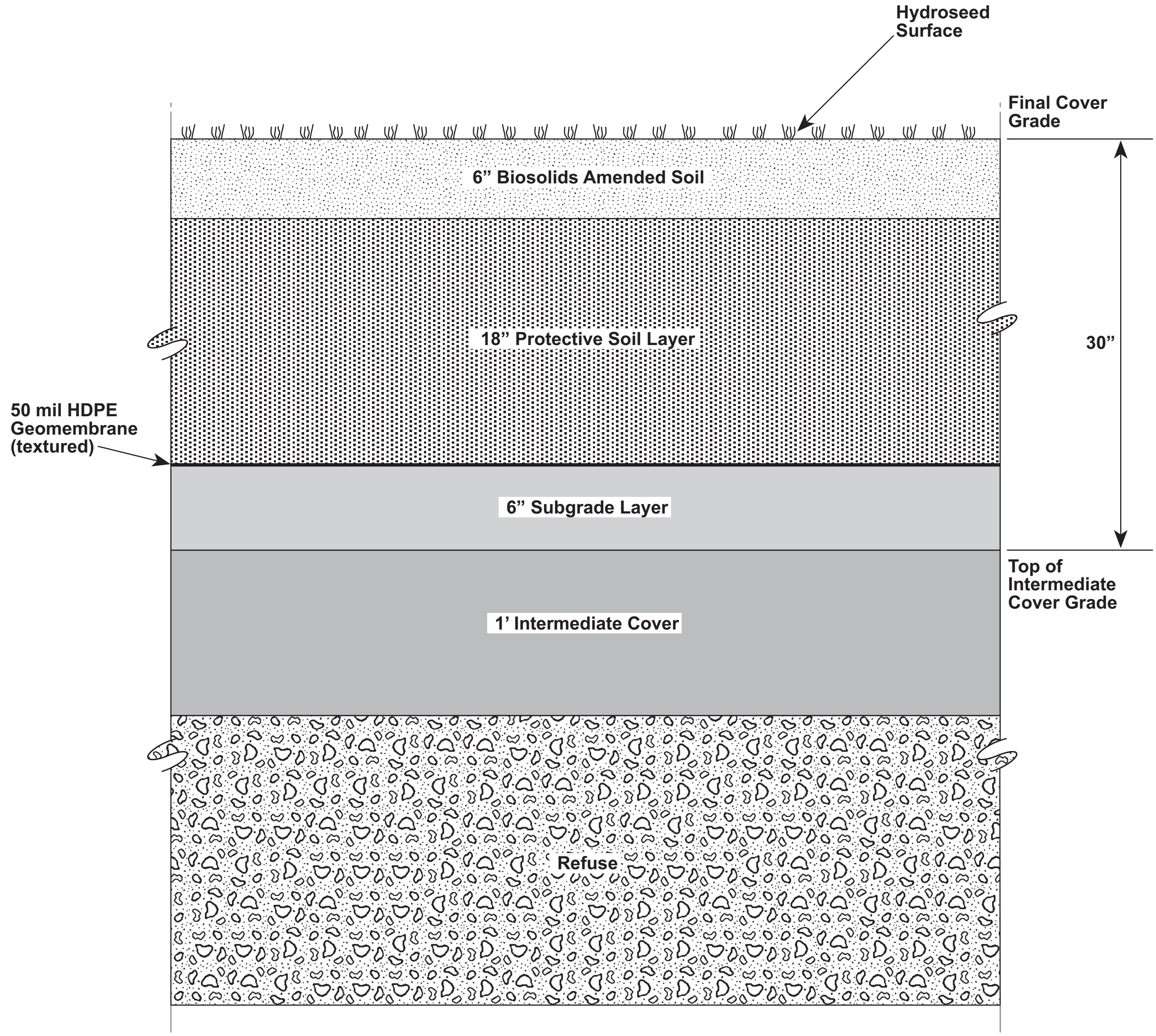
SECTION B-B'

HORIZ: 1"=100'
VERT: 1" = 40'

DRAFT

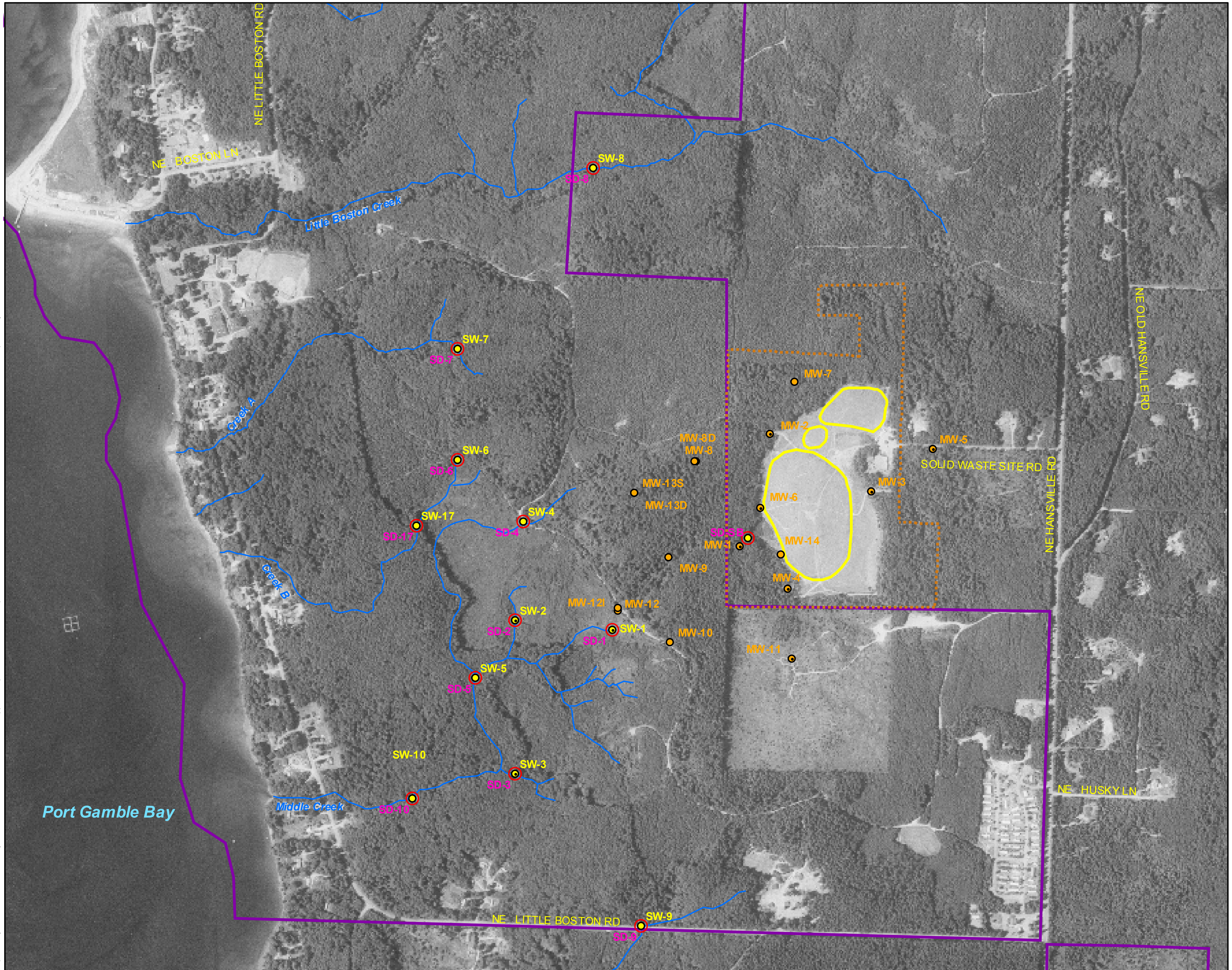
Note: Line of section shown on Figure 1-3.

Figure 2-2
Landfill Section B-B'
Hansville Landfill RI/FS



DRAFT

Figure 2-3
Final Cover System
Hansville Landfill RI/FS



Legend

- Monitoring Well (MW)
- Surface Water Sampling Station (SW)
- Sediment Sampling Station (SD)
- Existing Prior to RI
- Port Gamble S'Klallam Tribe Reservation Boundary
- Stream
- Hansville Landfill Property Boundary
- Waste Disposal Area

N

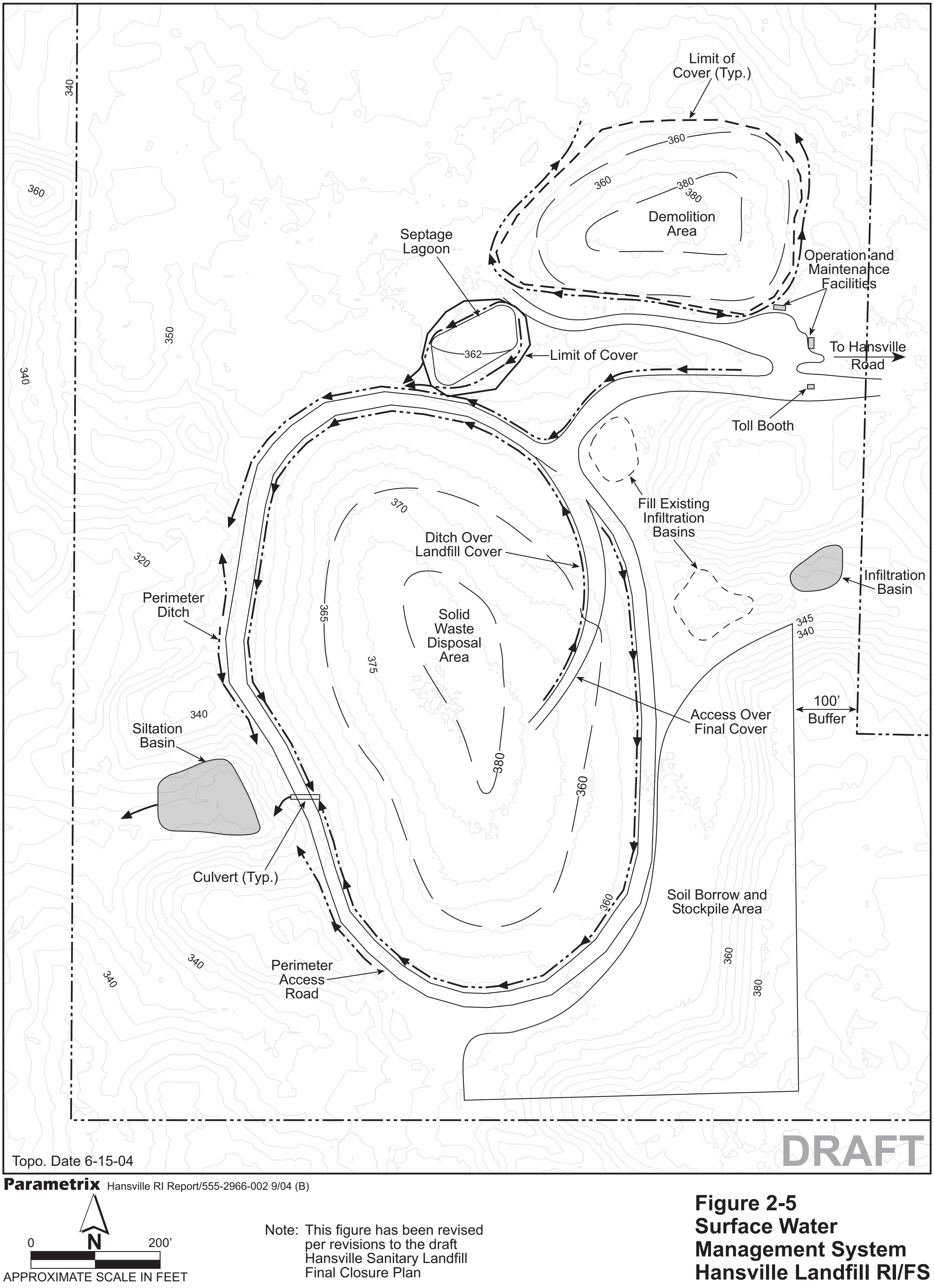
0 400 800 Feet

Parametrix

Figure 2-4
Location of Groundwater, Surface Water, and Sediment Sample Stations
Hansville Landfill RI/FS

DRAFT

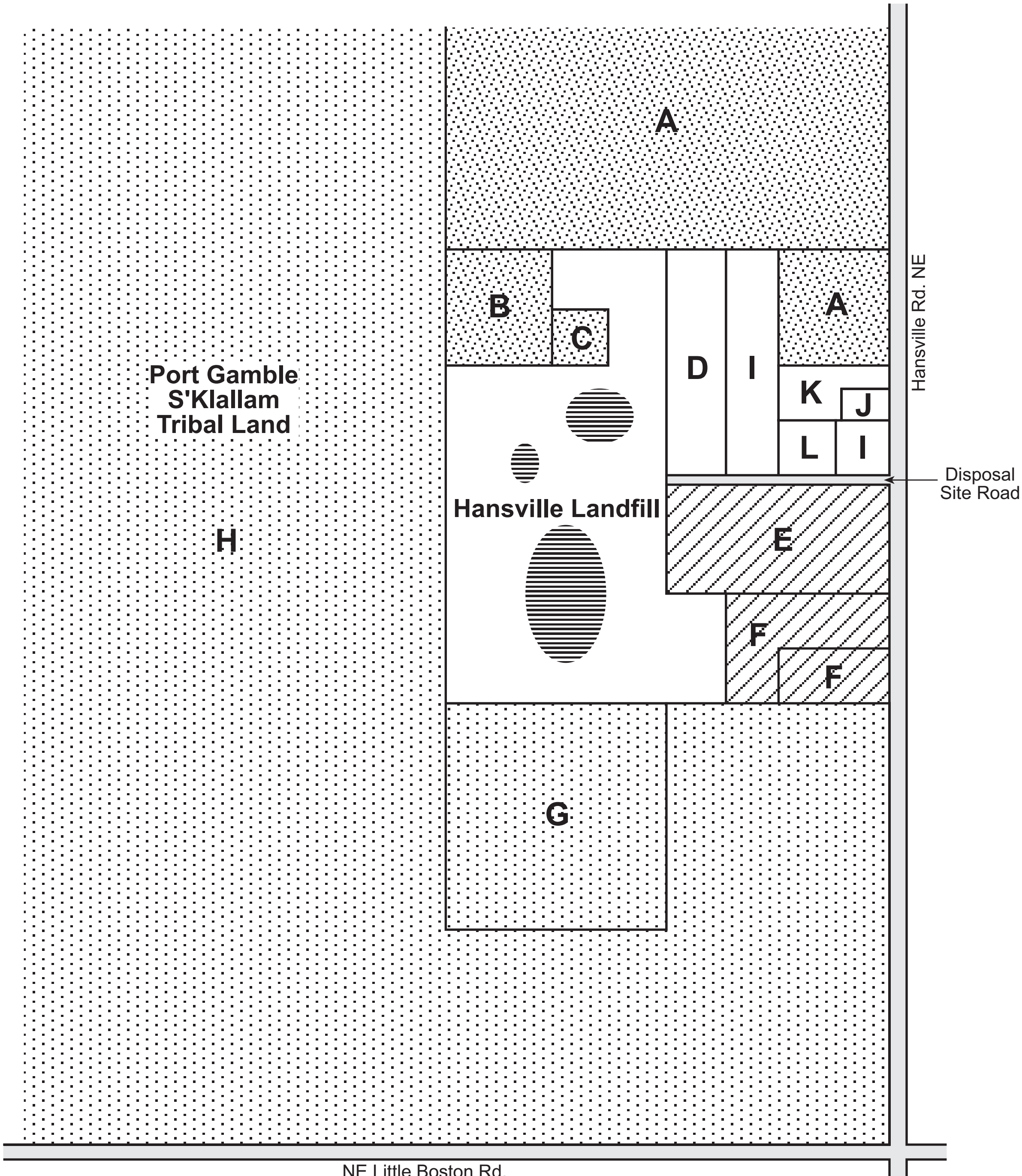
Prepared by Parametrix Inc. 24 May 2007, K:\GIS\2966\555\2966002\SupportMapDocuments\BaseMapAerial\22204.mxd. Data Sources: Port Gamble S'Klallam Tribe, Kitsap County



Parametrix Hansville RI Report/555-2966-002 9/04 (B)

Note: This figure has been revised per revisions to the draft Hansville Sanitary Landfill Final Closure Plan

Figure 2-5
Surface Water Management System
Hansville Landfill RI/FS



Adjacent Property Owners

A&B	Pope Resources	**F**	A&A Tree Farm, Inc.	**K**	Kitsap County Rd
C	L. Demerice	**G&H**	Port Gamble S'Klallam Indian Tribe	**L**	W. Nail
D	L. Scott	**I**	R. Phillips		
E	Akamai Properties, Inc.	**J**	Public Utility District		

DRAFT

Source: Kitsap County 2004

Parametrix Hansville RI Report/555-2966-002 6/05 (B)

N
NO SCALE

LAND USE: (Per Kitsap County Zoning Map, amended December 8, 2003)

- Interim Rural Forest
- Rural Protection 1du/10 acres
- Industrial
- Tribal Lands
- Waste Disposal Areas

Figure 2-6
Adjacent Land Use and Zoning
Hansville Landfill RI/FS

3. WASTE SOURCE INVESTIGATION

3.1 PURPOSE AND OBJECTIVES

The purpose of the waste source investigation is to identify the sources and general characteristics of waste disposed at each of the three disposal areas of the Landfill. General characteristics of municipal solid waste, demolition waste, and septage were used to supplement information obtained through the investigation outlined in this section.

The following approach was used to investigate the source of waste delivered to the Landfill:

- Review of KCSL customer charge records. These documents are limited by KCSL's document retention policy to those from the last few years of operations at the Landfill. They identify customers, waste volume, and charges, but not waste constituents.
- Review of records maintained by KCSL's corporate counsel.
- Review of BKCHD records.
- Interviews of individuals believed to have knowledge of waste disposed at the Landfill, including specific questions regarding potential disposal of hazardous substances.
- Review of consultant's reports prepared before Parametrix was retained and/or reports prepared for Ecology or the USEPA in conjunction with assessing the Site.
- Kitsap County reviewed its files for relevant information on waste sources and found only information that was duplicated in one or more of the other locations.

3.2 WASTE TYPES

According to the 1982 Kitsap County Comprehensive Solid Waste Management Plan (Parametrix 1982), solid wastes generated in the County were divided into five categories: mixed municipal solid waste, industrial waste, demolition waste, special waste, and dangerous and hazardous waste. The Solid Waste Management Plan noted that there were only two significant sources of industrial wastes in the County: the U.S. Navy at its various installations, and the forest products industry. Special wastes identified in the Plan included tires, septic tank pumpings, white goods (appliances), automobiles, coal ash, and sewage treatment plant sludge.

Automobiles were not accepted for disposal at the Landfill. Wood waste from the forest products industry was also not accepted for disposal. The only hazardous substance that was known to have been accepted at the Landfill, other than small unregulated quantities within mixed municipal solid waste, is asbestos. The Solid Waste Management Plan update noted that the categories of wastes generated within the County had not changed since the original plan was prepared in 1971. Information about waste stream components before 1971 was not available.

As described in Section 2.1 (Landfill Property Description), there are three separate closed disposal areas at the Landfill (see Figure 1-3). These include a 13-acre solid waste disposal area that accepted mixed municipal solid waste; a 4-acre demolition disposal area that accepted construction, demolition, and landclearing wastes; and a 1/3-acre septage lagoon area which accepted septic tank pumping waste. The wastes placed within each of these areas are discussed in the following sections.

3.2.1 Waste Placed in Solid Waste Disposal Area

The Landfill provided a refuse disposal site for the northerly portion of Kitsap County and Bainbridge Island through June 1989. In addition, central Kitsap County refuse was collected at the Silverdale Transfer Station and disposed at the Landfill.

The total estimated volume of waste disposed at the Landfill from 1983 to 1989 is itemized in Table 3-1. Total yardage has been converted to tons based on an average density of 270 pounds per cubic yard for all wastes. This average density was based on densities derived in the Kitsap County Refuse-Derived Fuel Feasibility Study in 1998. The demolition waste volumes for 1986 and 1987 were based on quantities reported by KCSL.

Refuse was placed in daily cells, compacted, and covered. Daily cover material was obtained on-site. The limit of refuse was determined through a series of topographic maps (1980, 1982, 1983, 1986, 1989). Study of these maps indicates the successive filling areas. All filling areas (as indicated by changing topography) are encompassed by the solid waste disposal area perimeter road and were capped with the final cover system. Only partial depth-of-refuse data is available for the Landfill from topographic maps. Conversations with the Landfill operator provided the remainder of the depth-of-refuse data.

As described in Section 2.1.2 (Solid Waste Disposal Area), filling in the solid waste disposal area was initially in a valley that varied from elevation 340 ft MSL on the east side of the Property (near MW-3) to elevation 310 ft MSL on the west side of the Property (near MW-1). No excavation is known to have occurred prior to waste placement, because the Landfill was operated as an open dump until 1972, when new regulations took effect. Based on this data, refuse likely extends no lower than elevation 310 ft MSL in the central area. The water table in the upper aquifer typically occurs at an elevation of approximately 260 ft MSL. Figures 2-1 and 2-2 provide cross sections of the solid waste disposal area.

During Landfill operations by KCSL, refuse in the north portion of the solid waste disposal area was filled to an elevation of about 370 ft MSL. To extend capacity, the southern portion of the solid waste disposal area was excavated to elevation 330 ft MSL, then filled. The area excavated to elevation 330 ft MSL is identifiable in the 1983 topographic map, shown in Figure 2 of the Hansville Sanitary Landfill Final Closure Plan (Parametrix 1994).

Over its operational life, the Landfill is estimated to have accepted over 600,000 tons of mixed municipal solid waste. The following companies and municipalities hauled mixed municipal solid waste to the Landfill: Hudson Disposal Company, North Sound Sanitation, City of Poulsbo, Bainbridge Disposal, and the City of Winslow. In addition, the following waste generators of particular interest have been identified:

- <u>U.S. Navy.</u> Mixed municipal solid waste from Naval Submarine Base Bangor was generally taken to the Olympic View Sanitary Landfill. However, between May 25, 1982, and October 11, 1982, this waste stream went to the Landfill. No information regarding the material included in this waste has been located. In addition, an unsigned memorandum to the BKCHD files notes that a company named Tranco Industries, Inc., of Spokane, Washington, was removing asbestos lagging from underground steam pipes at the Keyport Naval facility and transporting the asbestos to the Landfill. The memo includes no information about the volume of asbestos involved.

- Watson Furniture Systems. This furniture manufacturing company on Bainbridge Island routinely disposed of 55-gallon drums at the Landfill. Some of the drums contained liquids. The superintendent and caretaker believe Watson was the only company that sent 55-gallon drums to the Landfill. One drum exploded when it was moved and injured the equipment operator. The contents of that drum is unknown.
- Wyckoff. Ecology records include a record of communication dated October 1992 by Barbara Trejo, of an anonymous caller reporting that years ago Wyckoff used to truck oil and creosote to the solid waste dump at Hansville. The Wyckoff Company ran a wood treating operation on Bainbridge Island. This report was not confirmed by Ecology.

3.2.2 Demolition Waste Disposal Area

Demolition waste placement was limited to the demolition waste disposal area located northeast area of the Property, and was also used to cover former septage pumping lagoons in the northeast and north central areas of the Property. Other than general references in various documents to stumps and landclearing debris, no specific information about materials placed in the demolition waste disposal area was located.

3.2.3 Residential Septage Disposal Area

Information on wastes placed in the residential septage disposal area includes the following:

- The Washington State Department of Transportation Ferry System reportedly pumped liquid waste from ferry holding tanks into the septage lagoon at the Landfill.
- Bainbridge Septic Tank Pumping Company, Arness, Inc., North Kitsap-Bainbridge Septic Tank Pumping, and Rent-it-Center (also doing business as A-1 Septic Tank Service) delivered residential septic tank pumpings to the septage lagoon.
- Between 1985 and 1989, the Brownsville sewage treatment plant dumped sludges at the Landfill. If they were dewatered, they were placed in the solid waste disposal area. If not, they went into the septage lagoon.
- According to a May 27, 1994, letter from Glenn Tanner to Steve Thiele, Assistant Attorney General, the Wyckoff Company was reported to have taken between 10,000 and 30,000 gallons of tank bottoms to the Landfill for disposal in the septage lagoon in approximately 1975.

The amount of residential septage waste received at the Landfill in 1979 through 1981 as reported by KCSL is as follows:

1979: 1,322,500 gallons

1980: 1,884,800 gallons

1981: 2,089,200 gallons

The septage lagoon was closed to disposal of septic tank pumpings on May 1, 1982, when other disposal options became available.

3.3 WASTE COMPONENT CHARACTERISTICS

There is little information available regarding the exact characteristics of wastes disposed at the Landfill. General characteristics of mixed municipal solid waste, demolition waste, and septic tank pumpings are summarized in this section.

3.3.1 Mixed Municipal Solid Waste

Mixed municipal solid waste is generally comprised of putrescible and non putrescible solid and semisolid wastes including garbage, rubbish, ashes, industrial wastes, commercial waste, swill, sewage sludge, demolition and construction waste and small quantities of household chemicals.

The area served by the Landfill was rural and the majority of the waste source was residential, either self or commercially hauled. There are very limited industrial and commercial uses in this region during the period of Landfill operation. Table 3-2 reflects the estimated waste source composition based on a survey completed by Ecology in 1988.

The overall composition of the solid waste stream from the Kitsap County SWMP is summarized as follows:

Paper:	35.9%	Glass:	4.9%
Putrescible:	23.8%	Household Hazardous:	2.2%
Metals:	15.8%	Rubber:	1.6%
Plastic:	5.7%	Other:	9.8%

3.3.1.1 Demolition Waste

Little information is available regarding the specific types of wastes received at the Landfill and disposed in the demolition waste disposal area. Some understanding of the composition and characteristics of demolition waste can be obtained from studies performed in other parts of the state or country. Regionally, quantities and types of materials from demolition activities vary dramatically. Wood is typically the largest percentage of the demolition waste stream. Other materials could include construction debris, concrete, steel, glass, asphalt, masonry, sheet rock, and household fixtures.

3.3.2 Septic Tank Pumpings

Table 3-3, derived from the EPA design manual for septic systems (USEPA 1980), summarizes the general characteristics of septic tank pumpings. Septage waste is a mixture of sludge, fatty materials, and wastewater removed during the pumping of a septic tank. It is often highly odoriferous and may contain significant quantities of grit, grease, and hair. Of particular note is the high degree of variability of the septage waste, with quantities of some parameters differing by two or more orders of magnitude.

Generally, the heavy metal content of septage is low relative to municipal wastewater sludges, although the range of values may be wide. The characteristics of septage waste generated within Kitsap County is not expected to be significantly different than the ranges presented in the EPA manual. Therefore, in the absence of laboratory testing of the actual septage waste delivered to the Landfill, the data in Table 3-3 provide some understanding of the characteristics of septage waste disposed of at the Landfill.

Table 3-1. Hansville Landfill Waste Stream[a]

Year	Cubic Yards Received	Estimated MSW (Tons/Yr)	Estimated Demolition (Tons/Yr)
1983	141,790	NA	NA
1984	104,630	NA	NA
1985	185,820	NA	NA
1986	173,720	20,400	3,100
1987	181,713	21,300	3,200
1988	156,685	20,688	NA
1989	80,165	8,214	NA

Source: KCSL, Inc.,(1986, 1987, 1988, 1989)

a Assumes the average density of waste brought to the Landfill was 270 lb/cy. This number was derived from the Kitsap County Refuse-Derived Fuel Feasibility Study completed in 1988.

NA = Not Available

Table 3-2. Waste Source Composition

Source	Estimated Percentage of Total Waste
Residential	59.8
Commercial	13.6
Self-Haul	26.3
Industrial	0.3

a Based on a 1988 recycling and waste stream survey by the Department of Ecology

Table 3-3. Characteristics of Typical Domestic Septage

Parameter	Range of Mean Concentrations (mg/L)
Total Solids	12,000 - 40,000
Total Volatile Solids	8,000 - 28,000
Suspended Solids	2,000 - 21,000
BOD	3,000 - 6,000
COD	16,000 - 61,000
pH	6-7 (typical)
NH3-N	59 to 153
Arsenic	0.16
Cadmium	0.1 to 9.1
Chromium	0.6 to 1.1
Copper	8.3 to 8.7
Iron	160 to 210
Mercury	0.02 to 0.4
Manganese	5.4 to 4.8
Nickel	<1.0
Lead	2.0 to 8.4
Selenium	0.07
Zinc	9.7 to 62

Source: USEPA 1980.

4. LANDFILL GAS INVESTIGATION

4.1 PURPOSE AND OBJECTIVES

The purpose of the landfill gas investigation component of the RI was to evaluate the effectiveness of the existing active landfill gas extraction and flaring system at the Landfill in controlling landfill gas migration. The potential for using the active gas system to remediate volatile organic compounds (VOCs) was also assessed. The objectives of the investigation are stated in the Project Work Plan (Parametrix 1994) and are described as follows:

- Obtain, compile, and evaluate gas monitoring data to assess the effectiveness of the active landfill gas extraction and flaring system in controlling landfill gas migration from the solid waste and demolition waste disposal areas of the Landfill.
- Compile historical landfill gas data and correlate landfill gas system milestones (i.e., landfill capping, active system start-up, field adjustments, shut down of perimeter gas extraction wells, etc.) with groundwater data. Evaluate the impact of landfill gas and/or the gas control system on groundwater quality.
- Evaluate the vapor extraction potential of the perimeter gas wells to remediate VOCs in groundwater (principally vinyl chloride).
- Effectively operate and maintain the active landfill gas extraction and flaring system.

4.2 GENERAL CHARACTERISTICS OF LANDFILL GAS

4.2.1 Generation of Landfill Gas

Landfill gas is generated by biological decomposition of organic material in refuse. The decomposition occurs in a typical landfill under both aerobic and anaerobic processes.

Under aerobic decomposition (decomposition in the presence of oxygen), oxygen dependent bacteria break down the organic material within a landfill in the presence of oxygen. The principal by-products of aerobic decomposition are carbon dioxide, water, and residual nitrogen. Aerobic decomposition usually occurs in the initial stages of landfill operation, when the waste within the landfill is entrained with oxygen and exposed to air through the working face of the landfill. As waste becomes buried deeper by placement of additional garbage and daily and intermediate cover soil, the exposure to air decreases and the oxygen within the waste becomes consumed and depleted by the aerobic bacteria. Once this occurs, anaerobic decomposition begins within the landfill.

Anaerobic decomposition is decomposition of organic waste material in the absence of oxygen. This occurs when the aerobic bacteria deplete the oxygen within areas of a landfill. Once the oxygen is depleted, and the waste is no longer exposed to air, the aerobic bacteria die off, and the anaerobic bacteria become dominant. Under this decomposition process, organic waste and water are converted into carbon dioxide and methane gas. Methane, an explosive gas, becomes a major concern with regard to gas control at a landfill.

While landfill gas may be produced as soon as refuse is deposited, methane is not necessarily produced immediately. Landfill gas composition is a result of a complex biological process involving the breakdown (decomposition) of organic materials. Typically, different gases are produced in four characteristic phases of the decomposition process (Figure 4-1). In the final phase, landfill gas composition approaches a steady-state condition, with methane ranging from 50% to 70% and carbon dioxide from 30% to 50%.

For an active landfill, the transition time between phases is dependent upon a number of factors, including depth of refuse, cell design, daily cover operations, and rate of decomposition, all of which affect the amount of oxygen within the waste. However, after a landfill is closed and provided with a low-permeability cover system (as is the case at the Hansville Landfill), the entire landfill generally transitions to an anaerobic condition within 1 or 2 years.

Many variables contribute to the quantity and quality of landfill gas generated within a landfill. Some of the more significant variables include:

- Type of waste deposited,
- Waste burned or not,
- Moisture content within the waste,
- pH and temperature of the waste and landfill environment,
- Age of the waste and placement conditions, and
- Introduction or lack of oxygen.

Typically, mixed municipal solid waste that includes putrescible waste tends to decompose faster than non-putrescible waste (demolition and construction debris). By decomposing faster, mixed municipal solid waste landfills tend to generate greater quantities of landfill gas over shorter time periods than demolition and construction debris landfills. This is evident with the gas generation characteristics of the solid waste disposal area at the Landfill, as compared to the demolition waste disposal area. Although a significant amount of gas was generated in the solid waste disposal area, a much lower volume is now generated in that area of the Landfill. Only small amounts of gas are generated within the demolition waste disposal area.

Landfill gas can also include trace amounts of VOCs, including vinyl chloride. The migration of landfill gas with VOCs can be a contributing factor in transporting VOCs to groundwater, as discussed in Sections 4.2.3 and 9.2.

4.2.2 Landfill Gas Migration

As gas is generated within a landfill under an anaerobic decomposition process, it saturates the open void spaces within the waste and continues to build pressure. In a closed landfill with an impermeable cap, such as the waste disposal areas at the Hansville Landfill, the pressure continues to increase within the landfill. If adequate measures are not in place to control the landfill gas through venting or a collection system, migration into the surrounding soils can occur.

The extent of migration beyond the landfill footprint depends on the gas pressure generated within the landfill, the permeability of the media through which the migration occurs, and the time interval over which migration occurs. In the case of the Hansville Landfill, the permeable unconsolidated sand deposits that extend from beneath the Landfill down to the water table presented a low-resistance pathway to landfill gas that became pressurized under the geomembrane cap that was installed in 1990. Details of this gas migration and associated control measures are described in Section 4.5.

4.2.3 Potential for Groundwater Contamination

In addition to creating an explosion hazard, landfill gas migration can be a contributing factor to VOC transport in groundwater. In theory, there are three basic mechanisms that can contribute to groundwater impacts by VOCs through landfill gas migration (Prosser and Janecheck 1995):

1. <u>Direct contact with groundwater by landfill gas.</u> Generally, landfill gas will migrate toward the atmosphere; however, under pressure, the gas will tend to follow the path of least resistance, which includes the soils surrounding and underneath an unlined landfill. As the landfill gas reaches the capillary zone, the VOCs in the landfill gas have the opportunity to be absorbed directly into the groundwater.
2. <u>Formation of landfill gas condensate in the soils surrounding the landfill.</u> Landfill gas temperatures typically range from 80° to 100° F within a landfill. As the landfill gas moves through refuse, it is typically saturated with water vapor at these temperatures. The soil surrounding the landfill is usually cooler. Thus, as the vapor-saturated gas passes through the cooler soils, gas condensate is formed outside the refuse mass. Partitioning of the VOCs from the vapor to liquid phase will typically result in trace concentrations of VOCs within the condensate, which can flow as a liquid and ultimately come in contact with groundwater.
3. <u>Landfill gas impacts on the vadose zone and infiltration of water that carries the VOCs to groundwater.</u> As landfill gas migrates through the soil adjacent to a landfill, the landfill gas constituents (including VOCs) will partition between the gas phase and water retained in pores by capillary forces. Water infiltrating through the vadose zone may mix with and/or displace some of the pore water containing VOCs. The downward movement of this water may ultimately lead to VOCs migrating to the groundwater.

4.3 REGULATORY REQUIREMENTS

Applicable regulations governing landfill gas control at the Landfill are described in the State of Washington MFS regulations. Specifically, Chapter 173-304-460(2)(b)(i) WAC requires that:

An owner or operator of a landfill shall not allow explosive gases generated by the facility whose concentrations exceeds:

(A) Twenty-five percent of the lower explosive limit for the gases in facility structures (excluding gas control or recovery system components);

(B) The lower explosive limit for the gases at the property boundary or beyond; and

(C) One hundred parts per million by volume of hydrocarbons (expressed as methane) in offsite structures.

In addition, Chapter 173-304-460(3)(f)(i) WAC states:

All owners and operators shall design landfills, having a permitted capacity of greater than 10,000 cubic yards per year, so that methane and other gases are continuously collected and

(A) Purified for sale;

(B) Flared; or

(C) Utilized for its energy value.

In order to meet these minimum requirements, a passive gas venting and flaring system was constructed at the Landfill solid waste disposal area and demolition waste disposal area as part of the Landfill closure design in 1989. This system was upgraded to an active gas venting and flaring control system in 1991 in response to a request for additional corrective actions by BKCHD. A description of these gas control systems and their performance history is presented in the following sections.

4.4 LANDFILL GAS EXTRACTION AND FLARING SYSTEM

4.4.1 Passive Landfill Gas Venting and Flaring System

A passive gas venting and flaring system was originally installed at the solid waste and demolition waste disposal areas of the Landfill as part of the closure in 1989. The passive system consisted of horizontal trenches and piping installed at the top of the disposal areas under the geomembrane final cover. The piping system was installed in a filter fabric and drain rock envelope placed in the refuse. These gas collection/venting trenches were connected to several small flares located at high points on top of the closed disposal areas.

Positive pressure generated from the refuse decomposition process (see Section 4.2) pushed the landfill gas through the piping system to the small flares. The flares supported combustion of any landfill gas that entered the passive system. Valves were provided to close off the flares if insufficient gas was available for combustion. The locations of the passive gas system collection trenches are shown on Figure 4-2.

In 1991, groundwater monitoring results indicated that vinyl chloride concentrations in groundwater had risen to levels exceeding MCLs. Based on the groundwater data, BKCHD directed KCSL and Kitsap County to address the vinyl chloride issue. In response, KCSL and Kitsap County proposed to the BKCHD and Ecology that an active landfill gas extraction and flaring system be installed to address landfill gas control and migration (see Section 1.3.4). The BKCHD concurred, and the active landfill gas extraction and flaring system was designed and installed at the Landfill during the summer of 1991, and became operational in November 1991.

4.4.2 Active Landfill Gas Extraction and Flaring System

The active landfill gas extraction and flaring system installed at the solid waste disposal areas of the Landfill consists of five main components:

- Interior landfill gas extraction wells and trenches (installed in refuse),
- Perimeter gas extraction wells located in native soil adjacent to the solid waste disposal area,
- Perimeter gas monitoring probes located near the Property boundary,
- Motor blower/flare facility to extract and combust the collected landfill gas, and
- Condensate collection system.

A general layout of the landfill gas extraction and flaring system is shown on Figure 4-2.

The in-refuse gas extraction system (13 wells/eight trenches) was designed to create a negative pressure (vacuum) within the Landfill and collect landfill gas that is generated by the decomposing refuse. A typical gas extraction well is shown in Figure 4-3. The 13 wells and eight trenches were designed and spaced to collect and remove gas from all portions of the Landfill. The vertical gas extraction wells are installed to a depth of approximately 90 percent of the depth of refuse. All of the in-refuse wells were completed as single pipes in each borehole.

In addition to the in-refuse extraction system, five native-soil extraction wells were installed around the perimeter of the solid waste disposal area as part of the active landfill gas system. These extraction wells were designed to remove landfill gas from the surrounding soils, provide a second line of defense against future gas migration, and offer a potential method of vapor extraction to remove VOCs from the subsurface. The native-soil extraction wells were installed to a depth of approximately 40-45 ft below the depth of refuse. All of the native-soil gas extraction wells are double completions; one casing is installed to half the depth of the well, and a second casing is installed to the full depth of the well. A typical gas extraction well completed in native soils outside refuse is shown in Figure 4-3.

All the active landfill gas extraction wells and trenches are connected through a common piping network that routes the collected landfill gas to the motor blower/flare facility. Two 7.5-horsepower blowers alternate in service to induce a vacuum on the system and draw landfill gas to the open flare where combustion takes place. The flare combusts the landfill gas (methane), thereby destroying other trace compounds in the landfill gas.

As landfill gas is drawn to the surface, it begins cooling to ambient air temperatures and produces condensate. The condensate is removed from the pipe network by knockouts located at low points of the piping system. Gravity drains feed the condensate liquid into one of two holding tank sumps. The condensate is removed periodically from the sumps by vactor truck and transported to a local municipal wastewater treatment plant for disposal.

The five perimeter gas probes were designed and installed in the native soils around the solid waste disposal area to monitor potential landfill gas migration near the property boundary. Each probe bottom elevation extends to the approximate depth of refuse. Due to the increased depth requirement of gas probe GP-2, multiple completions were installed to monitor three incremental depth zones at that location. A typical multiple-completion gas probe is shown on Figure 4-4.

Two additional gas probes were installed in 1996. One probe (GP-7) was installed with new groundwater monitoring well MW-9 southwest of the solid waste disposal area. The other probe (GP-6) was installed in the northeastern corner of the Property near the demolition waste disposal area. Each monitoring probe is a single-completion and is installed in the soil above the saturated zone of the upper aquifer.

4.5 SUMMARY OF LANDFILL GAS EXTRACTION AND FLARING SYSTEM OPERATION

The transition to an active gas control system in 1991 had an immediate impact on landfill gas migration. Once the active system became operational, both the gas reservoir within the Landfill and gas that had migrated to the surrounding soils were steadily removed and flared over the first year of operation. The gas monitoring probes and native-soil extraction wells showed a quick response to the active operation, with steady reduction of methane concentrations. Figures 4-5a and 4-5b and show the summary results of the monitoring probe readings since 1991. These figures demonstrate the effectiveness of the active landfill gas extraction and flaring system in controlling landfill gas migration and removing residual landfill gas from the surrounding soils.

As the gas concentration and flow declined, the amount of gas combusted in the flare (measured as BTUs) decreased. Within the first 6 months of operation of the gas system, it became necessary to reduce the vacuum in most of the extraction wells (including the native-soil gas wells) as a result of the reduced gas flow.

By June 1992, most of the gas had been removed from the surrounding soil, as well as the residual gas within the solid waste disposal area. Because the wells were drawing mostly air (with little methane), it became necessary to close these wells to ensure that the flare had enough high-quality gas to burn continuously and efficiently. By that time, the gas system had generally reached steady-state conditions and was operated primarily to control gas production. Monitoring and operating data had demonstrated that migration of gas was no longer occurring (see Figure 4-5b).

In 1994 the system was again modified to address the reduced concentrations of landfill gas being generated. This modification included reconfiguring the collection piping system to segregate the low methane-concentration flow of the native-soil extraction wells from the high methane-concentration flow of the in-refuse wells. This modification allowed the perimeter well system (which draws primarily air) to be operated independently of the in-refuse system. Without this segregation, the native-soil wells could not be operated without diluting the methane concentrations in the collected gas to levels that would not support combustion.

The primary intent of segregating the two systems was to allow the native-soil extraction wells to be operated at a high flow rate, in an attempt to provide benefit as a vapor extraction system for removal of VOCs from the subsurface soils and groundwater. The native-soil well vacuum was set up to be provided by Blower No. 1. The landfill gas vacuum was provided by Blower No. 2. To ensure that the landfill gas portion of the system ran continuously in the event of a breakdown in Blower No. 2, the system was modified such that Blower No. 1 could be switched over and used as a backup.

After a 6-month trial period, it was determined the system could not operate reliably with the segregated native-soil extraction wells. Because these wells are located within 50 ft of the solid waste disposal area, applying increased vacuum on the native-soil extraction wells caused landfill gas to be drawn out of the Landfill into the native soil, defeating the original intent of the modification, which was to contain the landfill gas within the Landfill. The native-soil extraction wells were subsequently closed down.

Since 1995 the system has been operated continuously with the native-soil extraction wells closed, controlling landfill gas migration with the in-refuse wells and trenches. Monitoring results during the segregated flow trial period showed that the gas control system, without operating the native-soil extraction wells, was creating a measurable vacuum that extended beyond the limits of refuse into the surrounding soil. This information, in conjunction with gas probe monitoring that shows no detectable methane migration, demonstrates that continuous operation of the in-refuse portion of the landfill gas extraction and flaring system has been effective in controlling lateral landfill gas migration.

In 2003, a downsized flare was installed to handle the decreased volume of landfill gas generated at the Landfill. This improvement allows the facility to operate continuously under current landfill conditions without the need for supplemental fuel and ensures complete combustion of the landfill gas.

4.6 LANDFILL GAS MONITORING PROGRAM

4.6.1 Description of Monitoring Program

Routine monitoring has been performed at the Landfill since final closure and installation of the original passive landfill gas venting and flaring system in 1989. The primary objectives of the monitoring have been to ensure (a) proper operation of the gas control systems and (b) compliance with Chapter 173-304 WAC, BKCHD (was KCHD), Puget Sound Air Pollution Control Agency (now Puget Sound Clean Air Agency; PSCAA), and other applicable regulatory requirements.

Historical landfill gas extraction and flaring system monitoring data collected between April 1991 and May 1995 are available and are presented in the annual reports for the Landfill. These historical data document routine adjustments made to the gas collection system in response to seasonal changes. Typical adjustments include changing flow rates in response to measured methane production, management of increased condensate production during winter months, and pipe repairs due to expansion/contraction of the PVC pipe.

The current landfill gas extraction and flaring system monitoring program was implemented in 1995 to include the following:

- Monthly monitoring of the in-refuse gas extraction wells/trenches and native-soil extraction wells for individual performance. Measured parameters at the in-refuse gas extraction wells/trenches include methane, oxygen, and carbon dioxide concentrations; static pressure; flow rate; and temperature.
- Monthly monitoring of the flare facility for overall system performance. Measured parameters are the same as for individual extraction points.
- Monthly monitoring of the perimeter gas probes. Measured parameters include methane, oxygen, and carbon dioxide concentrations, and static pressure.
- Monthly monitoring of the native-soil extraction wells for static pressure.

Sampling and monitoring procedures are conducted in accordance with the RI Sampling and Analysis Plan (Parametrix 1996a). Landfill gas data collected from June 1995 to January 2004 are summarized in Appendix A.

During 1995 through 1997, the gas extraction wells were monitored twice monthly instead of monthly, to ensure that the system operated at the highest performance level possible, and to address any maintenance issues that occurred. Adjustments were made to individual extraction points in response to seasonal fluctuations and other changes in methane generation rates in the closed solid waste disposal area. The gas system is effectively meeting regulatory requirements and is monitored every 3 weeks. This frequency corresponds with the recommended maintenance interval for the gas control system blowers.

In addition to the routine monitoring program, gas samples were collected and analyzed for VOCs at selected locations of the extraction and monitoring systems. This included samples from each of the seven gas monitoring probes, one native-soil extraction well (N-3D), and the main gas transmission header at the motor blower/flare facility.

4.6.2 Summary of Monitoring Results

Several indicators are available for evaluating performance of the landfill gas extraction and flaring system. The most significant indicator is the concentration of methane detected. Methane is necessary for continuous operation of the motor blower/flare facility, but should not be present at the Landfill Property boundary (perimeter gas probes). Methane concentrations are therefore used as the primary indicator of the gas extraction and flaring system performance.

A secondary indicator of system performance is static pressure. Monitoring results of the native-soil extraction wells show a measurable negative pressure in the native soils surrounding the Landfill. The system is therefore effectively preventing off-site migration by inducing a vacuum beyond the limits of refuse. A positive pressure gradient must be present for off-site migration to occur.

The monitoring data for gas control system operation at the Landfill since the original passive venting and flaring system was installed in 1989 have shown that landfill gas migration is controlled with the active gas system. These data also show that gas that previously migrated into the surrounding soils has been removed and that landfill gas is no longer present in any of the gas monitoring probes or in any of the perimeter gas wells (see Figure 4-5a and b). Methane concentrations in the native-soil extraction wells rapidly declined, from levels as high as 70 percent by volume at startup of the active system (November 1991), to near zero within 8 months of operation. The gas probes showed similar results, with initial methane concentrations as high as 20 percent by volume declining to near zero within 12 months of operation.

The motor blower/flare facility showed an initial high methane concentration of 70 percent at start-up, declined to as low as 12 percent by volume in 1994, restabilized to near 30 percent through March 1998, and has been stable at around 20 percent since then. Maintaining a stable methane concentration at the motor blower/flare facility is necessary to sustain the gas extraction and flaring system.

A stable methane concentration ensures that the flare stays lit and destroys VOCs. The explosive range for methane is between 5 percent and 15 percent by volume. A minimum methane concentration of 20 percent by volume is recommended at all times to avoid explosive or flame-out conditions. This 20 percent methane criterion provides a factor of safety against fluctuations in methane production and dilution effects from wind and weather.

The static pressure measurements for the native-soil gas extraction wells show that the system is effective in inducing a vacuum that extends beyond the limits of refuse, thus eliminating landfill gas migration. The fluctuations shown are primarily due to seasonal weather conditions and changes in barometric pressure. The gas collection system is adjusted during routine monitoring events to address the weather impacts.

In addition to the time-series plots, vinyl chloride concentrations detected in the gas samples collected on August 8, 1996 and June 24, 2004, are presented in Table 4-1. Vinyl chloride was not detected in any of the samples collected from the monitoring probes or the native-soil extraction wells. Vinyl chloride was detected in the main gas piping at the motor blower/flare facility, indicating a continued presence of vinyl chloride in the gas generated within the closed solid waste disposal area. However, the latest vinyl chloride concentration at the motor blower/flare facility was approximately 10 percent of the original volume in 1996. The complete results of the laboratory analysis for VOCs analyzed in the gas samples are presented in Appendix P.

4.7 LANDFILL GAS EXTRACTION AND FLARING SYSTEM EFFECTIVENESS

Evaluation of the historical operation and monitoring records of the gas control systems at the Landfill leads to the following conclusions:

- The landfill gas extraction and flaring system can be maintained and adjusted to operate continuously. This was and is achieved by closing the extraction wells with low concentrations of methane that would otherwise reduce methane concentrations at the motor blower/flare facility, and by reducing the size of the open flare.
- The gas system induces a vacuum that extends beyond the Landfill footprint. This is indicated by measurable negative pressures in the native-soil gas extraction wells that have been closed.
- The gas system effectively prevents landfill gas migration beyond the Property boundary. Gas probe monitoring results indicate no detectable methane at the Property boundary.
- Vinyl chloride was not detected in any of the landfill gas monitoring probes in the native soils surrounding the Landfill.
- VOCs (including vinyl chloride) are present in the landfill gas extracted from the Landfill. However, based upon the monitoring data, the gas generated within the Landfill is being removed and combusted at the flare facility. This was demonstrated by the 10-fold reduction in the vinyl chloride concentration measured at the flare in 2004 compared to 1996. Thus, with continuous operation of the landfill gas extraction and flaring system, the VOCs within the gas collected from the Landfill will continue to be destroyed at the flare facility.

Based on these results, the landfill gas control system should continue to operate as prescribed in the RI/FS work plan, and as required by applicable regulatory requirements. Monthly monitoring of the system is recommended to ensure compliance and allow for routine maintenance/adjustments of the system in response to seasonal conditions.

4.8 LANDFILL GAS IMPACTS ON GROUNDWATER

Section 4.2.3 identified three potential mechanisms by which landfill gas can contribute to VOC transfer to groundwater:

1. Direct contact with groundwater by landfill gas,
2. Formation of landfill gas condensate in the soils surrounding the Landfill, and
3. Landfill gas contamination of the vadose zone and infiltration water carrying VOCs to the groundwater.

Prior to the activation of the active landfill gas extraction and flaring system, it is probable that all of the above mechanisms could have been contributing factors to VOC (specifically vinyl chloride) impacts on the groundwater at the Site. As previously noted, migration of landfill gas into soils surrounding the solid waste disposal area was documented in 1991. At that time, landfill gas was detected in all four original landfill gas monitoring probes. The farthest probe was approximately 500 ft from the solid waste disposal area. Thus, it is reasonable to conclude that soils in the vadose zone under and surrounding the solid waste disposal area were at one time saturated with landfill gas.

Based upon the landfill gas monitoring data obtained since the active landfill gas extraction and flaring system was installed, landfill gas has been effectively removed from the surrounding soils. The monitoring data further demonstrate that landfill gas migration is being controlled within the solid waste disposal area, and indicate that it is not currently migrating laterally into the surrounding soils. Therefore, the potential VOC transport mechanisms #1 and #2 noted above have been significantly reduced or possibly eliminated as ongoing contamination sources with the continuous operation at the landfill gas extraction and flaring system. One exception may be the vadose zone that is directly beneath the solid waste disposal area. No gas monitoring data are available to verify whether or not gas migration is occurring directly beneath the solid waste.

Vinyl chloride concentrations found in groundwater, particularly at off-site monitoring wells and surface water stations (see Chapter 9, Chemical Fate and Transport Evaluation, Figures 9-2 and 9-3, may be attributable to one or more of the three contributing landfill gas transport mechanisms, and/or historical leachate generation occurring prior to the capping of the disposal areas and the installation of the gas extraction and flaring system. Neither landfill gas nor vinyl chloride was detected since October 1993 or August 1996, respectively, in gas probes in the vadose zone around the closed solid waste disposal area. The potential source and release mechanisms of vinyl chloride to the groundwater are further described in Section 9.2.2, Release Mechanisms for Primary Contaminant Sources.

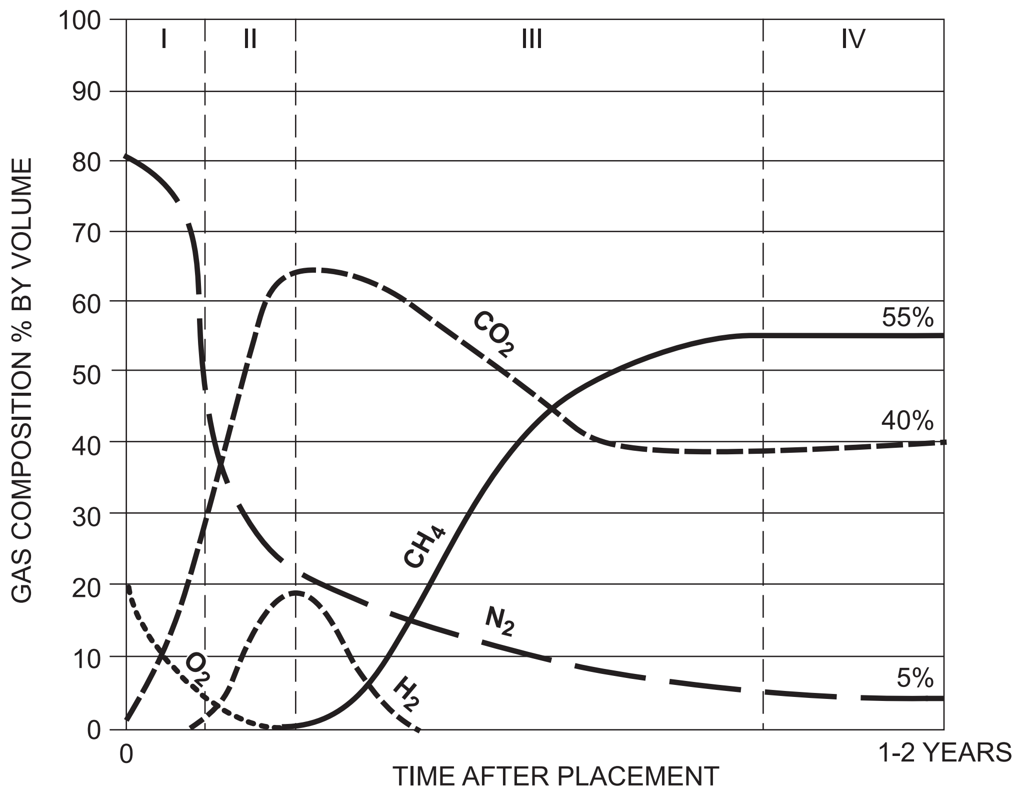
Table 4-1. Vinyl Chloride Concentrations in Parts Per Billion by Volume (ppbv)

Location	August 8, 1996		June 24, 2004	
	MDL (ppbv)	Concentration (ppbv)	MDL (ppbv)	Concentration (ppbv)
Main Flare	33.8	460.3	6.6	50.60 J
Gas Probe GP-1	0.7	ND	3.3	ND
Gas Probe GP-2D	3.2	ND	3.2	ND
Gas Probe GP-3	3.1	ND	3.7	ND
Gas Probe GP-4	3.2	ND	3.2	ND
Gas Probe GP-5	3.0	ND	3.3	ND
Gas Probe GP-6	3.0	ND	3.2	ND
Gas Probe GP-7	3.1	ND	3.7	ND
Native-Soil Extraction Well N-3D	3.1	ND	3.3	ND

MDL = Method detection limit

ND = Not detected at or above the MDL

J = Result between MDL and Reporting Limit



DRAFT

I = Aerobic
II = Anaerobic, Non-Methanogenic
III = Anaerobic, Methanogenic, Unsteady
IV = Anaerobic, Methanogenic, Steady

CO_2 = Carbon dioxide
O_2 = Oxygen
CH_4 = Methane
H_2 = Hydrogen
N_2 = Nitrogen

Figure 4-1
Evolution of Typical Landfill Gas Composition
Hansville Landfill RI/FS

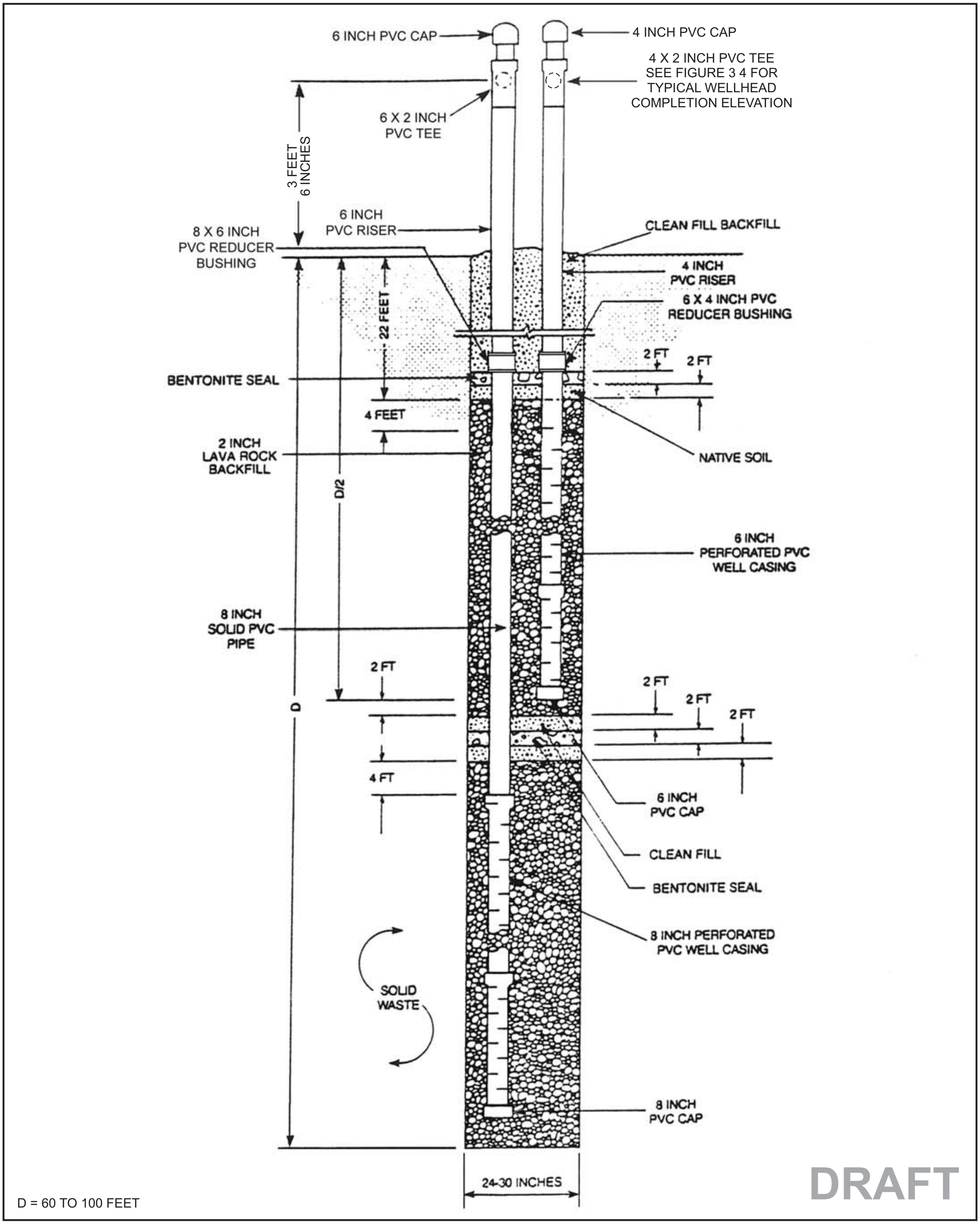
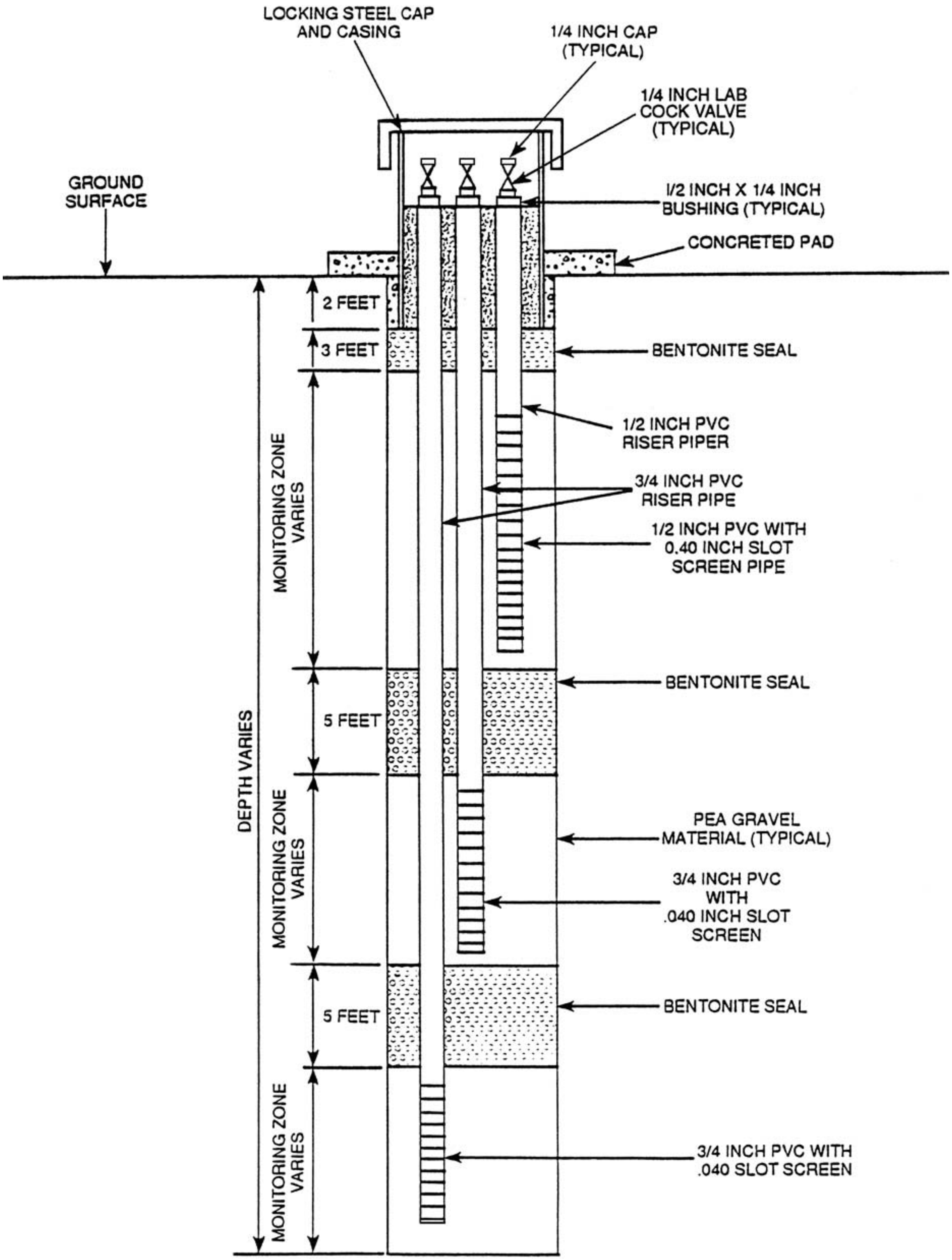


Figure 4-3
Typical Landfill Gas Extraction Well Construction Details
Hansville Landfill RI/FS



DRAFT

Figure 4-4
Typical Landfill Gas Monitoring Probe Construction Details
Hansville Landfill RI/FS

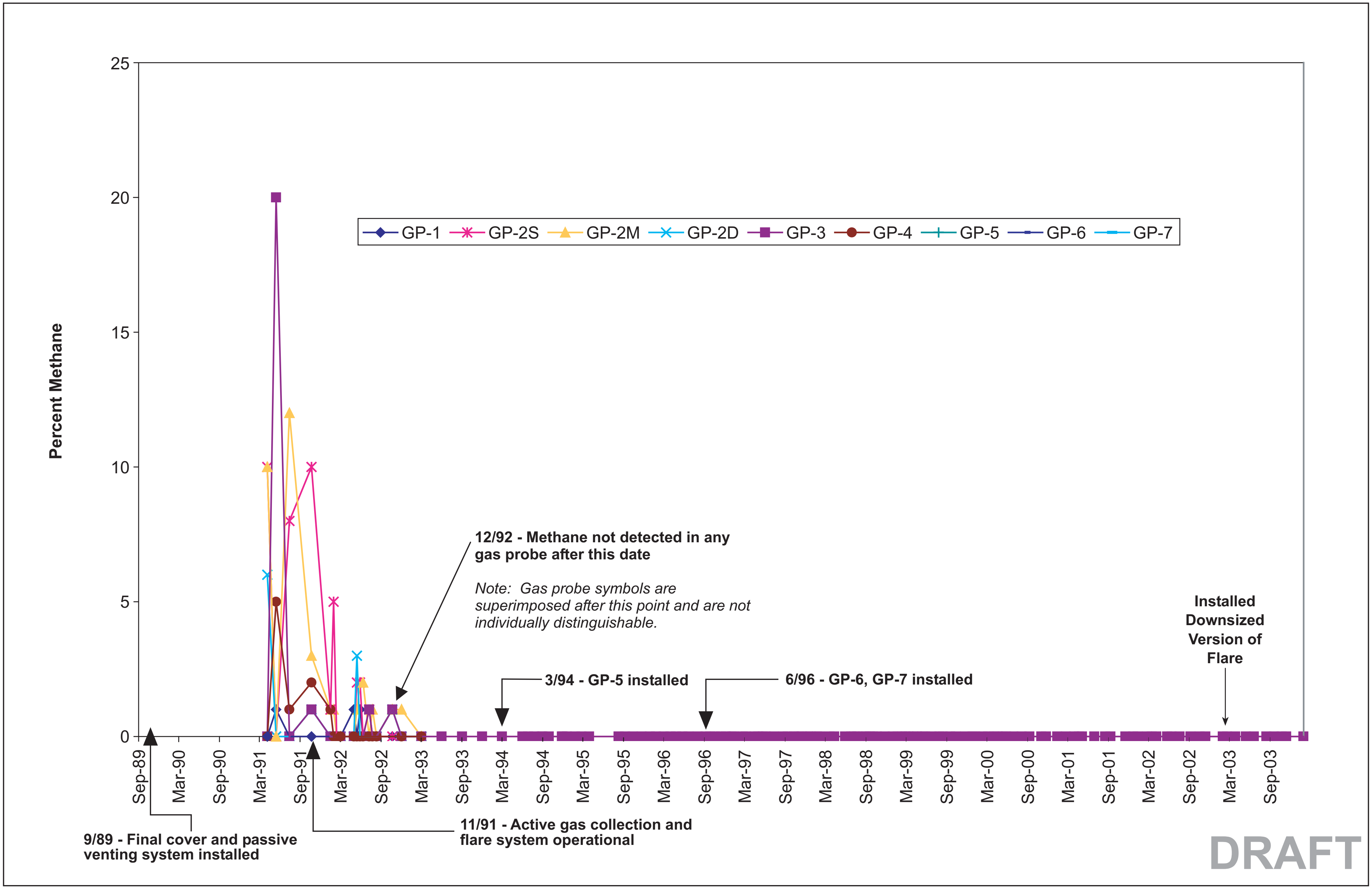


Figure 4-5a
Methane Concentrations in Landfill Gas Probes
Hansville Landfill RI/FS

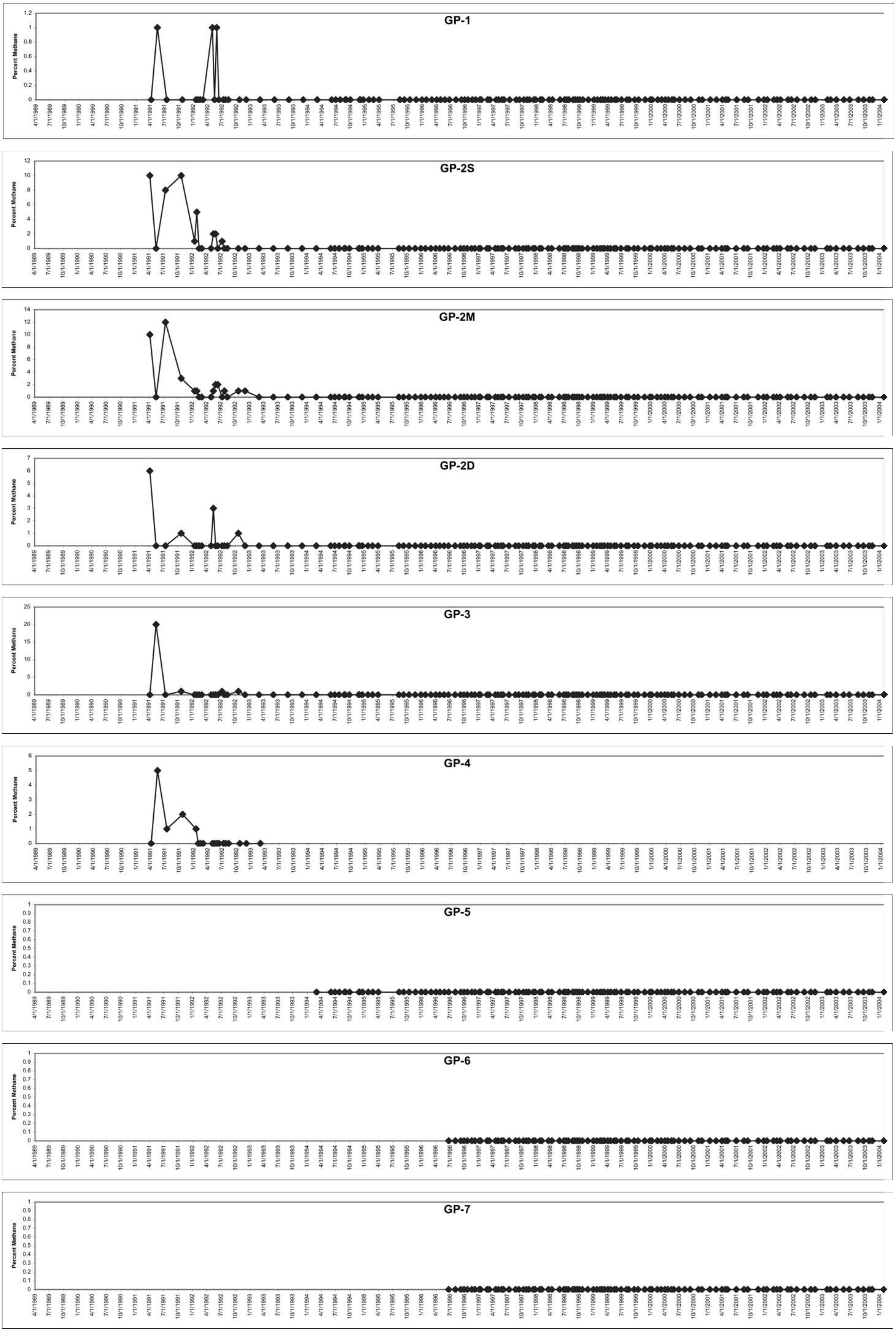


Figure 4-5b
Expanded-Scale Plots Methane Concentrations in Landfill Gas Probes
Hansville Landfill RI/FS

5. GROUNDWATER INVESTIGATION

5.1 PURPOSE AND OBJECTIVES

The purpose of the hydrogeologic investigation component of the RI is to assess the potential migration of chemicals of potential concern in groundwater from waste sources (solid waste disposal area, demolition waste disposal area, septage disposal area) at the Landfill. The objectives of the investigation are stated in the Project Work Plan (Parametrix 1995) and described as follows:

- Characterize the lateral and vertical extent of Landfill impacts in the upper aquifer by installation of additional monitoring wells on and off of the Property and by sampling of existing on-site monitoring wells and new monitoring wells.
- Refine the groundwater flow system understanding with respect to flow directions and hydraulic characteristics of the upper aquifer and relationships between upper aquifer discharge and flow of streams to the west of the Landfill.
- Further document the extent and thickness of the Kitsap Formation in the Study Area, with respect to the function of this clay unit as an aquitard separating the upper and lower aquifers. The extensive thickness of this aquitard (approximately 175 feet thick at the Site) blocks the downward migration of potential contaminants within the upper aquifer (monitored in this study). The lower aquifer is used in the area for drinking water supply.
- Develop current information regarding users of groundwater in the Study Area by updating the water well inventory previously completed as part of the Hansville Sanitary Landfill Final Closure Plan (Parametrix 1994).
- Determine whether sufficient data have been collected to delineate the nature and extent of Landfill impacts to the groundwater system and to support analysis of remedial alternatives in the Feasibility Study.

5.2 SUMMARY OF PREVIOUS HYDROGEOLOGIC INVESTIGATIONS

5.2.1 Installation of Monitoring Wells

The first monitoring wells at the Property were installed as part of a hydrogeologic characterization effort by Sweet, Edwards and Associates (1983). The Sweet Edwards work included drilling of monitoring wells MW-1, MW-2, and MW-3 in February 1982 and presentation of the initial hydrostratigraphic interpretation in their project report. Monitoring wells MW-4 and MW-5 were drilled in March 1988 as part of a field investigation by Parametrix to assess groundwater quality at additional locations upgradient (MW-5) and downgradient (MW-4) of the Landfill. Monitoring well MW-6 was drilled in July 1990 under the direction of Parametrix to confirm the depth to the top of the Kitsap Formation (discussed below in Section 5.4.2, Site Hydrogeologic Conditions) and to provide samples of this formation for testing of vertical hydraulic conductivity.

The locations of these monitoring wells are shown on Figure 5-1. Appendix G includes geologic logs and construction diagrams of these monitoring wells.

5.2.2 Historical Groundwater Quality Data

Groundwater quality data collection was initiated at the Hansville Landfill in 1982, when the first monitoring wells were installed. Early testing was conducted intermittently for landfill parameters (selected cations, anions, and field parameters). In 1987, a sampling plan was developed that established routine groundwater monitoring on a quarterly basis for Ecology Minimum Functional Standards (MFS) parameters. Monthly groundwater monitoring (MFS parameters, VOCs, and selected heavy metals) was initiated in 1991, in accordance with the Solid Waste Handling Permit issued by BKCHD, and continued through early 1994.

VOCs, semivolatile organic compounds (SVOCs), pesticides, and polychlorinated biphenyls (PCBs) were analyzed in March 1988 and April 1988 on samples from the five monitoring wells in place at that time. The analyses indicate that no pesticides, PCBs, or SVOCs were present in any of the five on-site monitoring wells. All of the VOCs detected were below their respective Federal Maximum Contaminant Level (MCL) except for vinyl chloride, which exceeded the Federal MCL of 0.002 mg/L in MW-1 (0.021 to 0.029 mg/L) and MW-3 (0.005 to 0.012 mg/L).

In 1991, SAIC collected groundwater samples from the lower aquifer (well 9G1) used for water supply at the Property (SAIC 1991). The results indicated that no organic compounds or pesticides were detected, but levels of iron and manganese in exceedance of drinking water standards were measured. This well is not used for drinking water, and was not included in the RI monitoring program because it is screened in the lower aquifer. A study of groundwater quality in Kitsap County found that drinking water standards for iron and manganese were frequently exceeded, as is expected for glacial aquifers of Western Washington (Kitsap Public Utility District 1997).

Historical groundwater sampling data collected before initiation of the RI and summarized in the Project Work Plan (Parametrix 1995) indicated the following:

- Four parameters were identified as representative indicators of Landfill impacts on groundwater: specific conductivity, dissolved arsenic, dissolved manganese, and vinyl chloride.
- Monitoring wells MW-2 and MW-6 showed the greatest impacts, with respect to statistically significant increases over background and exceedances of State or Federal groundwater quality standards.
- All four downgradient monitoring wells on the Property (MW-1, MW-2, MW-4, and MW-6) showed impacts from the Landfill.

5.3 OVERVIEW OF THE RI GROUNDWATER INVESTIGATION

The framework of the RI groundwater investigation was developed and presented in Chapter 6 of the Project Work Plan (Parametrix 1995). The technical approach for the groundwater investigation was documented in the Sampling and Analysis Plan (Parametrix 1996a), the Quality Assurance Project Plan (Parametrix 1996b), and the Health and Safety Plan (Clayton Environmental Consultants 1995).

The components of the RI groundwater investigation are described as follows:

5.3.1 Phase 1 Field Investigation

- Field work was conducted between January 8 and March 12, 1996.
- Six groundwater monitoring wells (MW-7 through MW-12) were installed at locations shown on Figure 5-1. Well construction details are summarized in Table 5-1.
- Discrete-depth groundwater quality samples were collected throughout the entire thickness of the upper aquifer at approximate 20-ft intervals during drilling of MW-8, MW-9, MW-10, and MW-12. Samples were analyzed for field parameters, VOCs, and selected metals and inorganic compounds indicative of Landfill impacts (see Appendix I for a listing of parameters).
- Split-barrel samples of the Kitsap Formation were collected during drilling of MW-8, MW-9, MW-10, and MW-12. Soil samples were submitted for laboratory analysis of vertical hydraulic conductivity.
- The results of the Phase 1 work were presented in Technical Memorandum No. 3 (Parametrix 1996c), including recommendations for the Phase 2 field investigation.

5.3.2 Phase 2 Field Investigation

- Field work was conducted between May 10 and August 21, 1996.
- Five groundwater monitoring wells were installed (MW-8D, MW-12I, MW-13S, MW-13D, and MW-14), as shown on Figure 5-1 and described in Table 5-1.
- Discrete-depth groundwater quality samples were collected throughout the entire thickness of the upper aquifer at approximate 20-ft intervals during drilling of MW-13D and MW-14. These samples were analyzed for field parameters (see Appendix I for a listing of parameters).
- The following activities were completed for all Phase 1 and Phase 2 monitoring wells: well development, aquifer testing (slug tests), dedicated sampling pump installation, and surveying of well casings.
- Golder Associates completed initial geophysical testing (May 10, 1996) and a geophysical survey (August 20 and 21, 1996) along the northern boundary of the Property using the Time Domain Electromagnetic (TDEM) method. The location of the TDEM survey is shown on Figure 5-2.

  The TDEM method measures differences in electrical resistivity (the reciprocal of conductivity) of soil and rock. Lower resistivities are typically associated with higher concentrations of ions in the pore water resulting from leachate impacts. The TDEM method involves introducing an electrical field via a transmitter loop placed at a series of adjacent points on the ground surface, measuring the resulting voltage at the receiver, and analyzing the data using computer modeling software.

  Vertical TDEM soundings were conducted along two profile lines (Line 1 and Line 2). The Line 1 soundings (1-1 through 1-4) extended from the area of known groundwater contamination in the vicinity of well MW-2 northward to well MW-7. Lower resistivities were measured in the sounding near MW-2 compared to other soundings further north. Line 2 soundings (2-1 through 2-10) were conducted near the northern border of the Property. The resistivities measured in the second profile did not indicate the presence of groundwater contamination. The results (Golder Associates 1996) indicated that migration of Landfill impacts in the upper aquifer was not evident along the northern Property boundary. The survey report is included in Appendix K.

- The results of the Phase 2 field investigation are documented in the draft Technical Memorandum No. 5 (Parametrix 1997b).

5.3.3 Groundwater Sampling and Analysis

- Four initial RI groundwater sampling events were completed between August 1996 and May 1997, and 23 subsequent Ecology-directed sampling events consisting of sample collection from selected pre-RI and RI monitoring wells were completed from March 1998 through January 2004.
- Groundwater samples from the dry season RI event (August 6 through 9, 1996) and wet season RI event (March 3 through 5, 1997) were tested for VOCs and SVOCs, pesticides, PCBs, metals, and conventional parameters.
- Groundwater samples from the two other RI events (November 20 through 22, 1996; May 21 through 23, 1997) and selected Ecology-directed events (between March 1998 and January 2004) were analyzed for VOCs, metals, and conventional parameters.
- The Ecology-directed events included a subset of the entire monitoring well network (monitoring wells MW-4, MW-5, MW-6, MW-7, MW-11, MW-12I, MW-13S, MW-13D, MW-14), per recommendations by Parametrix (1999a) and subsequent approval by Ecology.
- In the first quarter of 2000, the number of groundwater well sampled and parameters tested were further reduced to reflect the improved monitoring results (Parametrix 1999e). Sampling was eliminated at wells MW-4, MW-11, and MW-13S, and analysis for seven dissolved metals (antimony, cadmium, mercury, nickel, selenium, silver, and thallium) was discontinued. Vinyl chloride continued to be analyzed quarterly and the full VOC list was analyzed annually.

5.3.4 Groundwater Quality Data Management

Groundwater data from each sampling event were processed as follows:

- Digital data from the analytical laboratory were incorporated into the project database.
- Data quality reviews were conducted in accordance with the procedures described in the QAPP (Parametrix 1996b). Data requiring qualifications were annotated in the database and in summary data tables. The QA/QC data summary sheets for each event are provided in Appendix O.
- The summary data tables and time-series plots for selected parameters (specific conductivity, chloride, nitrate, dissolved arsenic, dissolved manganese, and vinyl chloride) are presented in Appendix B. Hard copies of the laboratory reports are presented in Appendix P.

5.3.5 Other Elements

- The network of pre-RI and RI monitoring wells was determined to be sufficient to assess the nature and extent of Landfill impacts in the upper aquifer and to support the Feasibility Study, as documented in draft Technical Memorandum No. 4 (Parametrix 1997a).
- The inventory of water supply wells within 1 mile of the Landfill Property was updated in 2004.
- Water levels in monitoring wells were measured prior to each sampling event (Tables 5-2a and 5-2b).
- The extent, thickness, and hydraulic characteristics of the Kitsap Formation were documented (Table 5-3 through 5-5).

Details of the RI groundwater investigation methods, procedures, and data are described in Appendices G through L.

5.4 HYDROGEOLOGIC SYSTEM DESCRIPTION

5.4.1 Regional Geologic Conditions

5.4.1.1 Geologic History

The oldest formations found on the Kitsap Peninsula are comprised of Eocene Age volcanic rocks overlain by thousands of feet of younger marine sedimentary rocks. These formations were deformed and eroded during the late Miocene and further deformed during the Pliocene, creating the present day Puget Trough (Garling et al. 1965).

During the late Pliocene and early Pleistocene, additional sedimentary materials were deposited on the earlier deformed rocks within the Puget Trough. These materials are believed to have accumulated in lakes, swamps, streams and as glacial drift laid down by several large ice sheets which occupied the Puget Sound lowland at least four times during the Pleistocene (Garling et al. 1965). The geologic materials of significance to this project include those deposited during the two most recent glaciations and the intervening interglacial period that affected the Puget Sound region. The deposits related to the older of the two glaciations have been tentatively correlated with the Salmon Springs Drift. The younger glacial deposits have been named the Vashon Drift. The non-glacially derived materials deposited between the two glacial drifts comprise the interglacial Kitsap Formation.

The Salmon Springs Drift is an undifferentiated deposit of coarse, stream-laid gravels and sands with local occurrences of glacial till. The overlying non-glacial materials of the Kitsap Formation are comprised of clays and silts, with minor amounts of sands and gravels along with intervening beds of peat and lignite. These materials were deposited on an aggradational floodplain during the interglacial period. The Vashon Drift is comprised of outwash sands, gravels, clays, and an extensive till sheet deposited during the advance and recession of the ice lobe, during the most recent glacial epoch in the Puget Sound region.

These unconsolidated deposits of clay and silt, sand, and till are the dominant materials exposed in the Study Area. The character, extent, thickness, and water-bearing properties of these deposits are described in Figure 5-3.

5.4.1.2 Regional Groundwater Occurrence and Movement

Hansen and Bolke (1980) divided the unconsolidated deposits discussed previously into three hydrologic units: the upper, middle, and lower. The three units correlate to the stratigraphic units described by Garling et al. (1965) shown in Figure 5-4. Hydrogeologic data indicate that all three units are present in the Study Area.

The areal extent and thickness of water-bearing strata in both the upper and lower hydrologic units is poorly understood. Hansen and Bolke (1980) found in their study that correlation of well data, even over distances of less than a mile, is difficult. No single water-bearing stratum can be traced over large distances. The many layers of sand and gravel are of limited extent and are imperfectly connected. These water bearing strata form a network of deposits in which permeability varies considerably both laterally and vertically. Collectively, these different strata form a system that is analogous to a laterally extensive aquifer.

The upper water-bearing unit (outwash sands and gravels of the Vashon Drift) contains fairly continuous water-bearing beds or layers, compared to the generally less continuous water-bearing strata in the lower unit (sands and gravels of the Salmon Springs Drift). The middle unit is not known to contain any major water-bearing deposits (Hansen and Bolke 1980).

In general, the direction of groundwater movement in the upper water-bearing unit is toward Puget Sound, Hood Canal, or major streams, depending upon geographical location. In areas where the upper water-bearing strata extend into Puget Sound or Hood Canal, discharge occurs directly to these bodies of salt water. Otherwise, discharge occurs to streams, springs, and as diffuse seepage at altitudes above sea level.

The silt and clay of the Kitsap Formation (middle unit) separates the upper and lower water-bearing units. The Kitsap Formation has a relatively low hydraulic conductivity and acts as an impedance to vertical movement of groundwater between the upper and lower water-bearing units.

Within the lower water-bearing unit (Salmon Springs Drift), productive zones are reported to occur at numerous depths within individual sand and gravel lenses that collectively form the lower regional aquifer. The areal distribution and depths of wells are insufficiently known to permit mapping of individual water-bearing strata within the lower unit.

5.4.2 Site Hydrogeologic Conditions

5.4.2.1 Soil Types

According to the Soil Survey of Kitsap County Area, Washington (United States Department of Agriculture 1980), the soils in the Study Area consist predominantly of fine sandy loam of the Poulsbo-Ragnar complex. This soil type is typically found on terraces and broad uplands, is deep and well drained, and formed from glacial outwash. Also present in minor amounts in the Study Area are soils of the Indianola-Kitsap complex and the Kitsap silt loam. These soil types are formed from glacial lake sediments and are present in the investigation area at locations where the silts and clays of the Kitsap Formation are exposed at ground surface (side slopes of Little Boston Creek valley and at elevations below approximately 150 ft MSL downgradient of the Landfill).

5.4.2.2 Site Hydrostratigraphy

Review of reports by others (Lum 1980; GeoEngineers, Inc. 1982; Sweet, Edwards and Associates 1983) indicate that the Study Area is underlain by several hundred feet of unconsolidated sediments consisting of gravel, sand, silt, and clay. However, none of these strata have been formally correlated to the regional stratigraphic units described in Section 5.4.1, Regional Geologic Conditions. Indications are that the stratigraphic units underlying the Site may correlate with the Colvos Sand, silt, and clay of the Kitsap Formation, and the Salmon Springs Drift.

Eight groundwater monitoring wells (MW-1 through MW-7 and MW-14) were drilled on the Landfill Property. In addition, nine groundwater monitoring wells (MW-8, MW-8D, MW-9, MW-10, MW-11, MW-12, MW-12I, MW-13S, MW-13D) were drilled on adjacent Tribal property. All 17 monitoring wells (see Figure 5-1) are completed above the Kitsap Formation. Geologic logs of these monitoring wells were used to construct geologic cross sections presented as Figures 5-5, 5-6, and 5-7, to illustrate the hydrostratigraphic conditions in the Study Area. Monitoring well construction details are summarized in Table 5-1.

The Site-specific stratigraphy described below is based on the regional information discussed in Section 5.4.1 and on the subsurface information obtained during the Phase 1 and Phase 2 field investigations. Boring logs are included in Appendix G. From ground surface downward, the following hydrogeologic units underlie the Site:

- <u>Sand</u> - This unit was encountered in all soil borings from the ground surface to depths ranging from 62 to 142 ft below ground surface (in MW-12 and MW-6, respectively). The sand deposit consists primarily of poorly graded, fine- and medium-grained sand with trace amounts of silt and gravel. It is dark yellowish brown to dark gray in color, dense to very dense, and dry to saturated. This unit is referred to as the upper aquifer.
- <u>Transition Zone</u> - This zone was encountered at three boring locations (MW-8, MW-9, and MW-14) and is approximately 15 ft thick. It consists of interbedded layers of sand, silty sand, and silt and does not appear to be areally extensive.
- <u>Silt</u> - This unit was encountered in all borings advanced through the upper aquifer. It was encountered at elevations ranging from approximately 175 ft MSL at MW-14 to 217 ft MSL at MW-9. The silt is dark gray, slightly to moderately plastic, very dense, and dry. This unit is interpreted to be the Kitsap Formation.

Groundwater level data measured during the study period in the upper aquifer are summarized in Tables 5-2a and 5-2b. Groundwater in the immediate vicinity of the Landfill occurred within the upper aquifer at depths below ground surface ranging from approximately 43 to 49 ft in MW-1 and 96 to 104 ft in MW-5. The water table occurred between approximately 255 ft and 271 ft MSL.

Groundwater to the west (downgradient) of the Landfill occurred within the upper aquifer at depths below ground surface ranging from approximately 7 to 10 ft in MW-12I and 39 to 45 ft in MW-8. Water table elevations in downgradient groundwater monitoring wells ranged from approximately 238 ft to 260 ft MSL.

The upper aquifer does not appear to be regionally extensive based on stratigraphic data from Hansen and Bolke (1980). However, monitoring well boring logs and surface geologic reconnaissance mapping indicate it is both present and continuous in the vicinity of the Site. The upper aquifer may be stratigraphically equivalent to the upper water-bearing unit (Section 5.4.1) described locally from other regions of Kitsap County, though not physically or hydraulically connected across the county due to local depositional and erosional variations.

The upper aquifer underlying the Site is perched on low-permeability silt and clay of the Kitsap Formation. Data from water supply wells inventoried within 1 mile of the Landfill Property indicate that the Kitsap Formation is present at all of these water well locations and that its thickness ranges from 39 ft to 372 ft, as summarized in Table 5-3 and shown on Figure 5-8. The high degree of variation in these data is attributable to inconsistencies of driller's geologic knowledge, stratigraphic terminology, and record keeping practices. Despite these uncertainties, the data confirm the broad lateral extent and thickness of the Kitsap Formation in the Study Area. The driller's log of the water well at the Property indicates that the Kitsap Formation is approximately 175 ft thick beneath the Property (Figure 5-8). The contact between the upper aquifer and the Kitsap Formation in the vicinity of the Landfill is at an elevation of between 175 ft and 217 ft MSL (Table 5-4), based on data from seven groundwater monitoring wells which were advanced through the upper aquifer to the top of the Kitsap Formation.

5.4.2.3 Properties of Hydrostratigraphic Units

Calculated horizontal hydraulic conductivity values for the upper aquifer are summarized in Table 5-6 and range from 9 x 10^{-4} cm/sec (3 ft/day) to 1 x 10^{-2} cm/sec (57 ft/day). Details of the field and data analysis procedures pertaining to the slug tests are described in Appendix I, and slug test data plots are included in Appendix J. These values are consistent with expected values for a fine to silty sand, a well-sorted sand, or glacial outwash deposits (Fetter 1994).

Vertical hydraulic gradients were calculated at locations where a shallow and deep groundwater monitoring well are located adjacent to one another (MW-8/MW-8D, MW-12/MW-12I, and MW-13S/MW-13D). Downward vertical gradients between 0.0022 ft/ft and 0.012 ft/ft were calculated at the MW-8/MW-8D and MW-13S/MW-13D locations. For the MW-12/MW-12I location, calculated vertical hydraulic gradients were primarily upward, between 0.004 to 0.008 ft/ft, although horizontal or downward gradients of up to 0.004 ft/ft were measured during some events. These results are consistent with expected vertical gradients, based on the locations of these wells with respect to local groundwater recharge and discharge areas within the upper aquifer.

Vertical seepage below the base of the upper aquifer is extremely slow due to the low vertical hydraulic conductivity of the underlying Kitsap Formation. Vertical hydraulic conductivity values for the Kitsap Formation determined from laboratory testing of soil samples are summarized in Table 5-5 and range from 1.5 x 10^{-7} cm/sec (0.16 ft/yr) to 1.4 x 10^{-6} cm/sec (1.4 ft/yr). The soils laboratory reports are provided in Appendix L. These values are consistent with expected values for clays (Fetter 1994).

5.4.3 Groundwater Flow Directions and Velocities

5.4.3.1 Groundwater Flow Directions

Potentiometric surface maps showing the groundwater flow directions for November 1996, May 1997, January 2003, and November 2003 are presented as Figures 5-9 through 5-12, respectively. These dates were selected to show wet- and dry-season conditions during two of the four initial RI sampling events (1996 and 1997) and during a recent monitoring year. The November 1996 and November 2003 maps represent dry-season conditions, and the May 1997 and January 2003 maps represent wet-season conditions. The groundwater flow direction in the upper aquifer is consistently to the west and southwest downgradient of the Landfill. This groundwater flow direction is consistent with groundwater flow directions measured since the late 1980s. Groundwater flows immediately downgradient of the siltation basin (basin location at surface water/sediment station "SW-SB") appears to be influenced by recharge from stormwater runoff.

Groundwater in the upper aquifer discharges along the hillside to the west of the Property, where the upper aquifer outcrops (see Figures 5-9 through 5-12). As discussed in Section 5.4.2.2 (Site Hydrostratigraphy) and shown on the cross sections of Figures 5-5 through 5-7, the entire thickness of the upper aquifer is exposed as the land surface slopes towards Port Gamble Bay. Groundwater discharge from the upper aquifer forms the headwaters of numerous streams, including Little Boston Creek, Creek A, Creek B, Creek C, and Middle Creek.

The lateral limits of the portion of the upper aquifer that could be affected by discharges from waste disposal areas at the Landfill are defined by the limiting groundwater flow lines shown on Figures 5-9 through 5-12. The eastern boundary is defined by potentiometric contours that are upgradient (east and northeast) of the Landfill, in the vicinity of monitoring well MW-5. The northern and southern/southeastern boundaries are defined by the limiting flow lines that skirt the Property boundary (perpendicular to the potentiometric contours), in the vicinity of monitoring wells MW-7 and MW-11, respectively. The western boundary is defined by the discharge area of the upper aquifer west of the Property, where the stream headwaters occur.

The upper aquifer is bounded vertically by the Kitsap Formation, a thick, laterally extensive, low-permeability unit (see Section 5.4.2.2, Site Hydrostratigraphy). As noted in Section 5.4.2.3 (Properties of Hydrostratigraphic Units), vertical seepage below the base of the upper aquifer is extremely slow due to the low vertical hydraulic conductivity of the Kitsap Formation.

5.4.3.2 Groundwater Flow Paths

The network of pre-RI and RI monitoring wells was used to evaluate groundwater flow velocities and travel times along two flow paths, listed from upgradient to downgradient stations:

- Flow from the northern portion of the closed solid waste disposal area, and the former demolition debris and septage disposal areas: MW-2, MW-8/8D, MW-13/13S, and SW-4.
- Flow from the closed solid waste disposal area: MW-6/MW-14, MW-1, MW-9, MW-12/12I, and SW-1. For the purpose of this analysis, MW-6 and MW-14 were considered as a single station because they are both very close to the solid waste disposal area and have shown similar groundwater elevations.

5.4.3.3 Groundwater Velocity And Travel-Time Calculations Using Hydraulic Data

Groundwater velocities and travel times along these two flow paths were calculated using the Darcy equation as follows:

$$V = (Ki)/n$$

where V = average groundwater velocity, ft/day
K = horizontal hydraulic conductivity, ft/day
i = hydraulic gradient, ft/ft
n = porosity

Hydraulic conductivity data from slug tests performed on upper-aquifer monitoring wells provided a groundwater hydraulic conductivity range from 3 to 57 ft/day (Table 5-6). The hydraulic conductivities measured in wells within the SW-4 flowpath ranged from 9 to 57 ft/day, while the hydraulic conductivities measured in wells within the SW-1 flowpath ranged from 3 to 28 ft/day.

The geometric mean (a logarithmic statistic) is often used to calculate effective hydraulic conductivity from a set of multiple measurements, since the data typically ranges over an order of magnitude and is commonly distributed with a long tail at the upper end (Fetter 1994). The geometric mean of a set of observations is the nth root of their product. The geometric mean of the hydraulic conductivity measurements for wells within each flowpath was calculated to determine a representative value of hydraulic conductivity for that flowpath. The resulting geometric means are 9.7 ft/day for the MW-2/SW-4 flowpath, and 24.1 ft/day for the MW-14/SW-1 flowpath. A porosity value of 0.2, typical for fine sand, was used in the velocity calculations.

The results of these calculations are shown in Tables 5-7 and 5-8. The tables present groundwater velocity calculations for high water-table conditions (August 1999) and for low water-table conditions (November 2003) during the study period. The high and low water tables conditions were selected from hydrographs plotted using data from Site wells (Figure 5-13). Groundwater velocities along the MW-2/SW-4 flow path range from 142 to 187 ft/yr. Along the MW-14/SW-1 flow path, groundwater velocities range from 593 to 686 ft/yr. The calculated groundwater travel times from former disposal areas to areas of groundwater discharge to creeks west of the Landfill ranged between 11 and 15 years along the MW-2/SW-4 flow path, and 2 to 3 years along the MW-14/SW-1 flow path.

5.4.4 Groundwater/Surface Water Interaction

The Site is part of a watershed that covers over 5,000 acres. The Site is located near the watershed boundary, the crest of the ridge that bisects the Kitsap Peninsula. Less than 10 acres of the watershed contributes to drainage onto the Site. Surface water east of the divide formed by the ridge flows easterly to Puget Sound.

Perennial streams are found within 1 mile of the Landfill Property and appear to originate as springs and seepage from the upper aquifer above its contact with the Kitsap Formation. The USGS topographic map for the area indicates initial base flows for these streams occur at elevations between 210 and 290 ft MSL to the north, west, and south of the Property. Discharge from these streams is to Port Gamble Bay and Puget Sound to the west and east of the regional watershed divide, respectively.

Local hydrogeologic conditions allow sampling of groundwater discharges at stream headwater stations (SW-1, SW-4, SW-6, and SW-7), where groundwater becomes surface water. Typically, it is not possible to sample surface water at groundwater discharge points, because the discharge point is at an inaccessible submerged location beneath a stream or lake shoreline. The headwater stream sampling stations established for this RI provide a direct means of evaluating groundwater discharge concentrations. However, surface water standards will be applied to groundwater per WAC 173-340-720(4)(b)(ii). A discussion of the applicability of surface water cleanup standards to groundwater has been deleted from the text of this RI report and incorporated into a separate Memorandum that is presented as Appendix R. Deletion of this section removes discussions alluding to the use of off-property conditional points of compliance.

5.4.5 Groundwater Use in the Property Vicinity

Water supply wells within 1 mile of the Landfill Property are shown on Figure 5-14; well logs are included in Appendix H. This inventory was updated in 2004. All but eight of these wells obtain their water from the lower water-bearing unit (Salmon Springs Drift) described in Section 5.4.1.2 (Regional Groundwater Occurrence and Movement). Numerous water-bearing zones within this unit occur within discontinuous, highly permeable sand and gravel layers confined by overlying low permeability silt and clay. These water-bearing zones are reportedly encountered at approximate elevations of between 90 ft MSL and -80 ft MSL. Collectively, they form the regional groundwater aquifer (referred to as the "lower aquifer") in the Study Area.

An evaluation of driller’s logs indicates that eight residential water supply wells within 1 mile of the Property draw their water from the upper aquifer (see Figure 5-14). Seven of these wells are located on the opposite side of a regional groundwater divide that roughly follows Hansville Road on the crest of the peninsula (Garling et al. 1965), and therefore, could not be affected by the Landfill. The eighth well is reported to be located approximately 1,200 ft northwest of the Property. Due to its location in steeply wooded terrain, it is likely mislocated. All other domestic, community, or irrigation wells inventoried within 1 mile of the Property draw water from the deeper regional aquifer (the lower aquifer), which is a confined aquifer. This includes the community wells (8A1 and 8A2) in the Little Boston area that currently provide the majority of water for the Port Gamble S’Klallam Tribe, and the other Little Boston area community wells (5R1, 5R2, 5R3) that are not currently in use (Fuller 2004b).

Review of driller’s logs indicates that approximately 15 wells located between 1 and 3 miles of the Property to the northeast, southeast, and southwest are completed in the upper aquifer (Parametrix 1994). The remainder of the wells located in this area are completed within the lower regional aquifer.

5.4.6 Estimates of Leachate Generation

Section 2.4 (Site Topography, Precipitation, and Drainage) describes climatic conditions in the Study Area. According to the mean annual precipitation map published by the Soil Conservation Service (SCS) in March 1965, the Site receives an average annual rainfall of 32 in.

For the purposes of estimating leachate generation in the Hansville Sanitary Landfill Final Closure Plan (Parametrix 1994), average monthly precipitation values were obtained from the nearest weather station and prorated to approximate the annual rainfall at the Site as reported by the SCS. The Chimacum station, which is the nearest weather station to the Site, reports an annual 29.87 in. of rainfall (Gale Research Company 1981). The prorated average monthly rainfall estimates and potential evapotranspiration estimates for the Site are provided in Table 2-1.

A water balance calculation for pre- and post-closure conditions is included in the Hansville Sanitary Landfill Final Closure Plan, Appendix F (Parametrix 1994). The water balance utilizes precipitation, potential evapotranspiration, and Landfill characteristics to estimate the portion of the total precipitation that runs off the closed disposal areas, evapotranspires, or percolates to form leachate. From this calculation, the total volume of leachate produced from precipitation was estimated to be 20,000,000 gallons per year prior to construction of the final cover. Additional analysis of the final cover design (using the Hydrologic Evaluation of Landfill Performance Model developed by the Army Corps of Engineers) indicated that leachate would be reduced to approximately 200,000 gallons by the geomembrane cover in the first five years (a 99 percent reduction), as illustrated by Figure 5-15.

5.5 GROUNDWATER INVESTIGATION FINDINGS

The groundwater investigation at the Site confirms the following:

- Groundwater in the upper aquifer flows to the west and southwest and discharges to headwaters of creeks downgradient of the Landfill.
- The Kitsap Formation is a laterally extensive, thick clay unit that separates the upper aquifer from the deeper regional aquifer.
- Upper aquifer groundwater is not currently used as a drinking water supply downgradient of the Property.
- This aquifer is unlikely to be used as a drinking water supply downgradient of the Property due to its low yield, the susceptibility of the shallow groundwater to contamination sources (such as septic systems and surface water runoff), and the existence of a dependable public water supply in the area.
- The RI groundwater quality data, in conjunction with the geophysical survey conducted along the northern Property boundary (Golder Associates 1996), are consistent with the groundwater level data (see Section 5.4.3, Groundwater Flow Directions and Velocities, and Figures 5-9 through 5-12) in confirming the northern and southern limits of groundwater impacts from the Landfill in the upper aquifer.
- Groundwater sampling results are tabulated in Appendix B and evaluated to select chemicals for the feasibility study in Chapter 8 (Chemical Screening). The distribution and transport of chemicals in groundwater is described in Chapter 9 (Chemical Fate and Transport Evaluation).

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Table 5-1. Summary of Monitoring Well Construction Details

Well ID	Date Completed	Ground Surface Elevation (NGVD)	Total Borehole Depth (ft)	Total Well Depth (ft)	Top of Screen		Bottom o	
					Depth (ft)	Elevation (NGVD)	Depth (ft)	Ele
MW-1	2/24/1982	303.7	64	63	53	251	63	
MW-2	2/24/1982	351.9	109	108	103	249	108	
MW-3	2/25/1982	329.7	84	83	73	257	83	
MW-4	3/2/1988	329.9	95	95	85	245	95	
MW-5*	3/5/1988	363.7	136	130	120	244	130	
MW-6	7/18/1990	332.0	200	86	72	260	86	
MW-7	2/28/1996	344.3	111	100	85	259	100	
MW-8	1/23/1996	296.6	127	57	42	255	57	
MW-8D	5/23/1996	292.9	98	95	85	208	95	
MW-9	2/22/1996	283.1	78	42	27	256	42	
MW-10	2/5/1996	259.1	80	26	11	248	26	
MW-11	3/11/1996	355.3	123	112	97	258	112	
MW-12	2/14/1996	246.6	72	20	5	242	20	
MW-12I	5/24/1996	245.6	43	39	29	217	39	
MW-13S	6/18/1996	259.6	22	21	6	254	21	
MW-13D	6/17/1996	258.1	77	63	53	205	63	
MW-14	6/27/1996	338.6	176	92	77	262	92	

Notes:
NGVD = National Geodetic Vertical Datum
* Background Well

Table 5-2a. Summary of Groundwater Level Data, August 1996 through January 2004

	Elevations		Screen Elevation		Depth to Water												
Well ID	**Ground**	**PVC**	**Top**	**Bottom**	**8/8/96**	**11/21/96**	**3/3/97**	**5/21/97**	**3/10/98**	**7/13/98**	**10/14/98**	**2/3/99**	**5/13/99**	**8/24/99**	**1/13/00**	**4/19/00**	**7/26/00**
MW-1	303.7	304.1	240	230	48.7	48.6	47.0	46.7	NM	45.76	NM	NM	NM	44.58	NM	43.55	44.41
MW-2	351.9	352.2	249	244	94.6	94.6	94.1	93.3	NM	91.48	NM	NM	NM	88.39	NM	89.27	89.73
MW-3	329.7	332.8	257	247	72.4	72.3	71.7	71.2	NM	68.94	NM	NM	NM	66.70	NM	66.12	66.71
MW-4	329.9	331.7	245	235	75.7	75.6	74.7	74.1	68.55	72.43	72.57	71.41	70.08	69.88	74.15	70.32	70.93
MW-5*	363.7	366.9	244	234	103.5	103.4	103.1	102.4	100.58	99.86	99.56	98.58	98.04	96.45	98.18	97.11	97.45
MW-6	332.0	332.7	260	245	76.2	76.2	75.5	74.8	67.27	73.29	73.23	72.59	71.00	70.48	71.77	71.09	71.55
MW-7	344.3	346.0	259	244	87.0	87.0	86.6	85.8	84.58	83.80	83.81	83.57	81.57	80.62	81.90	81.72	82.07
MW-8	296.0	298.9	254	239	44.5	44.6	43.6	43.0	NM	41.74	NM	NM	NM	39.37	NM	39.92	40.42
MW-8D	292.9	294.9	208	198	40.6	40.7	39.8	39.1	NM	37.95	NM	NM	NM	35.53	NM	36.12	36.64
MW-9	283.1	285.4	256	241	32.7	32.9	31.2	30.7	NM	30.32	NM	NM	NM	>40.68	NM	28.84	>40.62
MW-10	259.1	261.3	248	233	14.4	14.5	13.5	13.1	NM	12.50	NM	NM	NM	11.41	NM	11.61	12.01
MW-11	355.3	357.6	258	243	101.9	101.9	101.3	100.4	99.21	98.52	98.72	98.18	96.28	95.88	96.80	96.71	99.12
MW-12	246.6	248.8	242	227	10.0	10.0	9.3	9.2	NM	9.05	NM	NM	NM	8.62	NM	8.67	9.00
MW-12I	245.6	248.1	217	207	9.1	9.1	8.4	8.3	8.93	8.24	8.32	7.68	7.41	7.79	8.93	7.92	8.31
MW-13S	259.6	261.9	255	240	13.3	13.4	12.2	11.9	11.13	11.58	11.87	10.80	9.96	10.36	11.15	13.42	10.96
MW-13D	258.1	260.4	205	195	12.2	12.2	11.0	10.8	10.03	10.48	10.75	9.75	8.88	9.29	10.02	9.38	9.87
MW-14	338.6	341.1	262	247	84.5	84.4	83.2	82.7	80.85	81.38	81.52	79.29	78.92	78.85	78.96	79.02	79.75

Table 5-2a. Summary of Groundwater Level Data, August 1996 through January 2004

	Elevations		Depth to Water													
Well ID	**Ground**	**PVC**	**10/25/00**	**1/30/01**	**4/3/01**	**7/11/01**	**10/24/01**	**1/29/02**	**4/24/02**	**7/18/02**	**10/17/02 (b)**	**1/22/03**	**4/17/03**	**7/30/03**	**11/3/03**	**1/28/04**
MW-1	303.7	304.1	44.94	44.88	45.44	46.41	47.10	42.63	46.38	47.28	47.80	46.45	47.13	48.41	40.13 (a)	47.67
MW-2	351.9	352.2	72.45 (a)	90.76	91.14	91.79	92.53	92.20	92.74	92.94	93.25	93.53	93.69	94.05	94.45	94.55
MW-3	329.7	332.8	67.13	67.75	68.16	68.82	69.67	NM	70.20	70.41	70.66	70.95	71.18	71.50	71.90	72.00
MW-4	329.9	331.7	74.43	71.80	72.23	73.00	73.79	NM	73.73	74.16	74.60	74.39	74.65	75.30	75.55	75.38
MW-5*	363.7	366.9	97.92	98.58	98.99	99.61	100.41	100.63	101.29	101.49	101.63	101.90	102.11	102.57	102.92	103.10
MW-6	332.0	332.7	72.11	72.53	72.90	73.53	74.12	73.40	74.20	74.67	74.97	74.90	75.15	75.65	76.09	76.04
MW-7	344.3	346.0	82.61	83.24	83.64	84.29	85.10	84.85	85.28	85.43	85.70	86.00	86.26	86.60	86.95	87.12
MW-8	296.0	298.9	40.93	41.37	41.63	42.24	42.96	42.07	42.71	43.12	43.51	43.59	43.64	44.07	44.49	44.44
MW-8D	292.9	294.9	37.13	37.58	37.83	38.43	39.17	88.25 (a)	38.89	39.30	39.71	39.77	39.80	40.25	40.65	40.59
MW-9	283.1	285.4	29.96	30.25	30.51	34.10	34.81	29.61	30.74	31.54	32.23	34.69	31.71	32.56	32.80	32.39
MW-10	259.1	261.3	12.37	12.67	NA	NA	14.04	12.85	13.50	13.98	14.38	14.36	14.34	14.86	15.10	14.89
MW-11	355.3	357.6	97.62	NA	98.61	99.22	100.15	104.87	100.13	100.46	100.84	101.02	101.23	101.65	101.98	89.96 (a)
MW-12	246.6	248.8	9.22	9.28	9.45	>10.09	10.22	6.01	9.84	10.12	dry	10.14	10.32	10.90	10.92	10.68
MW-12I	245.6	248.1	8.46	8.55	8.74	9.18	9.50	8.33	9.12	9.52	9.78	9.53	9.60	10.16	10.14	9.98
MW-13S	259.6	261.9	11.25	11.43	11.61	12.03	12.57	11.06	11.93	12.46	12.89	12.68	12.55	13.26	13.45	13.13
MW-13D	258.1	260.4	10.19	10.31	10.46	11.03	11.38	9.96	10.80	11.38	11.82	11.48	11.45	12.44	12.25	11.96
MW-14	338.6	341.1	80.28	80.43	80.92	81.79	82.62	80.97	82.17	82.84	83.44	82.54	83.09	84.11	84.06	83.72

Notes:

All elevations are referenced to the National Geodetic Vertical Datum (NGVD).
* Background well
(a) Probable error in measurement
(b) MW-9 measured on 10/29/02
NM indicates not monitored. Between March 1998 and January 2000, water levels were measured only in the wells sampled.
NA = no access
> = Depth to water greater than the measured value, typically at the top of the pump.

Table 5-2b. Summary of Groundwater Elevations, August 1996 through January 2004

	Elevations		Screen Elevation		Water Level Elevation												
Well ID	Ground	PVC	Top	Bottom	8/8/1996	11/21/1996	3/3/1997	5/21/1997	3/10/98	7/13/98	10/14/98	2/3/99	5/13/99	8/24/99	1/13/00	4/19/00	7/26/00
MW-1	303.7	304.1	240	230	255.4	255.5	257.1	257.5	NM	258.3	NM	NM	NM	259.5	NM	260.6	259.7
MW-2	351.9	352.2	249	244	257.7	257.6	258.2	258.9	NM	260.7	NM	NM	NM	263.8	NM	262.9	262.5
MW-3	329.7	332.8	257	247	260.4	260.5	261.1	261.6	NM	263.9	NM	NM	NM	266.1	NM	266.7	266.1
MW-4	329.9	331.7	245	235	256.1	256.1	257.0	257.7	263.2	259.3	259.1	260.3	261.6	261.8	257.6	261.4	260.8
MW-5*	363.7	366.9	244	234	263.4	263.5	263.9	264.5	266.3	267.0	267.3	268.3	268.9	270.5	268.7	269.8	269.5
MW-6	332.0	332.7	260	245	256.5	256.5	257.2	257.9	265.4	259.4	259.5	260.1	261.7	262.2	260.9	261.6	261.2
MW-7	344.3	346.0	259	244	259.0	259.0	259.4	260.2	261.4	262.2	262.2	262.4	264.4	265.4	264.1	264.3	263.9
MW-8	296.0	298.9	254	239	254.5	254.3	255.3	255.9	NM	257.2	NM	NM	NM	259.5	NM	259.0	258.5
MW-8D	292.9	294.9	208	198	254.3	254.2	255.1	255.8	NM	257.0	NM	NM	NM	259.4	NM	258.8	258.3
MW-9	283.1	285.4	256	241	252.7	252.6	254.2	254.7	NM	255.1	NM	NM	NM	<244.7	NM	256.6	<244.8
MW-10	259.1	261.3	248	233	246.9	246.8	247.8	248.2	NM	248.8	NM	NM	NM	249.9	NM	249.7	249.3
MW-11	355.3	357.6	258	243	255.8	255.7	256.3	257.2	258.4	259.1	258.9	259.4	261.3	261.7	260.8	260.9	258.5
MW-12	246.6	248.8	242	227	238.8	238.8	239.6	239.6	NM	239.8	NM	NM	NM	240.2	NM	240.1	239.8
MW-12I	245.6	248.1	217	207	239.0	239.0	239.7	239.8	239.2	239.9	239.8	240.4	240.7	240.3	239.2	240.2	239.8
MW-13S	259.6	261.9	255	240	248.6	248.5	249.8	250.0	250.8	250.3	250.0	251.1	251.9	251.5	250.8	248.5	250.9
MW-13D	258.1	260.4	205	195	248.2	248.2	249.4	249.6	250.4	249.9	249.7	250.7	251.5	251.1	250.4	251.0	250.5
MW-14	338.6	341.1	262	247	256.6	256.7	257.9	258.4	260.3	259.7	259.6	261.8	262.2	262.3	262.1	262.1	261.4

Table 5-2b. Summary of Groundwater Elevations, August 1996 through January 2004

	Elevations		Water Level Elevation													
Well ID	**Ground**	**PVC**	**10/25/00**	**1/30/01**	**4/3/01**	**7/11/01**	**10/24/01**	**1/29/02**	**4/24/02**	**7/18/02**	**10/17/02 (b)**	**1/22/03**	**4/17/03**	**7/30/03**	**11/3/03**	**1/28/04**
MW-1	303.7	304.1	259.2	259.2	258.7	257.7	257.0	261.5	257.7	256.8	256.3	257.7	257.0	255.7	264.0 (a)	256.4
MW-2	351.9	352.2	279.8 (a)	261.4	261.1	260.4	259.7	260.0	259.5	259.3	259.0	258.7	258.5	258.2	257.8	257.7
MW-3	329.7	332.8	265.7	265.1	264.6	264.0	263.1	NM	262.6	262.4	262.1	261.9	261.6	261.3	260.9	260.8
MW-4	329.9	331.7	257.3	259.9	259.5	258.7	257.9	NM	258.0	257.5	257.1	257.3	257.1	256.4	256.2	256.3
MW-5*	363.7	366.9	269.0	268.3	267.9	267.3	266.5	266.3	265.6	265.4	265.3	265.0	264.8	264.3	264.0	263.8
MW-6	332.0	332.7	260.6	260.2	259.8	259.2	258.6	259.3	258.5	258.0	257.7	257.8	257.6	257.1	256.6	256.7
MW-7	344.3	346.0	263.4	262.8	262.4	261.7	260.9	261.2	260.7	260.6	260.3	260.0	259.7	259.4	259.1	258.9
MW-8	296.0	298.9	258.0	257.5	257.3	256.7	255.9	256.8	256.2	255.8	255.4	255.3	255.3	254.8	254.4	254.5
MW-8D	292.9	294.9	257.8	257.3	257.1	256.5	255.7	206.7 (a)	256.0	255.6	255.2	255.1	255.1	254.7	254.3	254.3
MW-9	283.1	285.4	255.4	255.2	254.9	251.3	250.6	255.8	254.7	253.9	253.2	250.7	253.7	252.8	252.6	253.0
MW-10	259.1	261.3	248.9	248.6	NA	NA	247.3	248.5	247.8	247.3	246.9	246.9	247.0	246.4	246.2	246.4
MW-11	355.3	357.6	260.0	NA	259.0	258.4	257.5	252.7	257.5	257.1	256.8	256.6	256.4	256.0	255.6	267.6 (a)
MW-12	246.6	248.8	239.6	239.5	239.4	238.7	238.6	242.8	239.0	238.7	dry	238.7	238.5	237.9	237.9	238.1
MW-12I	245.6	248.1	239.6	239.6	239.4	238.9	238.6	239.8	239.0	238.6	238.3	238.6	238.5	237.9	238.0	238.1
MW-13S	259.6	261.9	250.7	250.5	250.3	249.9	249.3	250.8	250.0	249.4	249.0	249.2	249.4	248.6	248.5	248.8
MW-13D	258.1	260.4	250.2	250.1	249.9	249.4	249.0	250.4	249.6	249.0	248.6	248.9	249.0	248.0	248.2	248.4
MW-14	338.6	341.1	260.8	260.7	260.2	259.3	258.5	260.1	258.9	258.3	257.7	258.6	258.0	257.0	257.0	257.4

Notes:

All elevations are referenced to the National Geodetic Vertical Datum (NGVD).
* Background well
(a) Probable error in measurement
(b) MW-9 measured on 10/29/02
NM indicates not monitored
NA = no access

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Table 5-3. Thickness Data for the Kitsap Formation

Township/Range/Section	Well No.	Kitsap Formation Thickness (ft)	Well No.	Kitsap Formation Thickness (ft)
T27N, R2E, 3	3E1	181	3N1	372
	3E2	156	3N2	196
	3E3	137	3N5	179
	3L1	181	3N6	138
	3M1	183	3Q	157
T27N, R2E, 4	4B	138	4L1	39
T27N, R2E, 5	5R1	53	5R3	262
	5R2	101		
T27N, R2E, 9	9G1	175	9R1	73
	9J1	184	9R2	146
T27N, R2E, 10	10B1	180	10D2	170
	10B2	91	10D3	187
	10B4	109	10D4	185
	10B5	46	10E1	140
	10B6	132	10E4	181
	10B7	47	10F3	216
	10B8	98	10F4	220
	10C1	111	10F5	140
	10C2	176	10M1	122
	10C3	162	10M2	123
	10C4	210	10M3	95
	10C5	215	10N	122
	10D1	222	10P	145
T27N, R2E, 15	15C	111	15D1	63
	15C2	107	15D2	113
T27N, R2E, 16	16D1	126	16H1	124
	16D3	86	16H2	171
	16D4	176		

Note: Thickness data are interpreted from driller's logs and are approximate.

Table 5-4. Elevations of the Top of the Kitsap Formation

Well ID	Ground Surface Elevation (NGVD)	Depth to Kitsap Formation (ft)	Top of Kitsap Formation Elevation (NGVD)
MW-6	332	143	189
MW-8	297	116	181
MW-9	283	66	217
MW-10	259	170	189
MW-12	247	61	186
MW-13	258	68	190
MW-14	339	164	175

NGVD = National geodetic vertical datum

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Table 5-5. Summary of Vertical Hydraulic Conductivity Results for the Kitsap Formation

Well ID	Depth (ft bgs[1])	Vertical Hydraulic Conductivity (cm/sec)
MW-8	125	1.5×10^{-7}
MW-9	76	1.2×10^{-6}
MW-10	80	3.5×10^{-7}
MW-12	70	1.4×10^{-6}

Notes:

Vertical hydraulic conductivity tests of soil samples were performed in the soils laboratory of Hong West, Inc. Laboratory reports and chain-of-custody documentation are included in Appendix L.

[1] Below ground surface.

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Table 5-6. Summary of Horizontal Hydraulic Conductivity Results for the Upper Aquifer

Well ID	Horizontal Hydraulic Conductivity (cm/sec)	Horizontal Hydraulic Conductivity (ft/day)
MW-7 [a]	$2x10^{-2}$	57
MW-8 [a]	$7x10^{-3}$	20
MW-8D [a]	$2x10^{-2}$	57
MW-9 [b]	$3x10^{-3}$	9
MW-10 [b]	$3x10^{-3}$	9
MW-11 [b]	$7x10^{-3}$	20
MW-12 [b]	$9x10^{-4}$	3
MW-12I [b]	$1x10^{-2}$	28
MW-13S [a]	$3x10^{-3}$	9
MW-13D [a]	$5x10^{-3}$	14
MW-14 [b]	$2x10^{-3}$	6

Notes:

In-situ hydraulic conductivity tests were performed in accordance with methods outlined in SAP (Parametrix, 1996a). Analysis performed using the method of Bouwer and Rice (1976).

[a] MW-2 to SW-4 flowpath

[b] MW-14 to SW-1 flowpath

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Table 5-7. Groundwater Velocity and Travel Time Calculations for the MW-2 to SW-4 Flow Path

	Low Water Table Conditions (November 2003)		High Water Table Conditions (August 1999)	
	MW-2	**MW-13S**	**MW-2**	**MW-13S**
Groundwater Elevation (ft)	257.8	248.5	263.8	251.5
Horizontal Distance between wells (ft)		1160		1160
Horizontal Gradient (ft/ft)		0.0080		0.0106
Hydraulic Conductivity, k (geomean)		9.7		9.7
Velocity, v (ft/days)[1]		0.39		0.51
Velocity, v (ft/years)		142		187
Distance from landfill to SW-4 (ft)		2100		2100
Travel time to SW-4 edge (days)		5401		4097
Travel time to SW-4 (years)		15		11

[1] Using equation V = (Ki)/n, where K = 9.7 ft/day, n = 0.2

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Table 5-8. Groundwater Velocity and Travel Time Calculations for the MW-14 to SW-1 Flow Path

	Low Water Table Conditions (November 2003)		High Water Table Conditions (August 1999)	
	MW-14	**MW-12I**	**MW-14**	**MW-12I**
Groundwater Elevation (ft)	257.0	238.0	262.3	240.3
Horizontal Distance between wells (ft)		1410		1410
Horizontal Gradient (ft/ft)		0.0135		0.0156
Hydraulic Conductivity, k (geomean)		24.1		24.1
Velocity, v (ft/days)[1]		1.62		1.88
Velocity, v (ft/years)		593		686
Distance from landfill to SW-1 (ft)		1600		1600
Travel time to SW-4 edge (days)		985		851
Travel time to SW-4 (years)		3		2

[1] Using equation V = (Ki)/n, where K = 24.1 ft/day, n = 0.2

STRATIGRAPHIC UNIT		CHARACTER AND EXTENT	THICKNESS IN FEET	WATER-BEARING PROPERTIES
VASHON DRIFT	RECESSIONAL OUTWASH	DISCONTINUOUS BODIES OF UNCONSOLIDATED SILT, SAND, AND GRAVEL, DEPOSITED BY MELTWATER OF VASHON GLACIER.	0-100	MAY YIELD SMALL TO MODERATE SUPPLIES OF GROUND WATER FOR DOMESTIC PURPOSES WHERE DEPOSITS HAVE CONSIDERABLE THICKNESS
VASHON DRIFT	TILL	EXTENSIVE TILL SHEET WHICH MANTLES MOST OF UPLAND AREAS. TILL VARIES GREATLY IN COMPACTION AND COMPOSITION.	0-80	ESSENTIALLY IMPERVIOUS, BUT MAY YIELD SMALL SUPPLIES OF PERCHED GROUND WATER.
VASHON DRIFT	ADVANCE OUTWASH	DISCONTINUOUS BODIES OF UNCONSOLIDATED SILT, SAND, AND GRAVEL, DEPOSITED BY MELTWATER STREAMS FROM ADVANCING VASHON GLACIER.	0-50	YIELDS MODERATELY LARGE TO LARGE QUANTITIES OF WATER WHERE DEPOSITS EXTEND BELOW WATER TABLE.
	COLVOS SAND	PRINCIPALLY STRATIFIED SAND. CONTAINS IRREGULAR LENSES OF FINE GRAVEL, AND THIN STRATA OF CLAY AND SILT. UNDERLIES VASHON DRIFT THROUGHOUT MOST OF PENINSULA.	0-300	PRIMARY FORMATION PRESENTLY UTILIZED BY DRILLED WELLS WHERE BASE BELOW WATER TABLE. SAND YIELDS DOMESTIC QUANTITIES; GRAVEL STRATA YIELD MODERATELY LARGE QUANTITIES.
UNNAMED GRAVEL		POORLY BEDDED, PEBBLE TO COBBLE GRAVELS. PRIMARILY RUST-STAINED, SOME DECOMPOSED, SOME CEMENTED. INCLUDES SILT AND PEAT BEDS.	0-400+	DOMESTIC SUPPLIES OBTAINED FROM UNCONSOLIDATED GRAVELS NEAR SEA LEVEL IN TAHUYA AREA OF HOOD CANEL.
KITSAP FORMATION		PRINCIPALLY WELL-BEDDED SILT AND CLAY, WITH OCCASIONAL LENSES OF SAND AND GRAVEL. IN PLACES CONTAINS PEAT BEDS.	0-200+	GRAVEL LENSES YIELD SMALL QUANTITIES OF WATER, BUT FORMATION NORMALLY OF LOW PERMEABILITY AND YIELDS LITTLE OR NO GROUND WATER.
SALMON SPRINGS(?) DRIFT		PRINCIPALLY STRATIFIED SAND AND GRAVEL. MAY BE STAINED BUFF OR ORANGE-COLORED IN OUTCROP. CONTAINS SOME SILT, CLAY AND TILL STRATA.	0-300+	YIELDS LARGE QUANTITIES OF GROUND WATER, FREQUENTLY UNDER ARTESIAN PRESSURE.
PRE-SALMON SPRINGS(?) DEPOSITS, UNDIFFERENTIATED		PRINCIPALLY MASSIVE BLUE CLAY AND SILT. DEFORMED IN MOST PLACES. CONTAINS TILL, VOLCANIC ASH, PEAT OR LIGNITE, SAND, AND SOME GRAVEL STRATA. TOP OF FORMATION USUALLY BELOW SEA LEVEL.	0-600+	CLAY, SILT AND TILL STRATA YIELD LITTLE OR NO GROUND WATER. GRAVEL MAY YIELD SMALL TO MODERATE QUANTITIES. SUCCESSFUL WELLS ARE FEW.

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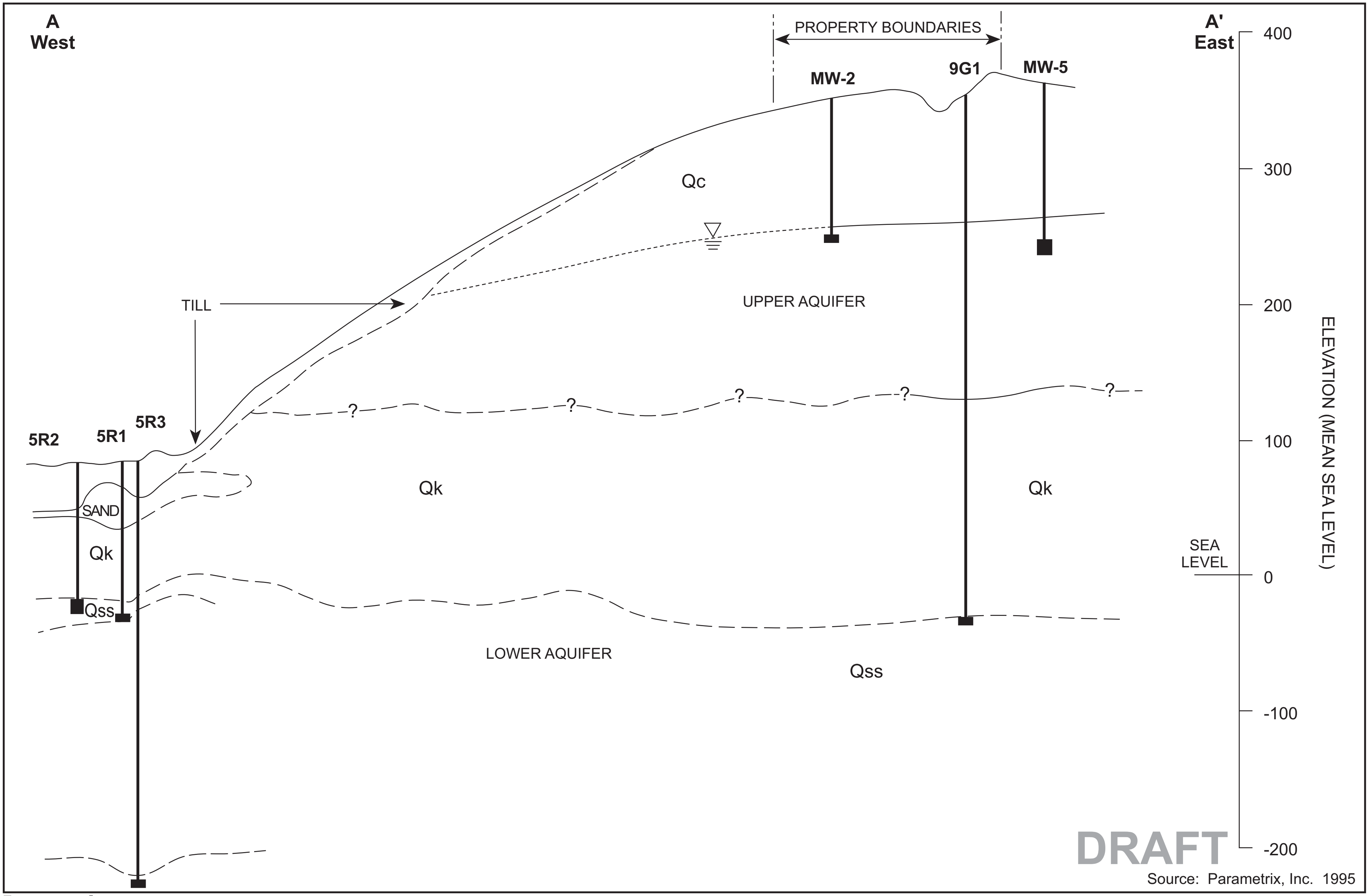
Figure 5-3
Stratigraphic Units of Pleistocene Age in the Kitsap Peninsula
Hansville Landfill RI/FS

Adapted From: Garling et al, 1965.

GARLING et al. (1965)		HYDROGEOLOGIC UNITS	HYDROGEOLOGIC PROPERTIES
VASHON DRIFT	RECESSIONAL OUTWASH	UPPER DRIFT	Thin, discontinuous, mostly dry; locally yields water for domestic use. Generally low hydraulic conductivity; some wells locally tap permeable melt-water deposits.
	TILL		
	ADVANCE OUTWASH	UPPER SAND-AND GRAVEL WATER-BEARING STRATA	Contains farily continuous water-bearing sand-and-gravel beds or layers whose thicknesses range from 10 to 80 ft.; most well yields are between 10 and 50 gal/min.
	COLVOS SAND MEMBER		
KITSAP FORMATION		MIDDLE UNIT (SILT AND CLAY)	Generally low hydraulic conductivity, underlies most of the peninsula.
SALMON SPRINGS DRIFT		LOWER UNIT LOWER SAND-AND GRAVEL WATER-BEARING STRATA	Contains numerous sand-and-gravel beds or layers of unknown areal extent and thickness of as much as 300 feet; well yields usually range between 20 and 100 gal/min.
PRE-SALMON SPRINGS DRIFT		LOWER SAND-AND GRAVEL WATER-BEARING STRATA	

Figure 5-4
Correlation of Stratigraphic Units with Hydrogeologic Units in the Kitsap Peninsula
Hansville Landfill RI/FS

Adapted From: Hansen and Bolke, 1980



Parametrix Hansville RI Report/555-2966-002 8/04 (B)

Note: Line of Cross Section Shown on Figure 5-1.

HORIZONTAL SCALE IN FEET:
1 INCH = 800 FEET

VERTICAL SCALE IN FEET:
1 INCH = 100 FEET

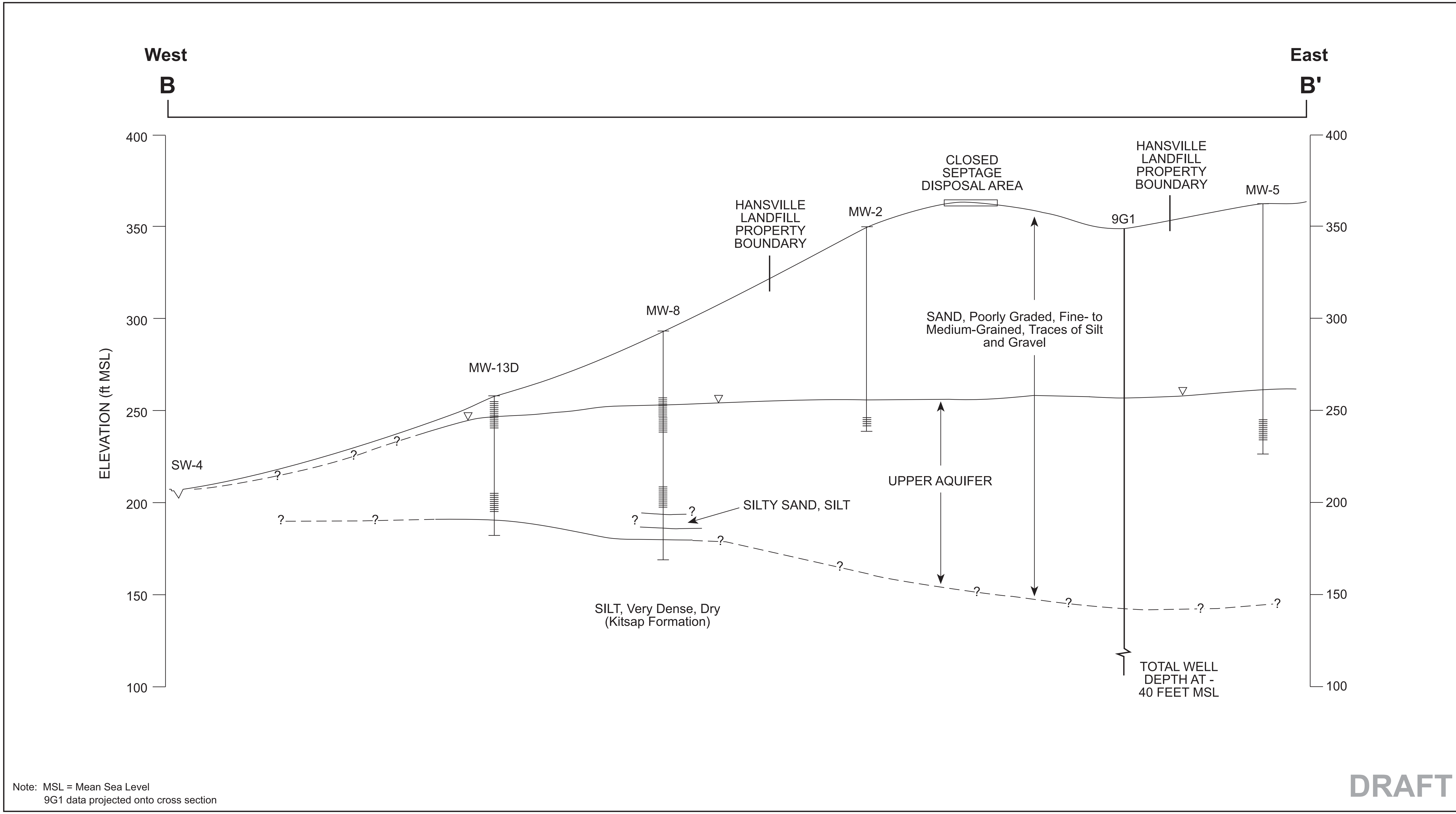
MSL=MEAN SEA LEVEL

Qc	Colvos Sand
Qk	Kitsap Formation
Qss	Salmon Springs Drift (?)

— — — Geologic Contact (dashed where inferred, question mark where uncertain)

----▽---- Groundwater Elevation (August 8, 1996)

Figure 5-5
Geologic Cross Section A-A'
Hansville Landfill RI/FS



Note: MSL = Mean Sea Level
9G1 data projected onto cross section

Parametrix Hansville RI Report/555-2966-002 8/04 (B)

HORIZONTAL SCALE IN FEET:
1 INCH = 400 FEET

VERTICAL SCALE IN FEET:
1 INCH = 50 FEET

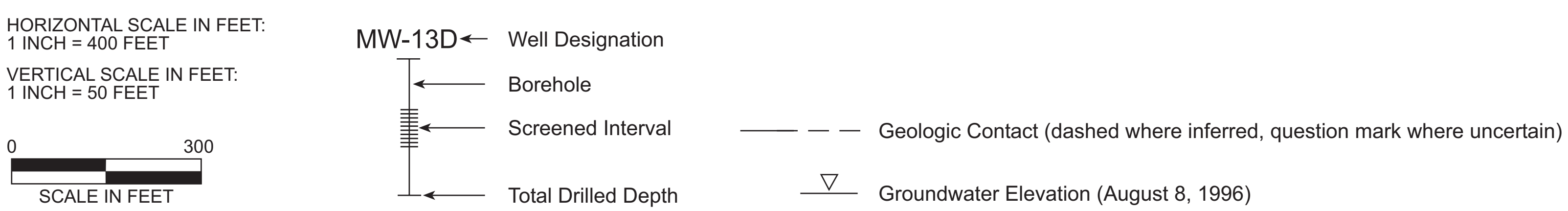
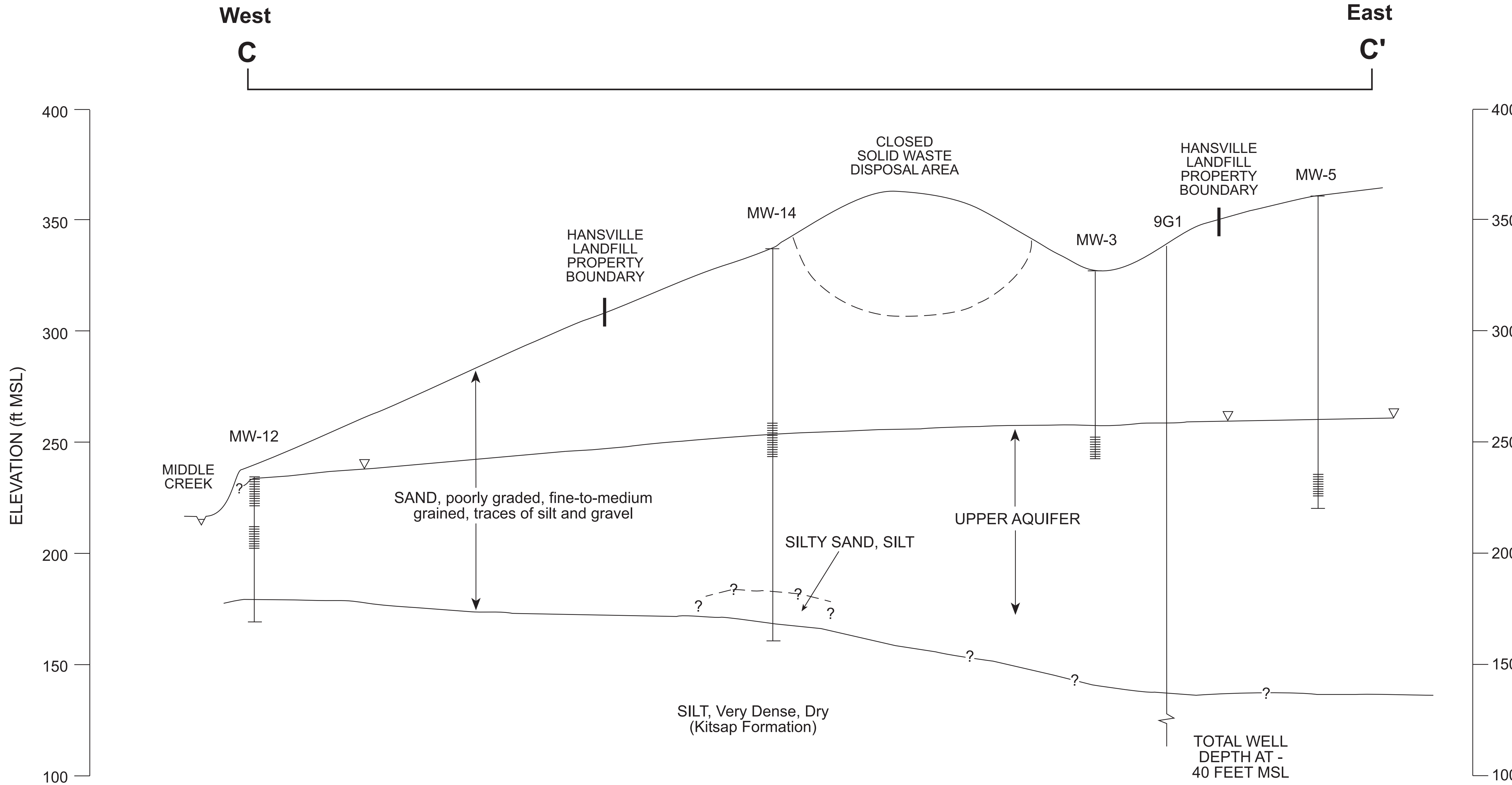


Figure 5-6
Geologic Cross Section B-B'
Hansville Landfill RI/FS



Note: MSL = Mean Sea Level

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Parametrix Hansville RI Report/555-2966-002 8/04 (B)

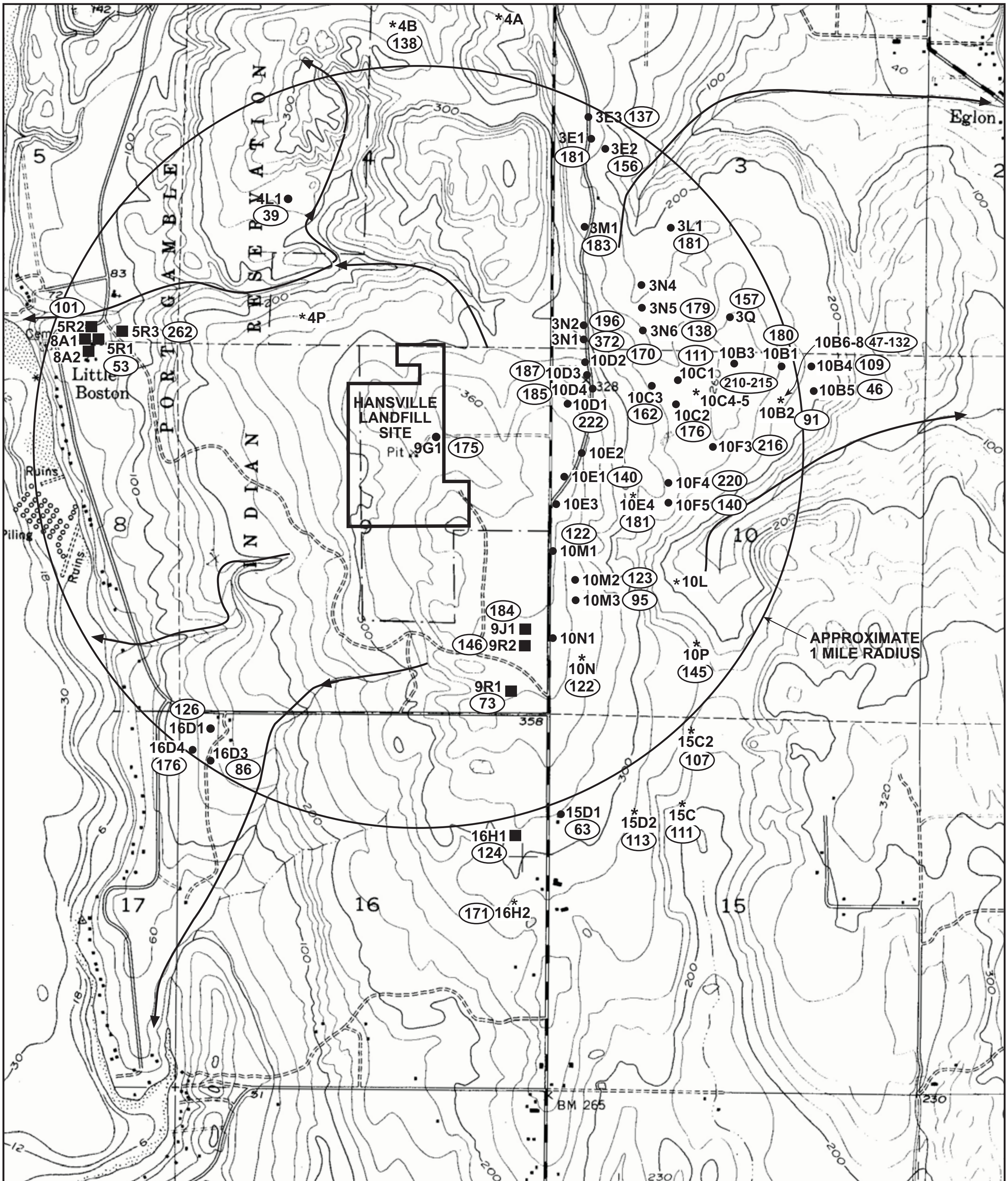
HORIZONTAL SCALE IN FEET:
1 INCH = 400 FEET

VERTICAL SCALE IN FEET:
1 INCH = 50 FEET

0 300
SCALE IN FEET

MW-12 ← Well Designation
← Borehole
← Screened Interval
← Total Drilled Depth
Geologic Contact (dashed where inferred, question mark where uncertain)
Groundwater Elevation (August 8, 1996)

Figure 5-7
Geologic Cross Section C-C'
Hansville Landfill RI/FS



Parametrix Hansville RI Report 555-2966-002 9/04 (B)

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N

0 2,000

SCALE IN FEET

■ Community Supply Wells

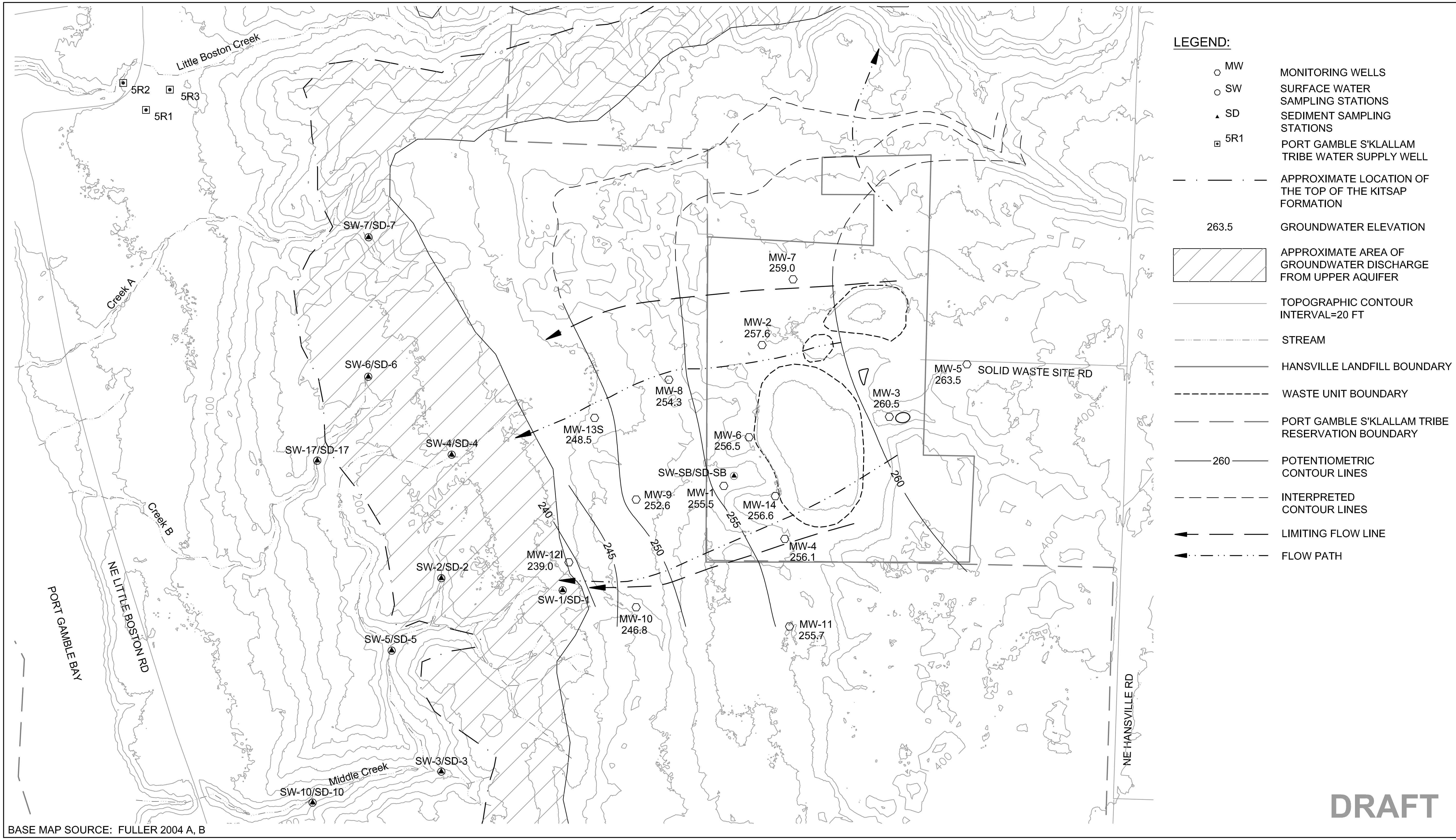
● Residential Supply Wells

* New Water Supply Wells Since Draft RI (Nov. 1999)

Creek and Flow Direction

(126) Reported Thickness or Range of Thicknesses of Kitsap Formation interpreted from Driller's Logs, feet

Figure 5-8
Thickness of the Kitsap Formation Near the Hansville Landfill
Hansville Landfill RI/FS

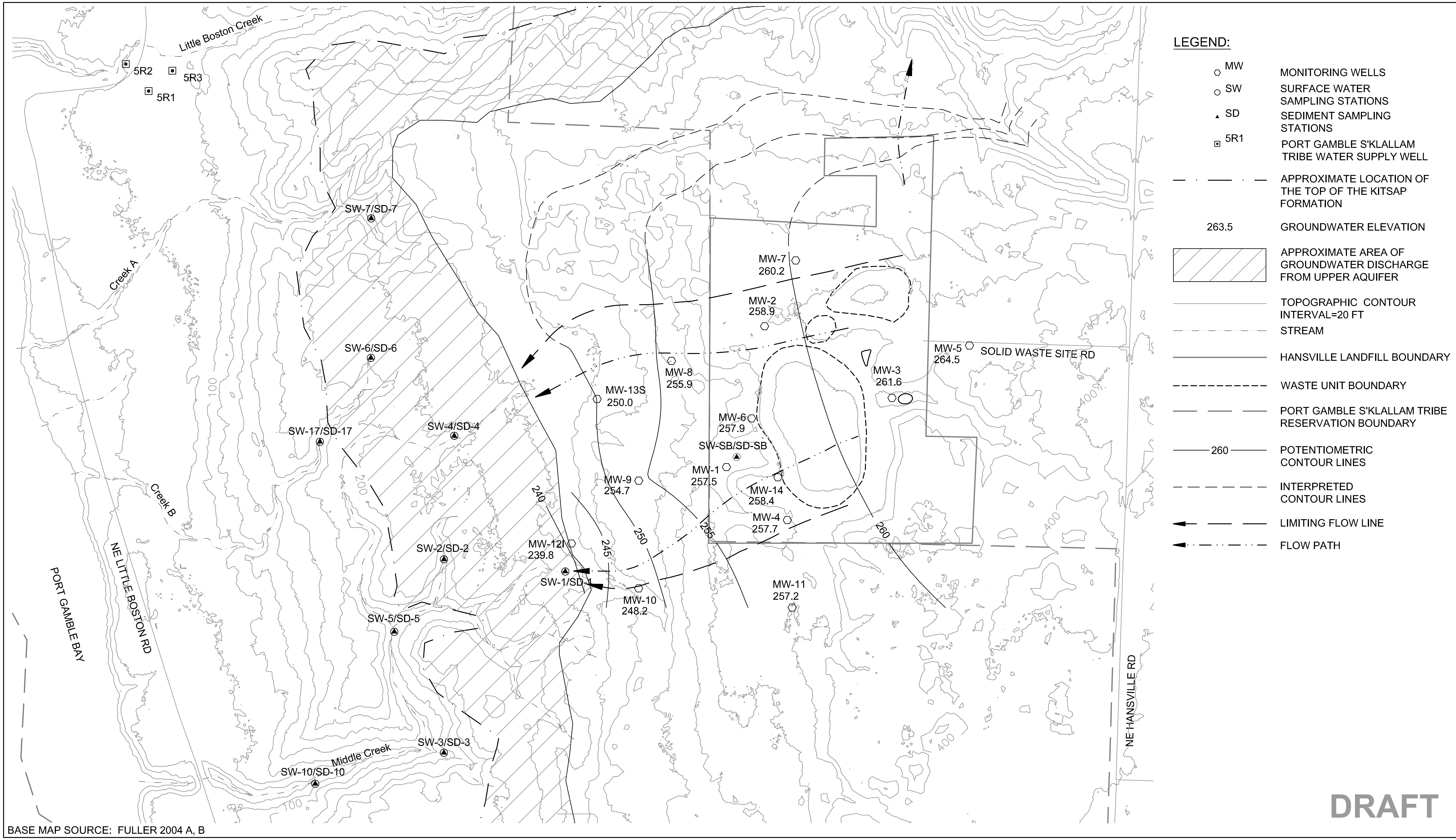


Parametrix DATE: 07/08/05 08:48am FILE: K2966002P01T02-F05-09

N
0 600
SCALE IN FEET

VERTICAL DATUM: NAVD 83

Figure 5-9
Upper Aquifer Potentiometric Surface Map, November 1996
Hansville Landfill RI/FS



Parametrix DATE: 07/08/05 08:51am FILE: K2966002P01T02-F05-10

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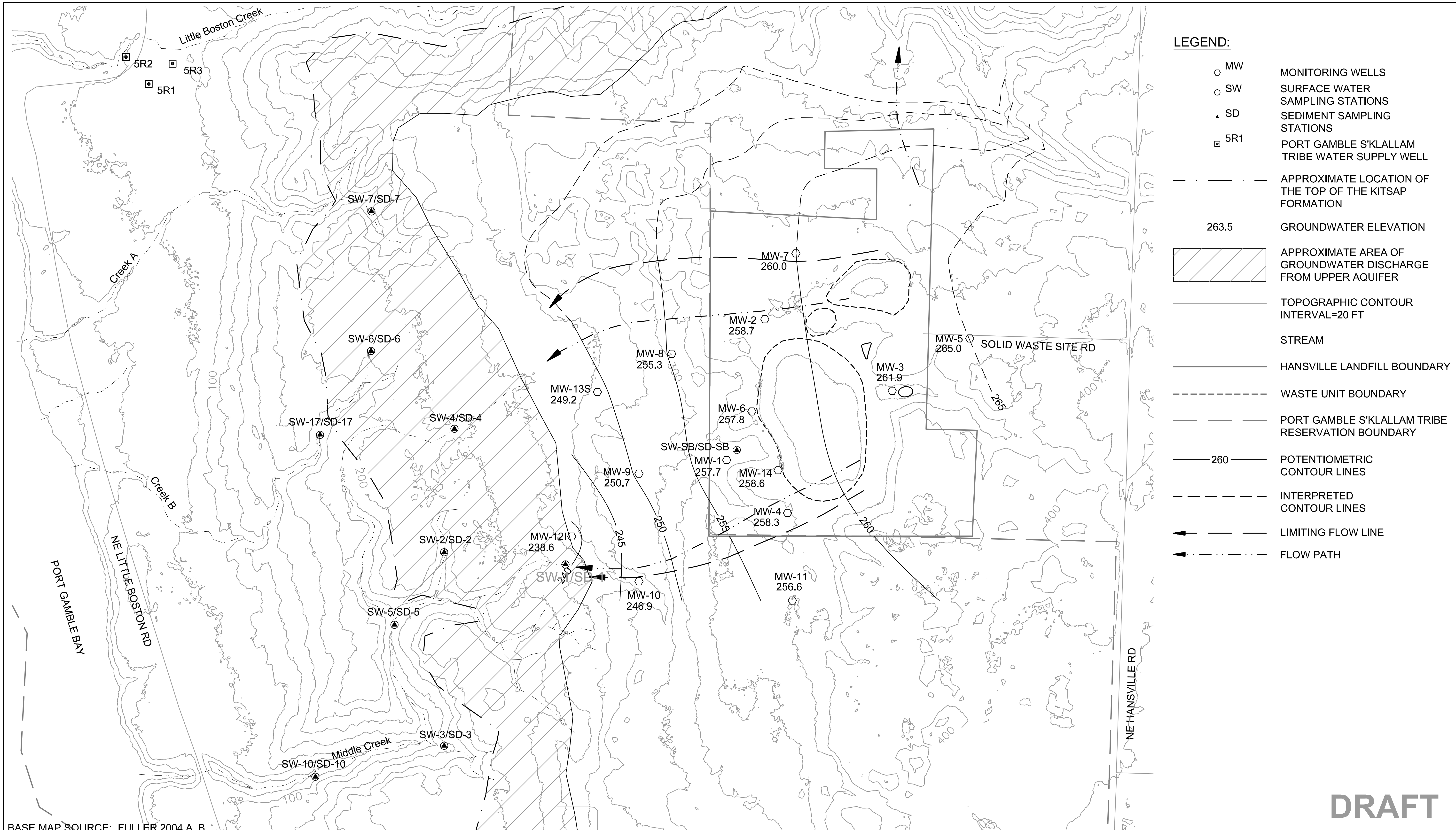
0 600
SCALE IN FEET

VERTICAL DATUM: NAVD 83

Figure 5-10
Upper Aquifer Potentiometric Surface Map, May 1997
Hansville Landfill RI/FS



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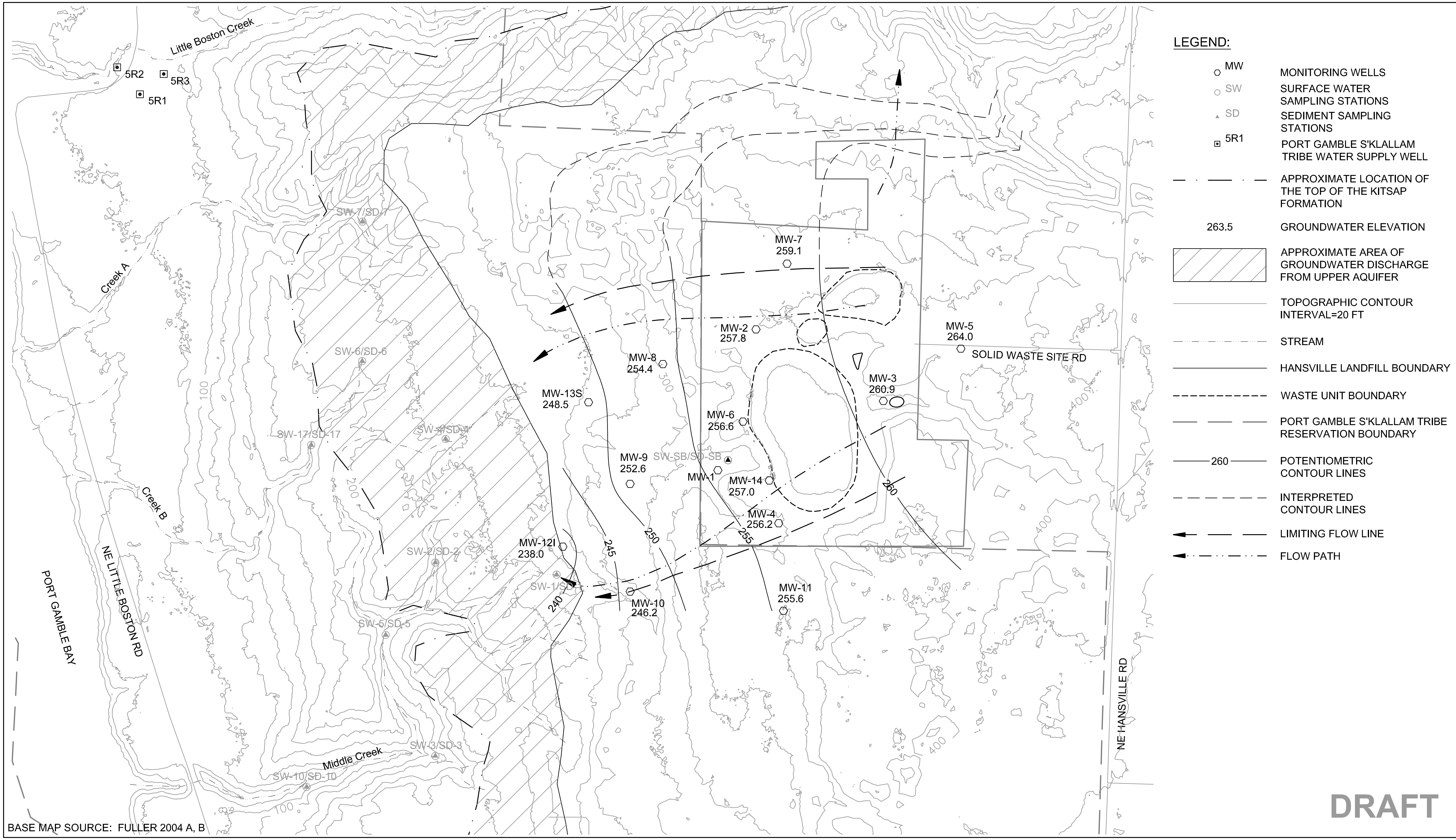
N

0 600
SCALE IN FEET

VERTICAL DATUM: NAVD 83

Figure 5-11
Upper Aquifer Potentiometric Surface Map, January 2003
Hansville Landfill RI/FS



Parametrix DATE: 07/13/05 10:52am FILE: K2966002P01T02-F05-12

N

0 600
SCALE IN FEET

VERTICAL DATUM: NAVD 83

Figure 5-12
Upper Aquifer Potentiometric Surface Map, November 2003
Hansville Landfill RI/FS

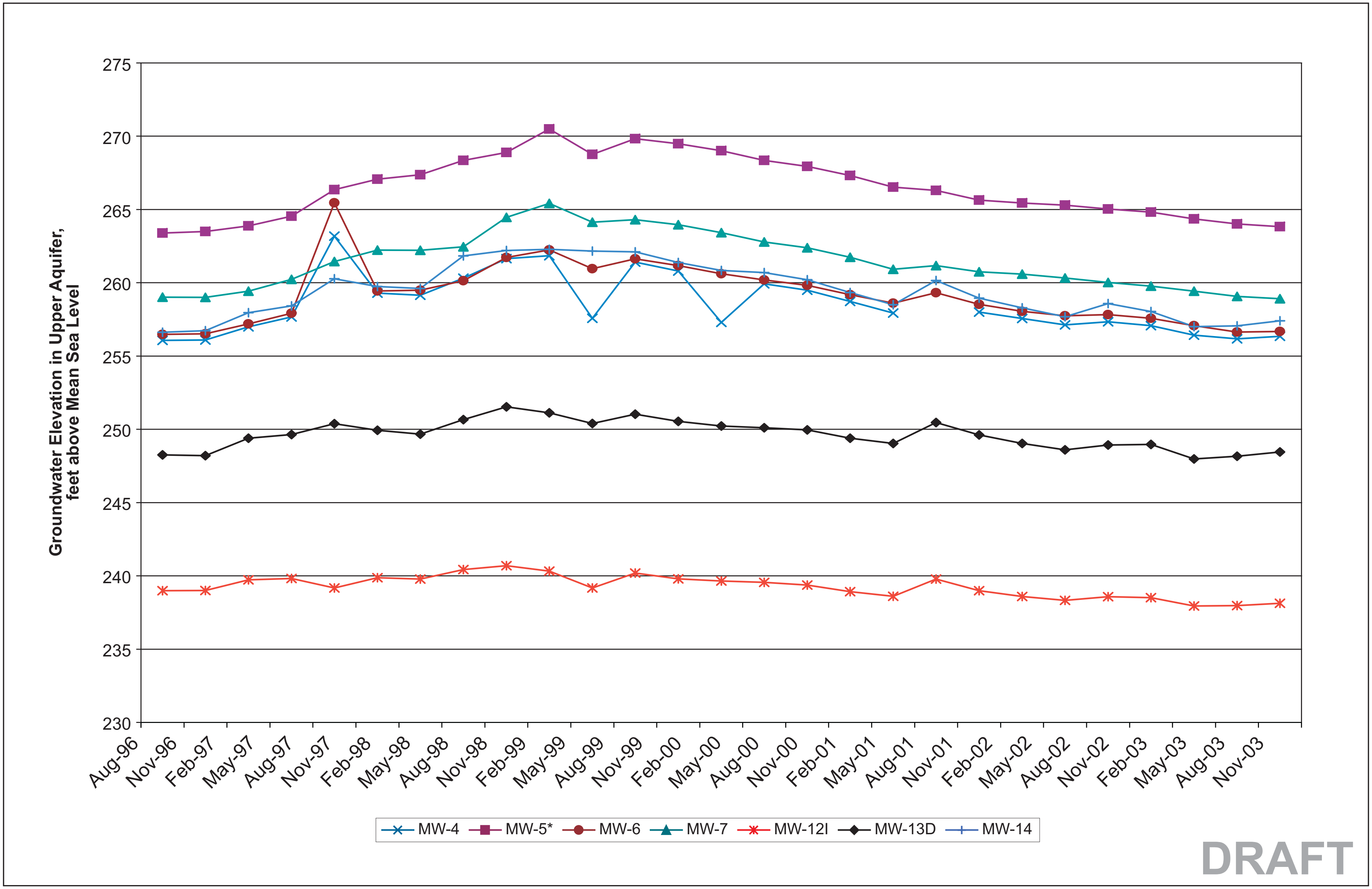
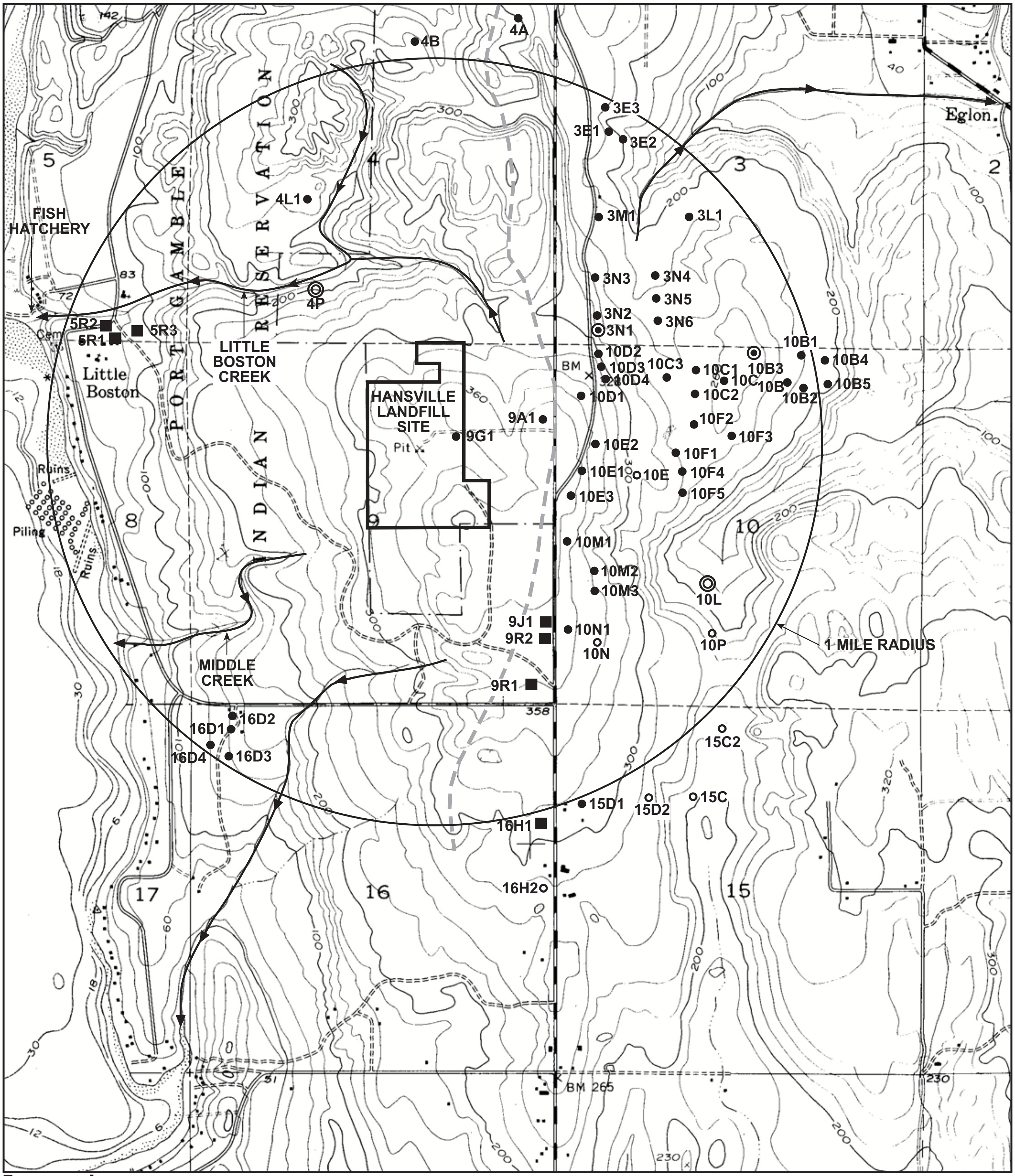


Figure 5-13
Groundwater Elevations in Monitoring Wells
Hansville Landfill RI/FS



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- Approximate Regional Groundwater Divide
- 9R1 ■ Community Supply Wells
- 15D1 ● Residential Supply Wells, Lower Aquifer
- ○ New Wells since Draft RI: Lower Aquifer
- 15D1 ◉ Residential Supply Wells, Upper Aquifer
- ◎ New Wells since Draft RI: Upper Aquifer
- Creek and Flow Direction

Figure 5-14
Approximate Locations of Water Wells Within 1 Mile of the Hansville Landfill
Hansville Landfill RI/FS

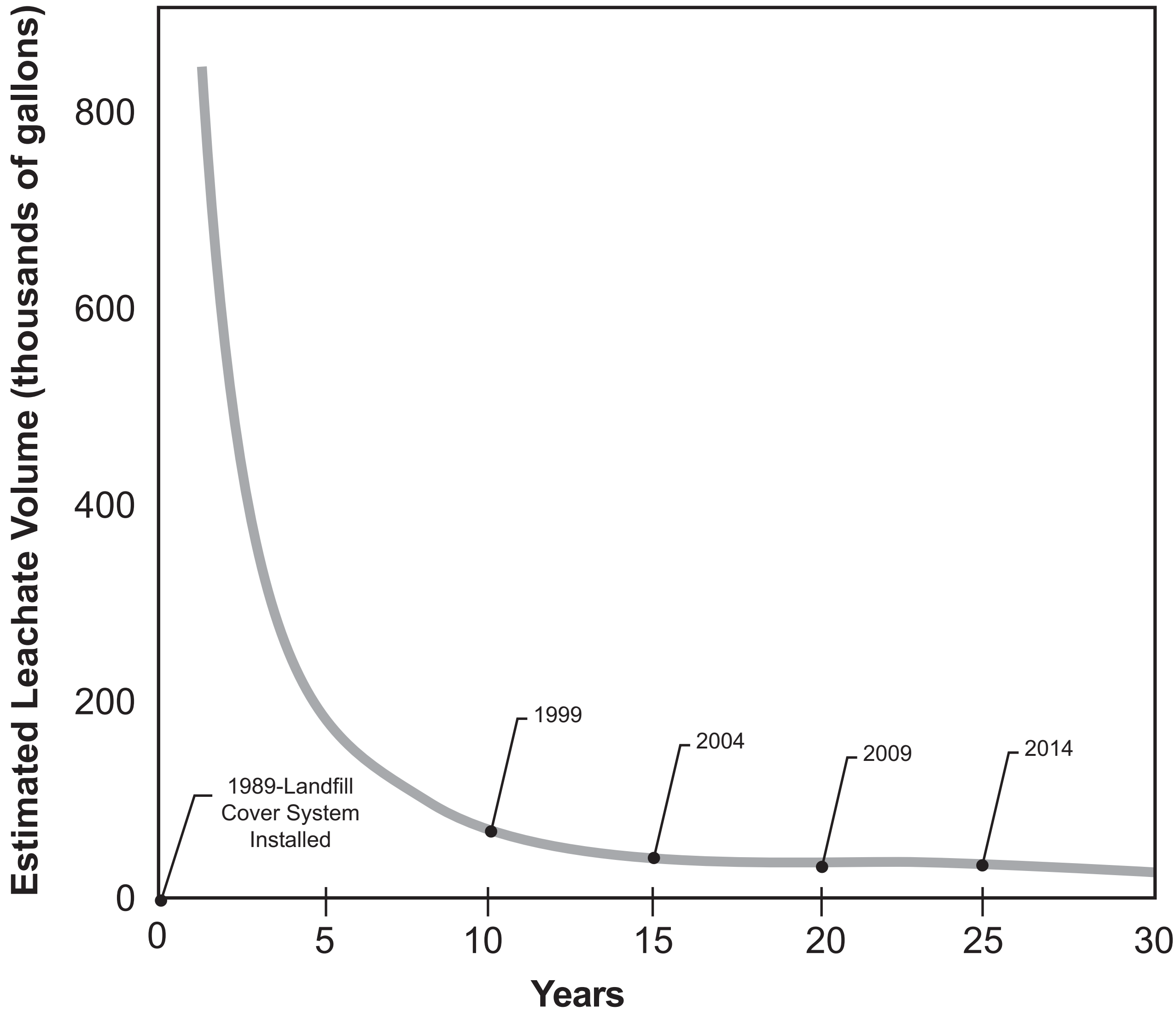

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Figure 5-15
Projected Landfill
Leachate Generation
Hansville Landfill RI/FS

6. SURFACE WATER INVESTIGATION

6.1 PURPOSE AND OBJECTIVES

The purpose of the surface water investigation component of the RI/FS is to identify potential surface water migration pathways from waste disposal areas at the Landfill and to assess water chemistry along these pathways using samples from representative locations. The objectives of this investigation are as follows:

- Characterize the flow systems of area streams with respect to origin of flow, tributary relationships, points of discharge, and distances from the Landfill.
- Establish surface water sampling stations on surface watercourses at locations appropriate for assessing background conditions and impacts from waste disposal areas at the Landfill.
- Collect surface water samples to determine concentrations of chemicals.
- Determine whether sufficient data has been collected to delineate the nature and extent of waste disposal area impacts on surface water and support analysis of remedial alternatives in the FS.

6.2 SUMMARY OF PREVIOUS SITE SURFACE WATER INVESTIGATIONS

Characterization and monitoring of surface water in the Study Area was initiated in 1990 at stations SW-1 and SW-2 (Figure 6-1) as part of the Landfill post-closure monitoring program (Parametrix 1995). The monitoring program included sampling water from a surface runoff siltation basin (SW-SB) constructed on the Property to provide storm water detention and sediment removal. Station SW-3 was added in 1994 as a downstream station on Middle Creek.

A Site Hazard Assessment performed for USEPA in 1991 in the Study Area included the collection and analysis of surface water samples from four locations: the headwaters of Middle Creek, a location approximately 1,200 ft upstream from the mouth of Middle Creek, an unnamed creek north of Middle Creek, and a reference creek discharging to Port Gamble Bay (SAIC 1991). Samples were analyzed for total metals, VOCs, organochlorine pesticides, PCBs, and herbicides. In Middle Creek water samples, only magnesium and manganese appeared to be elevated over the reference creek sample concentrations. Concentrations of several metals in water samples from the unnamed creek were elevated over reference concentrations. Because data were insufficient to determine the source of the metals, SAIC (1991) recommended that further study was required to confirm that the Landfill was not a contributing source.

6.3 OVERVIEW OF SURFACE WATER INVESTIGATION

The purpose, objectives, and approach for the RI surface water investigation were presented in Chapter 7 of the Project Work Plan (Parametrix 1995). The technical approach for the surface water investigation was further documented in the Sampling and Analysis Plan (Parametrix 1996a), the Quality Assurance Project Plan (Parametrix 1996b), and the Health and Safety Plan (Clayton Environmental Consultants 1995).

The components of the RI surface water investigation were sampling station selection, surface water sampling and analysis, and stream flow measurements.

6.3.1 Sampling Station Selection

Seven new surface water sampling stations (SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, and SW-10) were established in April 1996 at the locations shown on Figure 6-1. Stations were selected with consideration of existing station locations and stream channel mapping from aerial photographs, followed by field reconnaissance. Station SW-8 was initially established on Little Boston Creek as a background location outside of the potential influence of the Landfill. This station was later superseded by a series of background surface water monitoring samples. The procedures for establishing the surface water sampling locations are summarized as follows:

- Prepare a topographic map of the Study Area using aerial photographs.
- Plot stream channels on the topographic map, using aerial photographs and field reconnaissance information.
- Plot locations of sampling stations onto the topographic map.
- Install a staff gauge at each existing sampling station.
- Establish new surface water sampling stations by installing a staff gauge at each sampling location.
- Survey the top of each staff gauge with reference to MSL.

One sampling station, SW-9, was moved from its originally designated position, as described in a letter to Ecology from Parametrix (1999d). During initial field reconnaissance the location of SW-9 was inadvertently moved from Creek C to another intermittent stream that crosses under Little Boston Road NE further west. This second location was surveyed and became the SW-9 station that was sampled during the initial RI sampling events in 1996 and 1997 and subsequent Ecology-directed monitoring events. However, after reviewing groundwater flow maps developed for this RI, it was determined that neither the original SW-9 location, nor the second location, was positioned to detect contaminant migration from the Landfill, and sampling at this station was discontinued.

6.3.2 Surface Water Sampling and Analysis

6.3.2.1 Downstream Sampling Stations

Generally, surface water samples were collected at the four existing and seven new downstream sampling stations during four quarterly sampling events conducted over a 1 year period. Surface water samples were collected at the following times:

- Between August 1, 1996 and August 13, 1996 (dry season event);
- Between November 13, 1996 and November 20, 1996;
- March 12, 1997 (wet season event conducted within 24 hours of a rainfall event); and
- Between May 27, 1997 and June 2, 1997.

SW-6, SW-9, and SW-SB were not sampled during the August dry season event because flows were not sufficient to collect samples. Samples were not collected at SW-9 and SW-SB during the fourth quarterly event because there was not sufficient water present to collect samples.

Stream flows were estimated at the time of sample collection by measuring the cross-section of a relatively uniform reach of stream channel and timing a float as it traveled through a measured distance of the stream reach. Surface water elevations read from surveyed staff gauges were also recorded during each sampling event.

Surface water samples collected during the August dry season event and the March wet season event were analyzed for an extensive list of metals, organic compounds, and conventional water quality parameters as follows:

- Volatile organic compounds (VOCs);
- Semi-Volatile organic compounds (SVOCs);
- Pesticides/PCBs;
- Total petroleum hydrocarbons (TPH);
- Metals;
- Total cyanide;
- Total phenols;
- Conventional parameters (COD, TOC, ammonia, nitrite, nitrate, chloride, sulfate, bicarbonate, hardness, TSS, and turbidity); and
- Field parameters (water temperature, pH, specific conductivity, dissolved oxygen).

Samples collected during the other two quarterly events were analyzed for a shorter list of constituents:

- VOCs;
- Metals;
- Conventional parameters (COD, TOC, ammonia, nitrate, nitrite, chloride, sulfate, bicarbonate, hardness, TSS, turbidity); and
- Field parameters (water temperature, pH, specific conductivity, dissolved oxygen).

Samples from the first two quarterly events were analyzed for total metals only. Samples from the final two quarterly events were also analyzed for the dissolved or total recoverable fractions of some metals to allow for direct comparisons to water quality criteria.

The adequacy of the network of surface water monitoring stations to assess the nature and extent of waste disposal area impacts and to support the Feasibility Study was evaluated after the first two rounds of quarterly sampling. Based primarily on evaluations of vinyl chloride and metals, Technical Memorandum No. 4 (Parametrix 1997a) documented, with concurrence from Ecology, that no additional surface water stations were necessary.

This RI report also includes data that were collected during 23 Ecology-directed monitoring events between March 1998 and January 2004. A list of sampling locations and analytical parameters was approved by Ecology prior to sampling that occurred between March 5 and March 9, 1998. Sampling stations selected for the Ecology-directed monitoring events were documented in a June 5, 1998, letter from Parametrix to Ecology. Samples were collected at SW-1, -4, -6, -7, -8, and -10. These samples were analyzed for:

- VOCs;

- Metals (dissolved antimony, arsenic, cadmium, calcium, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silver, sodium, and thallium; and total arsenic, mercury, and selenium);
- Conventional parameters (alkalinity, ammonia, carbonate, COD, chloride, nitrate plus nitrate, bicarbonate, sulfate, TOC, TSS, turbidity, fecal coliform, and hardness); and
- Field parameters (water temperature, pH, specific conductivity, dissolved oxygen, and redox).

Following further review and Ecology approval, samples were collected at the same six locations between July 7 and July 30, 1998; and again between October 12 and 13, 1998. These samples were analyzed for:

- Vinyl chloride;
- Metals (dissolved arsenic, cadmium, calcium, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, and sodium; and total recoverable mercury);
- Conventional parameters (chloride, nitrate, nitrite, ammonia, sulfate, turbidity, alkalinity, bicarbonate, TOC, COD, TSS, hardness, fecal coliform); and
- Field parameters (water temperature, pH, specific conductivity, dissolved oxygen, redox, static water level).

In the first quarter of 2000, the station parameters were further reduced to reflect the improved monitoring results (Parametrix 1999e). Analysis was eliminated for seven dissolved metals (antimony, cadmium, mercury, nickel, selenium, silver, and thallium). Vinyl chloride continued to be tested quarterly and the full VOC list was analyzed annually. In addition, surface water station SW-8 was eliminated from ongoing monitoring and data from SW-8 were not used to assess Landfill contaminant effects (see Chapter 8). This station had initially been established as a background station, but the associated sediment station SD-8 was determined not to be representative of the sediment types found in small creeks downgradient from the Landfill (see Chapter 7).

6.3.2.2 Background Surface Water Sampling Stations

In November 2002, surface water background stations were selected in coordination with Ecology and the Tribe at adjacent drainages to the south (SW-17B through SW-20) and north (SW-15) of downgradient creeks. The locations of surface water background stations are shown on Figure 6-2. The background stations were selected as having (1) the same basic characteristics as downgradient stations (headwaters of small streams originating as discharge from the upper aquifer), (2) locations outside of potential influence from Landfill releases, and (3) no apparent influence by releases from other localized human activities. The selection of the background surface water sampling stations is described in the Sampling and Analysis Plan Addendum for Background Surface Water (Parametrix 2002).

Surface water samples were collected from these five background stations and from station SW-8 during two sampling events conducted on November 1, 2002 and January 27, 2003. The samples were analyzed for:

- Vinyl chloride;
- Metals (arsenic, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, sodium, and zinc). (Note: cadmium, chromium, mercury, nickel, and zinc were not analyzed in November 2002);

- Conventional parameters (alkalinity, ammonia, COD, chloride, nitrate, nitrite, sulfate, TOC, TSS, turbidity, fecal coliform, and hardness); and
- Field parameters (temperature, pH, specific conductivity, dissolved oxygen, and redox).

Summary data tables are presented in Appendix C, and the laboratory data are provided in Appendix P.

6.3.3 Surface Water Quality Data Management

Surface water quality data were managed as follows:

- Digital data from the analytical laboratory were incorporated into the project database.
- Data quality reviews were conducted in accordance with procedures described in the QAPP (Parametrix 1996b). Data requiring qualifications were annotated in the database and in data summary tables. Results of the data quality reviews are described in the QA/QC data summary sheets presented in Appendix O.
- The surface water summary data tables and time-series plots for selected parameters (specific conductivity, chloride, nitrate, dissolved arsenic, dissolved manganese, and vinyl chloride) are presented in Appendix C. Hard copies of the laboratory reports are presented in Appendix P.

6.3.4 Fish Habitat Assessment

Three small (<5 cfs base flow) creeks are formed by seeps and groundwater discharges that emanate downgradient of the Landfill. The largest of these, Middle Creek, is composed of approximately five small tributaries that meet about 2,000 ft east of Port Gamble Bay. Two smaller, unnamed creek north of Middle Creek (identified as Creeks A and B on Figure 6-1) also drain into the Bay.

The lower reaches of creeks that discharge into Port Gamble Bay west of the Hansville Landfill were surveyed for fish habitat (see Technical Memorandum No. 1, Appendix Q). The upper reaches of Middle Creek and Creek B, the two creeks directly downgradient of the Landfill with respect to groundwater flow, were surveyed for fish habitat by Parametrix staff on June 7, 1997, and the results of the survey are summarized in Appendix N.

The survey concluded that limitations to adult salmonid habitat use in the upstream creek segments would most likely be caused by a lack of water depth and habitat features (e.g., spawning gravel, pools, etc.). Much of the surveyed area could provide limited habitat for juvenile salmonid rearing.

6.4 REGIONAL/SITE SURFACE WATER SYSTEM

The following provides a general description of surface water hydrology in the Study Area.

6.4.1 Precipitation and Runoff

Average annual precipitation at the Site is approximately 32 in., more than half of which falls during the 4-month period of November through February. Average monthly precipitation ranges from a low of 0.9 in. in July to a high of 4.8 in. in December (see Table 2-1).

The quantity of surface runoff that occurs in the Study Area is limited by the small watershed areas, and by the permeable nature of the sandy surface soils. With the exception of a few narrow roads, the watershed areas for the creeks west of the Landfill are comprised of heavily vegetated, undeveloped land with permeable soils. Rainfall predominantly infiltrates before it can produce runoff.

The Landfill closure system was designed to promote drainage from the capped waste disposal areas. This includes a geosynthetic cap that completely covers the waste disposal areas (solid waste, demolition waste, and septage). Surface water runoff does not come into contact with any waste disposed on the Landfill Property. Runoff from the closed solid waste disposal area is collected in the perimeter ditch, located inside the perimeter access road (see Figure 2-5) and is discharged to a siltation basin, where it evaporates or infiltrates at the western boundary of the Property (see Section 2.4, Site Topography, Precipitation, and Drainage). During large storm events in the wet season, surface water is discharged to a channel west of the basin where it infiltrates into native soils. Surface water entering the Property from the east is routed to the siltation basin located east of the Landfill.

Because surface runoff from the Property infiltrates to the ground, there is no direct overland flow connection between the waste disposal areas and the downgradient streams. A reconnaissance of the area downgradient of the siltation basin confirmed that there is no connecting surface channel that flows to the streams. Thus, the only pathway for migration of chemicals from the waste disposal areas at the Landfill to off-site surface waters or sediment is via discharge of groundwater to the headwaters of the streams.

6.4.2 Small Creeks West of the Landfill

The Landfill is located near the crest of the ridge that bisects the Kitsap Peninsula, on the western side of the drainage divide. Several small creeks originate as springs and seeps downgradient of the Landfill from the upper aquifer, where this formation outcrops at its contact with the underlying Kitsap Formation.

The headwaters of streams located to the north, west, and south of Landfill occur at approximate elevations of 160 to 290 ft above sea level. The known perennial streams are Middle Creek and Little Boston Creek, and the intermittent streams have been designated as Creeks A, B, and C (see Figure 6-1). Middle Creek and Creek B drain the area between the Landfill and Port Gamble Bay. Little Boston Creek, Creek A, and Creek C may represent streams unaffected by groundwater passing beneath the Landfill because of their locations with respect to groundwater flow (see Figures 5-9 through 5-12).

Three small creeks (i.e., Middle Creek, Creek A, and Creek B) originate at seeps and springs west of the Landfill and flow west into Port Gamble Bay. The headwaters of these creeks are formed between approximately 160 and 225 ft above sea level. These headwater areas remain wet all year and support a variety of wetland vegetation.

The stream bottoms in the headwaters are dominated by sand- and silt-sized particles with fine particulate organic matter (e.g., decomposing leaves). In the middle and lower reaches of the creeks, the streams flow in well-defined channels with primarily sand and gravel substrate. Little Boston Creek and the lower reaches of Middle Creek are larger streams with predominantly gravel and sand substrate.

Because the creeks are primarily fed by groundwater rather than surface runoff, flows appear to be relatively constant (within one order of magnitude) and infrequently subject to high peak flows during extreme storm events. Typical of other streams in the Puget Sound area, base flows are lowest in late summer and early fall with seasonal high flows occurring in the winter and spring. Stream flows measured at RI surface water stations during the sampling events are summarized in Table 6-1. Due to the difficulty of precisely measuring the relatively low flows observed, these flow measurements are intended as estimates only, and are reported for the first three RI sampling events in 1996 and 1997 only.

6.5 SURFACE WATER INVESTIGATION FINDINGS

The surface water investigation at the Site confirms the following:

- There is no direct overland flow connection between the disposal areas at the Landfill and downgradient streams, due to the permeable nature of soils and rapid infiltration of surface runoff.
- The network of surface water monitoring stations is representative of background and downgradient conditions, and is sufficient to assess potential impacts of the Landfill on surface water.
- Surface water sampling results are tabulated in Appendix C and evaluated to select chemicals for the feasibility study in Chapter 8 (Chemical Screening). The distribution and transport of chemicals in surface water is described in Chapter 9 (Chemical Fate and Transport Evaluation).
- The fish habitat survey concluded that limitations to adult salmonid habitat use in the upstream creek segments would most likely be caused by a lack of water depth and habitat features, although much of the surveyed area could provide limited habitat for juvenile salmonid rearing.

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Table 6-1. Summary of Stream Flow Data at RI Surface Water Stations

Station ID	Flow rate (in cfs)		
	August 1996	**November 1996**	**March 1997**
SW-1	0.1	--	0.2
SW-2	0.5	0.4	0.5
SW-3	0.8	0.6	2.3
SW-4	0.1	0.1	0.1
SW-5	0.2	<0.1	0.8
SW-6	NF	<0.1	0.1
SW-7	<0.1	0.3	0.1
SW-8	0.6	0.6	2.0
SW-9	NF	<0.1	0.1
SW-10	1.2	0.9	3.3
SW-SB	NF	<0.1	<0.1

Notes:
NF = No flow
-- = Not measured

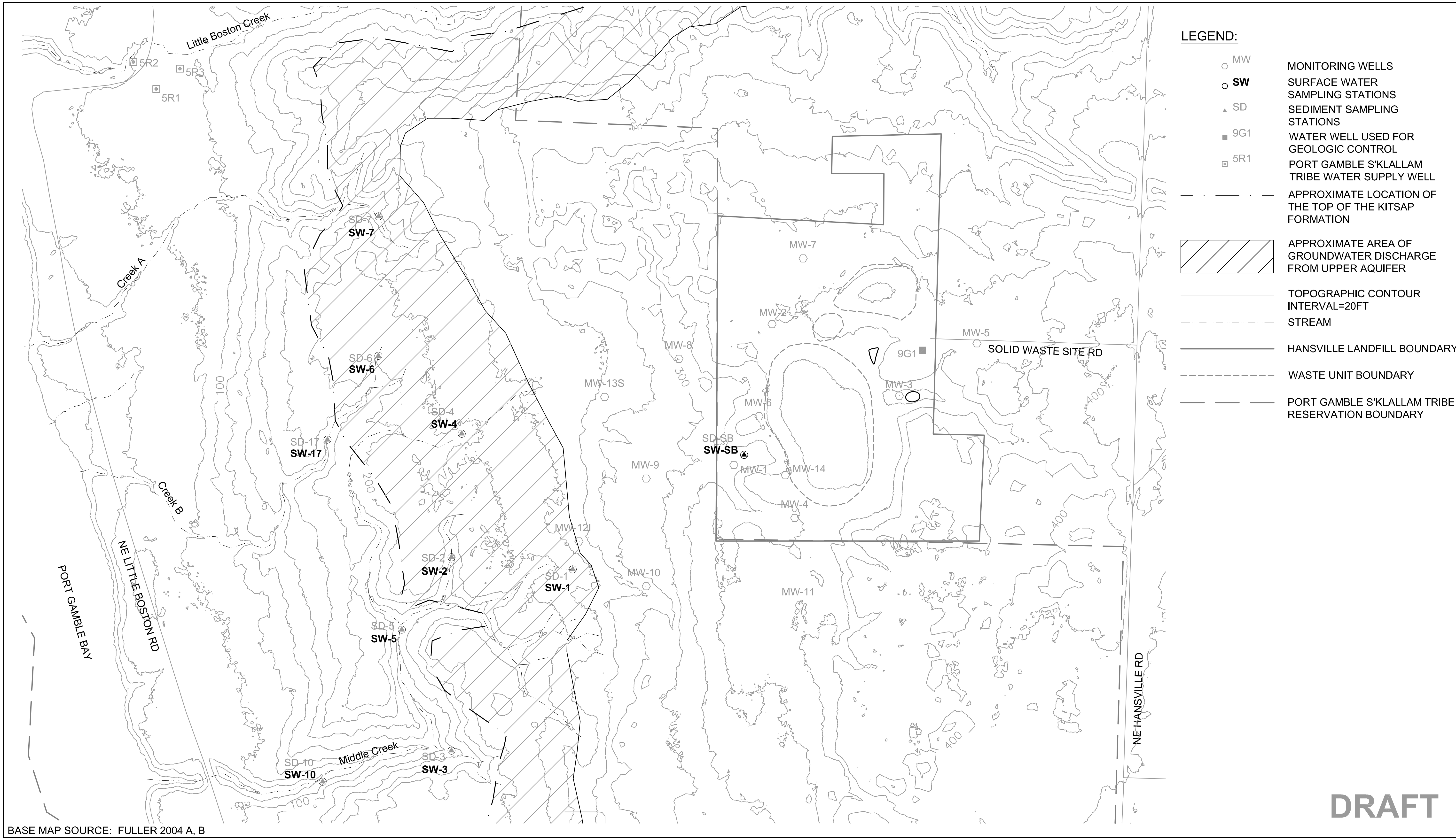

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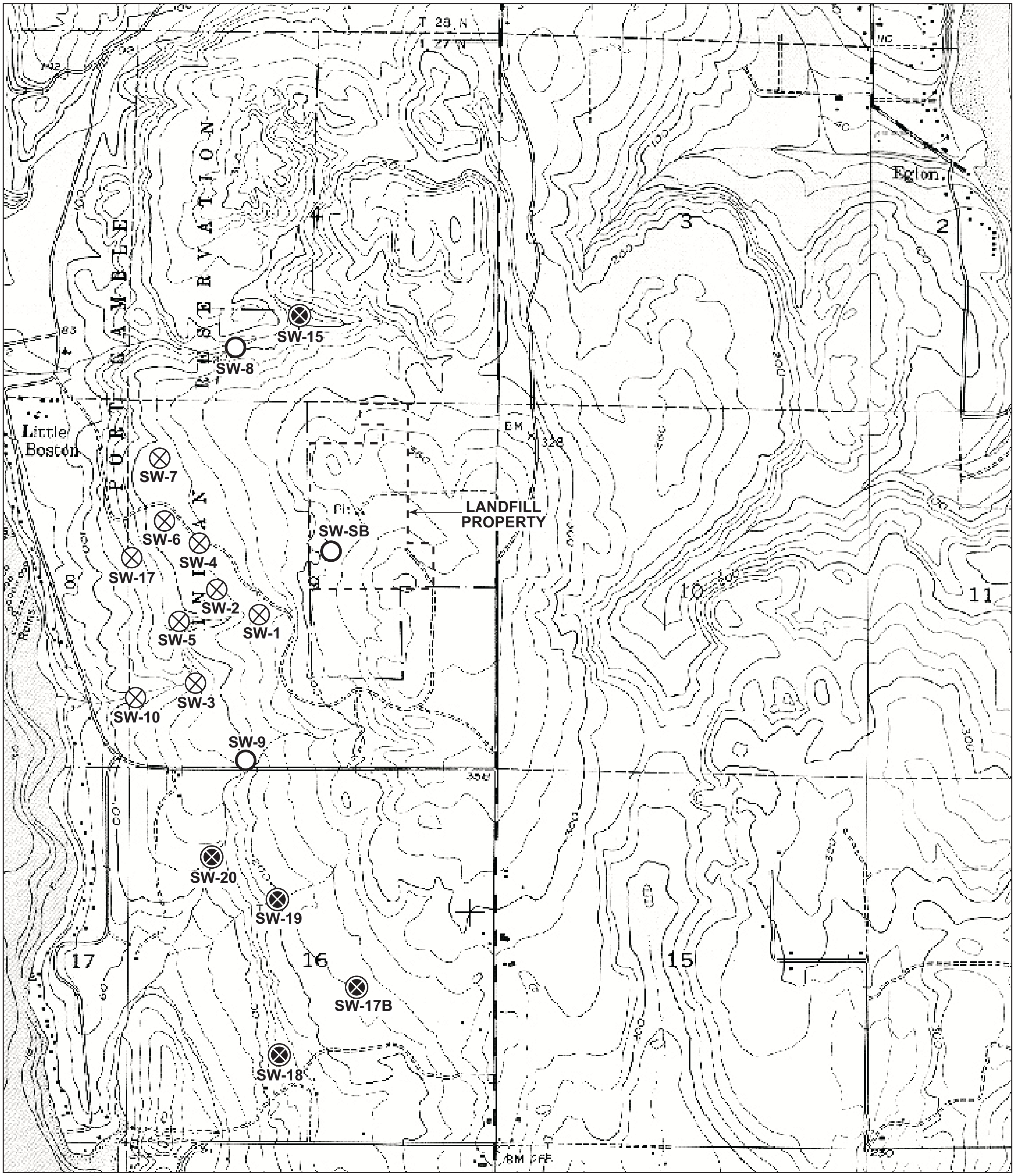
Figure 6-1
Downstream Surface Water Sampling Stations
Hansville Landfill RI/FS



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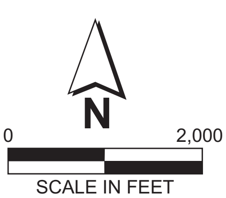

Background Surface Water Stations

Downstream Surface Water Stations

Other Surface Water Stations

Figure 6-2
Background and Downstream Surface Water Sampling Stations
Hansville Landfill RI/FS

7. SEDIMENT INVESTIGATION

7.1 PURPOSE AND OBJECTIVES

The purpose of the sediment investigation component of the RI/FS is to identify potential sediment migration pathways from waste disposal areas and assess water and sediment chemistry along these pathways using samples from representative locations. The objectives of this investigation are as follows:

- Establish sediment sampling stations at each surface water station in streambed locations that are representative of sediment deposition conditions.
- Collect sediment samples to determine concentrations of chemicals.
- Determine whether sufficient data has been collected to delineate the nature and extent of waste disposal area impacts on these media and support analysis of remedial alternatives in the FS.

7.2 SUMMARY OF PREVIOUS SITE SEDIMENT INVESTIGATIONS

Previous sediment sampling in the Study Area was conducted by SAIC for Ecology and was limited to site hazard assessment samples collected from the surface sediments of Middle Creek, an unnamed creek, and a reference creek (SAIC 1991). Sediment samples were analyzed for total metals, VOCs, organochlorine pesticides, PCBs, and herbicides. The sediment chemistry analyses indicated that some metals may be elevated over reference sample concentrations; however, the authors considered these results inconclusive and further sampling was recommended. In addition, a bioassay using Hyalella azteca was performed with sediment samples. The bioassays did not result in any statistically significant effects from mortality (Cubbage et al. 1997).

7.3 OVERVIEW OF SEDIMENT INVESTIGATION

The purpose, objectives and approach for the RI sediment investigation were presented in Chapter 7 of the Project Work Plan (Parametrix 1995). The technical approach for the sediment investigation was further documented in the Sampling and Analysis Plan (Parametrix 1996a), the Quality Assurance Project Plan (Parametrix 1996b), and the Health and Safety Plan (Clayton Environmental Consultants 1995).

The components of the RI sediment investigation were sampling station selection and sediment sampling and analysis.

7.3.1 Sampling Station Selection

Eleven new sediment sampling stations (SD-1 through SD-10, and SD-SB) were established in April 1996 at the locations shown on Figure 7-1. Stations were selected in the vicinity of the new and existing surface water sampling stations. Station SD-8 was established on Little Boston Creek as a background location outside the potential influence of the Landfill. Sediment sampling was performed at representative depositional areas. Sediment sampling locations were established by locating an area of sediment deposition (i.e., a pool) near the surface water sampling station that contained sufficient sediment for sampling and that appeared to be representative of sediment deposits observed within that stream reach in terms of grain size distribution and organic matter content.

One sampling station, SD-9, was moved from its originally designated position, as described in a letter to Ecology from Parametrix (1999d). During initial field reconnaissance the location of SD-9 was inadvertently moved from Creek C to another intermittent stream that crosses under Little Boston Road NE further west. This second location was surveyed and became the SD-9 station that was sampled during the initial RI sampling events in 1996 and 1997 and subsequent Ecology-directed monitoring events. However, after reviewing groundwater flow maps developed for this RI, it was determined that neither the original SD-9 location, nor the second location, was positioned to detect contaminant migration from the Landfill. The SD-9 data were therefore not used to assess Landfill impacts on sediment quality (see Chapter 8).

7.3.2 Sediment Sampling and Analysis

Surficial sediment was sampled during the first quarterly event (between July 31, 1996 and August 13, 1996) at the 11 original RI sediment stations. Sediment samples were analyzed for the following:

- VOCs,
- SVOC,
- Pesticides/PCBs,
- TPH,
- Total metals,
- Total cyanide,
- Total phenols,
- Total organic carbon,
- Total solids, and
- Grain size distribution.

The adequacy of the sediment monitoring data to assess the nature and extent of Landfill impacts and to support the Feasibility Study was evaluated after the initial round of sediment sampling. Similar to the surface water evaluation, the sediment data evaluation focused primarily on vinyl chloride and metals. Based on those evaluations, as documented in Technical Memorandum No. 4 (Parametrix 1997a), no additional downgradient sediment sampling stations were recommended at that time. Ecology concurred with this analysis and the recommendation that additional downgradient sediment samples were not required for the RI.

After the initial sediment sampling event, it was determined that background station SD-8 was generally not representative of the sediment types found at other sampling locations because its sediments differed in grain size and total organic carbon content. Therefore, additional sediment sampling was recommended at other background areas (i.e., the headwaters of other local streams). At a February 27, 1997 meeting with Ecology, BKCHD, Port Gamble S'Klallam Tribe, Kitsap County, and OVSL, it was agreed that more background sediment information was necessary to determine the need for collecting additional sediment samples on Creek B or Middle Creek.

On April 3, 1997, additional background sediment samples were collected at six new sampling stations selected in coordination with Ecology and the Tribe (SD-11 through SD-16) established near the Landfill (Figure 6-2). The background locations do not receive runoff from the Landfill Property and are outside of the area where groundwater sources may be influenced by the Landfill. Samples SD-11, SD-12, and SD-14 were collected from small tributaries of a stream that flows into Port Gamble Bay. These background locations were also similar in origin to the small tributaries downgradient of the Landfill that flow from seeps and springs within young stands of timber. SD-13 was located in the headwaters of a small stream approximately 2 miles southeast of the Landfill. This sample location was within a stand of mature timber with recent logging activity upgradient. SD-15 was located north of the Landfill on the east branch of Little Boston Creek, approximately one-quarter mile upstream from SD-8. SD-16 was located on a small tributary of Little Boston Creek.

The supplemental background samples were collected and analyzed in accordance with the approved RI Sampling and Analysis Plan (Parametrix 1996a). The results and evaluations of this supplemental background sediment sampling were presented in Technical Memorandum No. 6 (Parametrix 1997b).

Based on the Technical Memorandum No. 6 evaluations, one additional sampling station (SD-17) was recommended and approved to further characterize the extent of metals in sediments downstream from SD-6 on Creek B. To complete the characterization similar to other downgradient stations, both water and sediment samples were collected at SD-17 on August 4, 1997, and analyzed for the complete lists of metals, organic compounds, and conventional parameters.

Sediment data (including the supplemental background sediment data) are summarized in Appendix D.

At the request of Ecology, triplicate sediment core samples were collected on January 29, 1999, at SD-10 on Middle Creek and SD-17 on Creek B. The purpose of this sampling was to collect confirmation stream sediment samples to verify the presence and concentrations of specific metals. The samples were analyzed for the metals listed in Table 11 of Ecology's latest freshwater sediment quality guidelines (Cubbage et al. 1997), and for beryllium. A Sampling and Analysis Plan Addendum (Parametrix 1999b) was written to address the change in methods, and this Addendum was approved by Ecology prior to sampling. The purpose, methods, results, and conclusions from the sediment core sampling were presented in Technical Memorandum No. 8 (Parametrix 1999c). No further sediment sampling was recommended or required for completion of the Hansville Landfill RI. Ecology and BKCHD concurred with this recommendation.

7.3.3 Sediment Quality Data Management

Sediment quality data were managed as follows:

- Digital data from the analytical laboratory were incorporated into the project database.
- Data quality reviews were conducted in accordance with procedures described in the QAPP (Parametrix 1996b). Data requiring qualifications were annotated in the database and in data summary tables. Results of the data quality reviews are described in the QA/QC data summary sheets presented in Appendix O.
- The sediment summary data tables are presented in Appendix D. Hard copies of the laboratory reports are presented in Appendix P.

7.4 EVALUATION OF REPRESENTATIVENESS OF SEDIMENT SAMPLES

A comparison between the physical properties analyzed in background sediment samples and sediment samples collected downgradient of the Landfill Property (SD-1, SD-2, SD-3, SD-4, SD-5, SD-6, SD-7, and SD-10) indicated that the two groups of samples had similar ranges of conditions with respect to grain size, total solids, and organic content:

- Total organic carbon (TOC) ranged from 0.63 to 12 percent in background samples compared to a range of 0.72 to 11 percent in downgradient samples.
- Total solids ranged from 9.6 to 62 percent in background samples compared to a range of 9.3 to 71 percent in downgradient samples.
- The percent of silt and finer grain sizes in background samples ranged from 4.3 to 37.3 compared to 1.3 to 38.9 percent in downgradient samples.

These results indicated that, collectively, the seven background samples were representative of the range of physical conditions that may influence chemical concentrations in sediments downgradient from the Landfill.

7.5 SEDIMENT INVESTIGATION FINDINGS

- Results of the RI sediment investigation in the Study Area confirm that the network of sediment sampling stations is representative of background and downgradient conditions, and is sufficient to assess potential aspects of the Landfill on creek sediment.
- Sediment sampling results are tabulated in Appendix D and evaluated to select chemicals for the feasibility study in Chapter 8 (Chemical Screening). The distribution and transport of chemicals in sediment is described in Chapter 9 (Chemical Fate and Transport Evaluation).

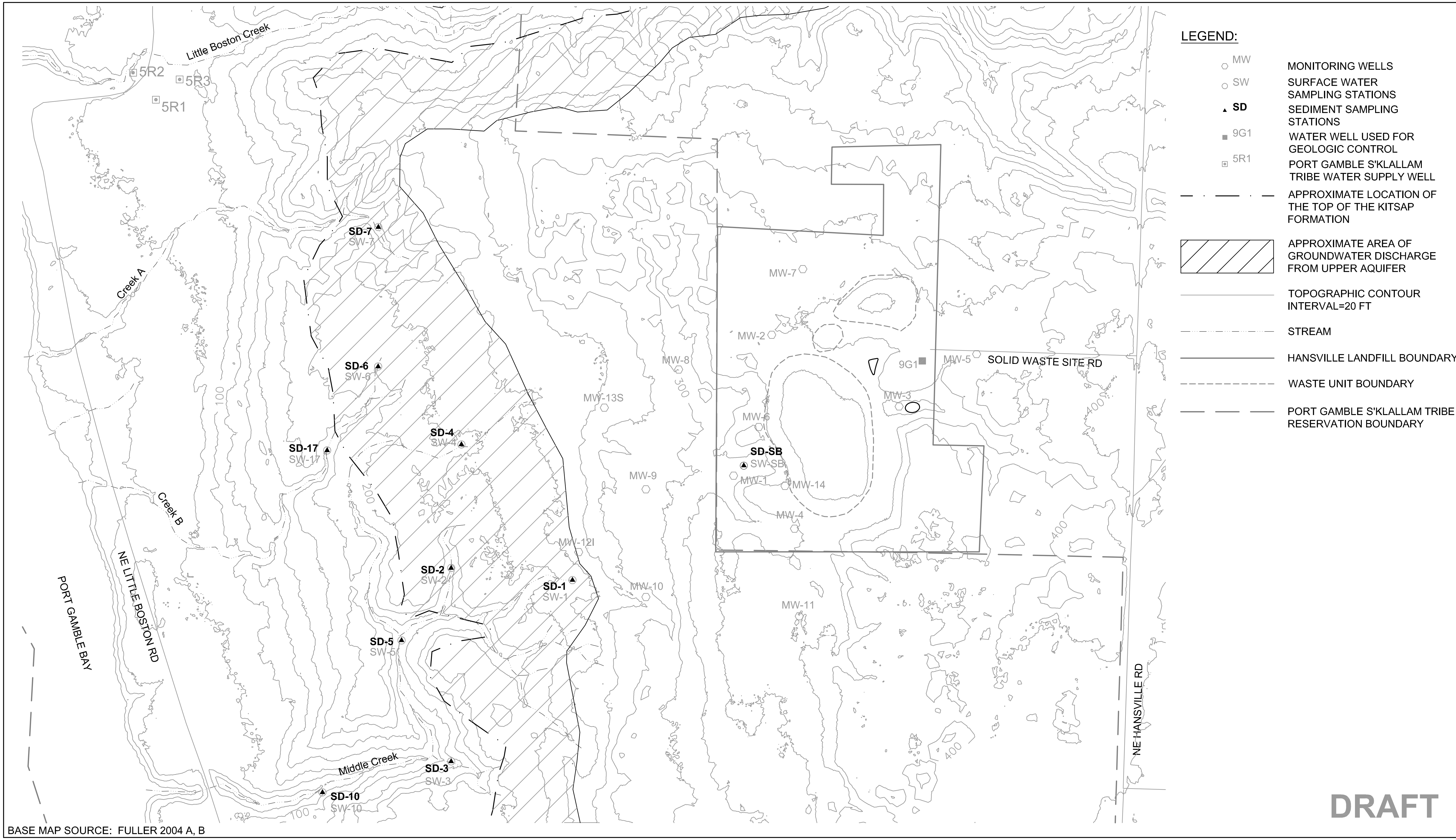

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Figure 7-1
Downstream Sediment Sampling Stations
Hansville Landfill RI/FS

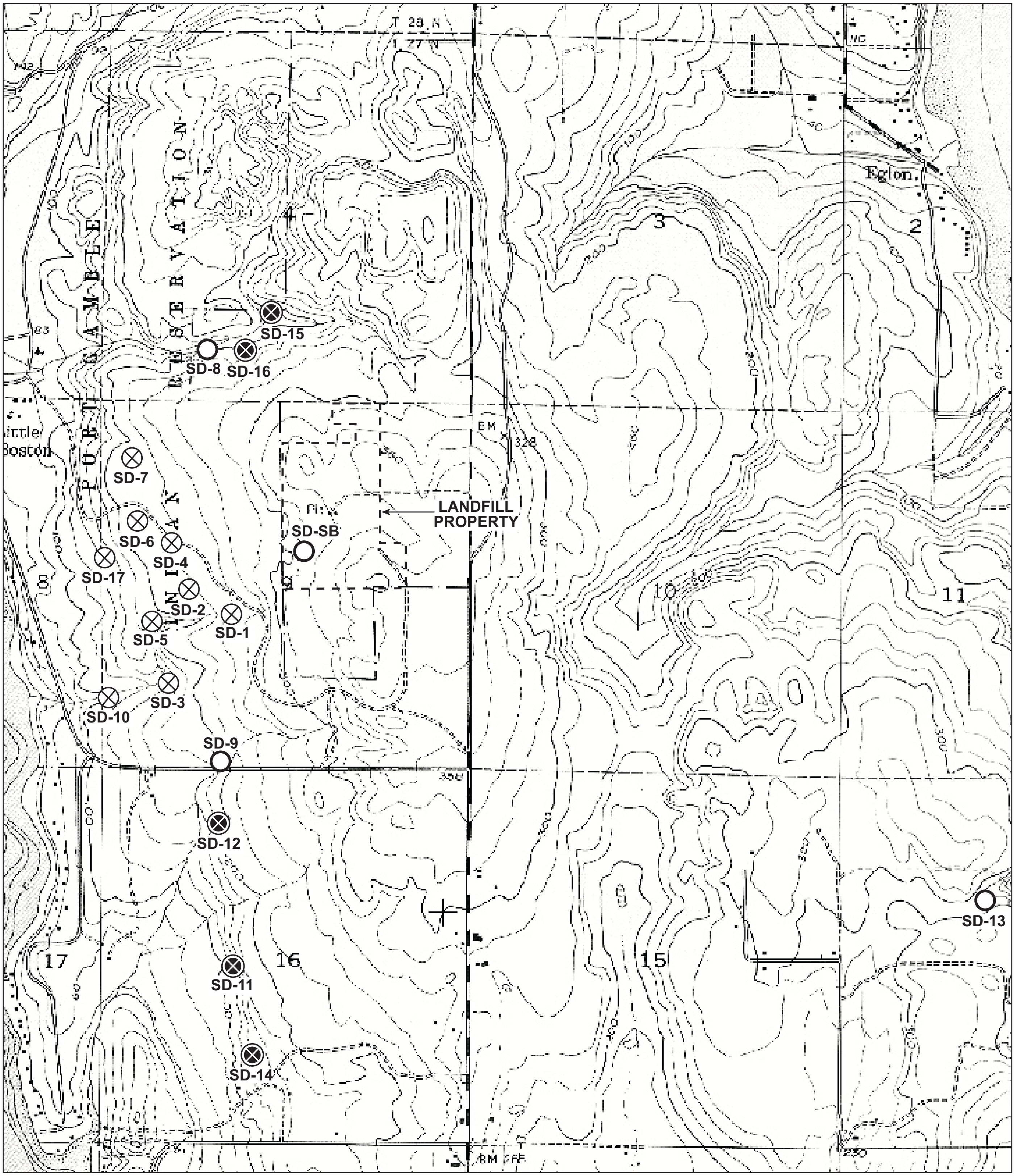

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Figure 7-2
Background and Downstream Sediment Sampling Stations
Hansville Landfill RI/FS

8. CHEMICAL SCREENING

8.1 OVERVIEW

The process of chemical screening described below was used to select chemicals for further consideration in the Hansville Landfill Feasibility Study. This process was applied to chemicals detected downgradient of the Landfill in samples from groundwater monitoring wells, groundwater discharge areas at the heads of small creeks west of the Landfill, downstream samples from these creeks, and sediments from the same groundwater discharge areas and creeks. The data used in the chemical screening included data from the original four quarters of RI monitoring, Ecology-directed monitoring that occurred between the end of the RI monitoring (November 1996) and January 2004, and data collected from other surface water and sediment sampling events, including sampling designed to establish surface water and freshwater sediment background concentrations.

All data were collected in accordance with Ecology-approved sampling and analysis plans. The screening process was developed through extensive discussions with Ecology, KCHD, the Port Gamble S'Klallam Tribe, Kitsap County, and WMW, and incorporates recent correspondence from Ecology's Project Manager regarding the approach for completing the RI report (Ecology 2002, 2003, 2004, 2005). Specifically, Section 8.2 discusses the basis for selecting a method for identifying groundwater cleanup levels under MTCA. Section 8.3 presents the chemical screening process ultimately selected for the RI report, pursuant to discussions with Ecology.

The results of the chemical screening are presented in Section 8.4 and summarized in Table 8-5 at the end of this chapter. The chemicals identified for further evaluation in the FS, based on the results of the chemical screening, are: antimony, arsenic, bis(2-ethylhexyl) phthalate, chromium, copper, lead, manganese, nickel, nitrate, silver, vinyl chloride, and zinc. The FS will include a risk assessment that evaluates the potential impacts, if any, from exposure to these chemicals on human health and the environment.

For each of the environmental media evaluated (groundwater, surface water, and freshwater sediment), the screening process described in this chapter establishes preliminary cleanup levels for specific chemicals. The "preliminary" terminology is used at this screening stage to acknowledge that "final" cleanup levels will be established in the Feasibility Study (FS) report, and is consistent with correspondence from Ecology (2002). It will be these final cleanup levels that will be used to the select an appropriate remedial alternative for the Site.

8.2 SELECTION OF GROUNDWATER CLEANUP LEVEL METHOD UNDER MTCA

8.2.1 Groundwater Non-Potability Evaluation

The regulations implementing MTCA, Chapter 173-340 WAC, require groundwater cleanup levels to be based on the highest beneficial use of the water under current and future conditions. The regulations presume that the highest beneficial use of groundwater at any site will be drinking water, per WAC 173-340-720(1). The initial step in establishing preliminary groundwater cleanup levels under MTCA is, therefore, to ascertain whether groundwater beneath the site should be classified as potable to protect drinking water beneficial uses, per WAC 173-340-720(2).

In order for groundwater to be classified as non-potable, all of the conditions in WAC 173-340-720(2) must be met. These criteria include current and potential use as a drinking water source, minimum yield rates to water wells, and acceptable groundwater quality. The evaluation for groundwater non-potability at the Site is summarized in Table 8-1.

The results of this analysis indicate that groundwater in the upper aquifer beneath the Site may be a potential future source of drinking water and, therefore, is classified as potable groundwater. The regulations do allow certain groundwater that is classified as a future drinking water source to be treated as non-potable for purposes of setting cleanup standards if the conditions in WAC 173-340-720(2)(d) are met. In essence, this section allows groundwater to be treated as non-potable if it is very close to surface water that is not suitable as a drinking water supply, for example, where the surface water is marine water. Because it is possible (though not likely) that the streams into which groundwater discharges here could be used as drinking water, further analysis under this section is not necessary. The scenario described in WAC 173-340-720(2)(d) does not apply at the Hansville Landfill Site.

8.2.2 Cleanup Level Method Evaluation

MTCA identifies three possible methods of selecting cleanup levels and the applicability of any one depends on the circumstances of the site. For the Site, Method B is the most appropriate as Methods A and C are not applicable. Method A cleanup levels are used at sites that have few hazardous substances and are either undergoing a routine cleanup action as defined in WAC 173-340-200 or at which there are numerical standards in either Chapter 173-340 WAC or applicable state or federal law available for all indicator hazardous substances found at the Site. The Hansville Landfill is not a routine cleanup situation, and there are no published standards for all chemicals of interest associated with the Site. Therefore, this is not a site at which Method A cleanup levels are appropriate. The one exception is application of the Method A cleanup level for arsenic in groundwater, which represents regional background for this chemical in Washington and is applied per Ecology direction.

The second possibility is that Method C cleanup levels apply. Under WAC 173-340-706(1)(a)(ii), Method C may be used when Method A or Method B cleanup levels are below area background concentrations, or where attainment of Method A or B cleanup levels has the potential for creating a "significantly greater overall threat to human health or the environment than attainment of Method C cleanup levels. . . ." Even if this test can be met, the property must also be an industrial property, per WAC 173-340-706(1)(b). Again, the Site does not meet this test.

Accordingly, the appropriate method for calculating cleanup levels at this Site is Method B, under WAC 173-340-705. Method B cleanup levels for potable groundwater are addressed in WAC 173-340-720(4)(b) which requires that cleanup levels shall be as stringent as all of the following:

(i) applicable federal and state laws;

(ii) protection of surface water beneficial uses; and

(iii) human health protection.

The applicable federal and state laws for groundwater are the federal Maximum Contaminant Levels (MCLs) for drinking water. The federal MCLs were adopted by the State of Washington in Chapter 246-290 WAC. It should be noted that secondary MCLs (which are aesthetic parameters) are considered in the Hansville Landfill RI for informational purposes only, because evaluation of alternatives designed to address chemicals exceeding only secondary MCLs are not required in the FS and cleanup actions addressing only those exceedances will not be required (Ecology 2004).

Protection of surface water beneficial uses requires application of Method B surface water cleanup levels, WAC 173-340-730, to potable groundwater, unless it can be demonstrated that the hazardous substances in groundwater are not likely to reach surface water, per WAC 173-340-720(4)(b)(ii). A detailed discussion questioning the technical applicability of surface water standards to groundwater is presented in a Memorandum entitled *Discussion of the Applicability of Surface Water Cleanup Standards to Groundwater* (Parametrix 2006). This Memorandum is presented in Appendix R of this RI report. Based on Ecology's response to the PLP Group opinion described in the Memorandum, the PLP Group has agreed to include preliminary surface water cleanup levels in the groundwater chemical screening process, per the requirements of WAC 173-340-720(4)(b)(ii).

The PLP Group also acknowledges that compliance with WAC 173-340-720(4)(b)(ii) for the Hansville Landfill Site will require meeting the off-site point-of-compliance provisions of WAS 173-340-720(8)(d)(ii) with respect to applying groundwater cleanup levels at the heads of the streams on Tribal Property. This scenario will be discussed in detail in the Feasibility Study.

Human health is protected by application of MTCA Method B Cleanup Levels, which are risk-based concentrations established using equations provided by Ecology.

8.3 CHEMICAL SCREENING PROCESS

8.3.1 Development of Preliminary Cleanup Levels and Chemical Screening Methodology

The initial step of the chemical screening process consisted of identifying potentially applicable state and federal laws (also known as Applicable or Relevant and Appropriate Requirements [ARARs]) that apply to groundwater, surface water, and sediment quality at the Site. The preliminary cleanup levels for each of the three environmental media were then established using the lowest ARAR for each chemical. This initial screening step is documented in an initial table for each medium (Tables 8-2a, 8-3a, and 8-4a).

A second screening table for each medium was created to compare preliminary cleanup levels to downgradient sampling results, background data (surface water and sediment), and frequency of detection criteria. Site-specific background data were technically not applied to the groundwater screening process because insufficient data were available to establish background per Ecology requirements. The exception was arsenic, for which a state background concentration was used for comparisons (Ecology 2004). These comparisons are shown in Tables 8-2b, 8-3b, and 8-4b. A summary of concentrations that exceeded screening criteria for each medium is presented in Appendix E.

The background concentrations for organic chemicals and metals that were not analyzed in background samples were assumed to be zero, which is a conservative approach for metals. For surface water, a range of background concentrations was obtained from two sampling events at adjacent drainages to the south (SW-17 through SW-20) and north (SW-15) of downgradient creeks, as discussed in Chapter 6. These background stations were selected, in coordination with Ecology and the Tribe, as having (1) the same basic characteristics as downgradient stations (headwaters of small streams originating as discharge from the Kitsap aquifer), (2) locations outside of any potential influence from Landfill releases, and (3) no apparent influence by releases from other localized human activities. Background sediment samples were collected in April 1997 from the same streams where background surface water was collected, using the same station selection criteria. Because the data for background surface water and background sediment is limited, a statistical background value was not calculated for each chemical, and downgradient samples were compared to the range of background concentrations.

Frequency of detection was also calculated for each chemical detected in groundwater and surface water. Those chemicals that were detected in less than 5 percent of downgradient samples were removed from consideration as potential indicator hazardous substances (Ecology 2002; US EPA 1989). Because fewer than 20 downgradient freshwater sediment samples were collected there was no possibility of a frequency of detection of 5 percent or less, so frequency of detection was not a screening factor for freshwater sediment.

Because water concentration units of mg/L were used in the screening evaluation, these units were also used in figures and tables throughout the report. Standardization was necessary since laboratory reports (Appendix P) and summary tables (Appendix B and C) report data in both mg/L and µg/L, MTCA cleanup levels are cited in units of µg/L, and other ARARs including MCLs are cited in units of mg/L.

8.3.2 Preliminary Cleanup Levels and Screening Results for Surface Water

The concentrations of chemicals detected in surface water were compared to water quality criteria from ten regulations, as shown in Table 8-2a. The regulations include the Port Gamble S'Klallam Tribe Water Quality Standards for Surface Water (PGST 2002) that were conditionally approved by EPA (2005). MTCA surface water cleanup levels were calculated using a fish consumption rate of 142.4 grams per person per day, a value taken from the Port Gamble S'Klallam Tribe Water Quality Standards for Surface Water (PGST 2002), as directed by Ecology. The screening process (Table 8-2b) identified the following chemicals in surface water for evaluation in the FS report: arsenic, copper, zinc, and vinyl chloride.

8.3.3 Preliminary Cleanup Levels and Screening Results for Groundwater

The concentrations of chemicals detected in groundwater were compared to water quality criteria from three regulations, as shown in Table 8-3a.

Consideration of the "cross-media contamination" provision for establishment of groundwater cleanup levels required examination of the data for groundwater discharge to surface water (Table 8-2b). As discussed in Section 8.2, the selected approach includes comparing groundwater to preliminary cleanup levels established for surface water. The resulting screening process (Table 8-3b) identified the following chemicals in groundwater for evaluation in the FS report: arsenic, bis(2-ethylhexyl)phthalate, copper, lead, manganese, nickel, nitrate, silver, zinc, and vinyl chloride.

8.3.4 Preliminary Cleanup Levels and Screening Results for Freshwater Sediment

The concentrations of chemicals detected in freshwater sediment were compared to water quality criteria from three potentially applicable State guidelines and laws, as shown in Table 8-4a. Specific regulatory levels for freshwater sediments have not been established; however, freshwater sediment quality levels (FSQVs) and lowest apparent effects thresholds (LAETs) have been published by Ecology as the best available scientific data for evaluating freshwater sediments (Cubbage et al. 1997; SAIC and Avocet 2003). In addition, MTCA Method B cleanup levels for soils (except MTCA Method A for arsenic and lead) were also considered as potentially applicable for sediment. The resulting screening process (Table 8-4b) identified the following chemicals in sediment for evaluation in the FS report: antimony, arsenic, chromium, manganese, nickel, and silver.

8.4 CHEMICAL SCREENING RESULTS

The chemical screening results are summarized by medium in Table 8-5. The following chemicals will be assessed in the FS report: antimony, arsenic, bis(2-ethylhexyl)phthalate, chromium, copper, lead, manganese, nickel, nitrate, silver, vinyl chloride, and zinc.

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Table 8-1. Summary of Non-Potable Groundwater Evaluation

Criterion	Applicable Subsection of Section (2)	Site Conditions	Meets Non-Potable Criterion?
Not a current source of drinking water, AND	(a)	Groundwater not currently used as drinking water downgradient of the Property.	Yes
Not a potential future source of drinking water, AND	(b)(i) *or*	The upper aquifer is sufficiently thick and permeable near the Property boundary to yield > 0.5 gallons per minute, the regulatory standard. However, this aquifer rapidly decreases in thickness on Tribal property and pinches out at the stream heads, which affects viability as a water supply.	No
	(b)(ii) *or*	Natural groundwater quality makes drinking water use impracticable ;	No
	(b)(iii)	The depth or location of the upper aquifer does not preclude the technical ability to withdraw groundwater from wells.	No
Unlikely for hazardous substances to be transported from the contaminated groundwater to a current or potential future source of water supply, AND	(c)	The potential exists, due to discharge of the upper aquifer to streams downgradient of the Landfill that flow on Tribal property. The Tribe reserves the option to use these streams as a source of water supply.	No
Extremely low probability that the groundwater will be used for drinking water, due to proximity to surface water that is unsuitable for water supply.	(d)	Not the case, as discussed above in (c).	No

Table 8-2a. Potentially Applicable State and Federal Laws and Preliminary Cleanup Levels for Surface Water (mg/L), Hansville Landfill

	Aquatic				Human Health									
Chemical	Freshwater Chronic Standard (SWQS)	USEPA Chronic Criterion for Aquatic Life[1]	WQS (freshwater chronic criteria)[11]	Lowest Aquatic Criteria	USEPA Human Health Criterion[2]	NTR - Human Health Criterion[3]	MTCA-B Surface Water (fish consumption)	MTCA [4](Tribal surface water)	MTCA-B Groundwater (ingestion)	USEPA MCL (ingestion)	WQS (human health, water and organisms)	Lowest Human Health Criteria	Preliminary Cleanup Level	Method Detection Limit (MDL) [10]
METALS														
Antimony	none	none	none	none	0.0056	0.014	1.04	0.39	0.0064	0.006	0.013	0.0056	0.0056	0.001
Arsenic	0.19	0.15	0.15 [6]	0.15	0.000018	0.000018	0.0000982	0.000037	0.0000583	0.01	0.000005 [7]	0.000005	0.000005	0.00005
Barium	none	none	none	none	1	none	none	none	3.2	2	none	1	1	0.003
Cadmium	0.000369	0.000094	0.00025	0.000094	none	none	0.0203	0.00135	0.008	0.005	none	0.00135	0.000094	0.0005
Calcium	none	none	none	none	none	none	none	none	none	none	none	none	none	0.1
Chromium	0.01 [8]	0.0238	0.011 [8]	0.01	none	none	0.486	0.184	0.048	0.1	none	0.1	0.01	0.006
Copper	0.00347	0.00274	0.009	0.00274	1.3	none	2.66	1.01	0.592	1.3	none	0.59200	0.00274	0.001
Iron	none	none	1	1	0.3	none	none	none	none	0.3 [5]	0.3	0.3 [5]	0.3 [5]	0.005
Lead	0.000541	0.000541	0.0025	0.000541	none	none	none	none	none	0.015	none	0.015	0.000541	0.001
Magnesium	none	none	none	none	none	none	none	none	none	none	none	none	none	0.1
Manganese	none	none	none	none	0.05	none	none	none	2.24	0.05 [5]	0.05	2.24 / 0.05 [5]	2.24 / 0.05 [5]	0.0005
Mercury	0.000012	0.00077	0.00077	0.000012	none	0.00014	none	none	0.0048	0.002	0.000002	0.000002	0.000002	0.0002
Nickel	0.049	0.016	0.052	0.016	0.61	0.61	1.10	0.418	0.32	0.1	0.16	0.100	0.016	0.005
Potassium	none	none	none	none	none	none	none	none	none	none	none	none	none	1
Selenium	0.005	0.005	0.005	0.005	0.170	none	2.7	1.024	0.08	0.05	none	0.05	0.005	0.001
Silver	0.00032 [9]	0.00030	0.0034	0.00030	none	none	25.9	9.831	0.08	0.1 [5]	none	0.1 [5]	0.0003 / 0.1 [5]	0.0001
Sodium	none	none	none	none	none	none	none	none	none	none	none	none	none	0.5
Thallium	none	none	none	none	0.00024	0.0017	0.00156	0.00059	0.00112	0.002	0.00025	0.00024	0.00024	0.001
Zinc	0.032	0.036	0.12	0.032	7.4	none	16.5	6.275	4.8	5.0 [5]	none	5.0 [5]	0.032 / 5.0 [5]	0.002
CONVENTIONALS														
Ammonia	none	none	none	none	none	none	none	none	none	none	none	none	none	0.005
Chloride	none	none	230	230	none	none	none	none	none	250 [5]	none	250 [5]	250 [5]	1
Nitrate-N	none	none	none	none	none	none	none	none	25.6	10	10	10	10	0.01
Sulfate	none	none	none	none	none	none	none	none	none	250 [5]	none	250 [5]	250 [5]	not reported
VOLATILE ORGANICS														
1,1-Dichloroethane	none	none	none	none	none	none	none	none	0.8	none	none	0.8	0.8	0.001
1,2-Dichloroethene	140	none	none	140	none	none	33	none	0.080-0.160	0.070-0.100	0.63	0.070-0.100	0.070-0.100	0.001
Carbon disulfide	none	none	none	none	none	none	none	none	0.8	none	none	0.8	0.8	0.001
Chloroform	none	none	none	none	0.0057	0.0057	0.28	0.283	0.00717	0.08	0.0045	0.0045	0.0045	0.001
Methylene chloride	none	none	none	none	0.0046	0.0047	0.96	0.364	0.005	0.005	0.0044	0.0044	0.0044	0.001
Phenol	none	none	none	none	21	21	1,110	421	4.8	none	19	4.8	4.8	0.002
Trichlorofluoromethane	none	none	none	none	none	none	none	none	2.4	none	none	2.4	2.4	0.001
Vinyl chloride	none	none	none	none	0.000025	0.002	0.00369	0.0014	0.000029	0.002	0.0019	0.000025	0.000025	0.00001
SEMIVOLATILE ORGANICS														
bis(2-ethylhexyl)phthalate	none	none	none	none	0.0012	0.0018	0.0036	none	0.0063	0.006	0.00024	0.00024	0.00024	0.002
Diethyl phthalate	none	none	none	none	17	23	28	none	12.8	none	4.5	4.5	4.5	0.002

[1] Chronic criteria are from USEPA (2004a), assumes 25 mg/L hardness for hardness-dependent metals criteria.
[2] Human health criteria for consumption of water and organisms (USEPA 2004a).
[3] Values shown are applicable criteria for water supply (domestic) for Washington State, as identified in 40 CFR, Section 131.36 (7-1-03 Edition).
[4] These values represent MTCA method B surface water cleanup levels based on a tribal consumption rate of 142.4 grams/day rather than the default 54 grams/day.
[5] Value represents a secondary MCL based on aesthetics instead of ingestion.
[6] Criteria refer to trivalent form only
[7] Criteria refer to inorganic form only
[8] Cr (VI)
[9] Acute criteria
[10] Lowest Method Detection Limit (MDL) for groundwater from Hansville Database.
[11] Aquatic life criteria approved by EPA subject to completion of consultation under Endangered Species Act.

MTCA = Model Toxics Control Act (Chapter 173-340 WAC); Method B values were used for all chemicals except lead, for which Method A was used in the absence of a Method B value.
SWQS = Surface Water Quality Standard (Chapter 173-201A WAC), assumes 25 mg/L hardness for hardness-dependent metals criteria (minimum hardness measured at all stations).
WQS = Port Gamble S'Klallam Tribe Water Quality Standards for Surface Waters; dissolved metals values are a function of total hardness and correspond to a hardness of 100 mg/L.

Table 8-2b. Summary of Chemical Screening for Surface Water, Hansville Landfill

Chemical[1]	Preliminary Cleanup Level (PCL), (mg/L)	Method Detection Limit (MDL)	Number of Downgradient Samples > Preliminary Cleanup Level [Data Range in ( )]	Background Concentration (mg/L)	Number of Downgradient Samples > Preliminary Cleanup Level and > Background[2]	Frequency of Detection (FOD) (%)	Downgradient Samples > Preliminary Cleanup Level and > Background and FOD > 5%?	Comments
METALS								
Antimony	0.0056	0.001	none	not available	none	21.9	no	No samples > screening criteria
Arsenic	0.000005	0.00005	113 (0.00021-0.0057)	0.00021 to 0.0032	11	99.1	yes	11 samples > PCL & Background
Barium	1	0.003	none	not available	none	100	no	No samples > screening criteria
Cadmium	0.000094	0.0005	none	all <0.0005	none	13.3	no	No samples > screening criteria
Chromium	0.01	0.006	none	<0.001 to 0.004	none	6.7	no	No samples > screening criteria
Copper	0.00274	0.001	19 (0.003-0.011)	<0.001 to 0.005	3	21.4	yes	3 samples > PCL & Background
Iron	0.3 [3]	0.005	7 (0.31-0.64)	<0.005 to 0.54	1	78.9	no	1 sample > secondary MCL and background
Lead	0.000541	0.001	5 (0.001-0.007)	<0.001 to 0.002	2	3.8	no	FOD ≤ 5%
Manganese	2.24 / 0.05 [3]	0.0005	none / 5 (0.1-0.2)	<0.0005 to 0.013	none / 5	92.1	no	5 samples > secondary MCL
Mercury	0.000002	0.0002	1 (0.0004)	all <0.0002	1	4.2	no	FOD ≤ 5%
Nickel	0.016	0.005	none	all < 0.017	none	0.0	no	No samples > screening criteria
Selenium	0.005	0.001	none	not available	none	5.6	no	No samples > screening criteria
Silver	0.0003 / 0.1 [3]	0.0001	none	not available	none	26.7	no	No samples > screening criteria
Thallium	0.00024	0.001	2 (0.001)	not available	2	3.1	no	FOD ≤ 5%
Zinc	0.032 / 5.0 [3]	0.002	3 (0.04-0.089) / none	<0.001 to 0.007	3 / none	88.2	yes	3 samples > PCL & Background
CONVENTIONALS								
Chloride	250 [3]	1	none	not available	none	100	no	No samples > screening criteria
Nitrate-N	10	0.01	none	0.23 - 2.0	none	91.1	no	No samples > screening criteria
Sulfate	250 [3]	not reported	none	not available	none	100	no	No samples > screening criteria
VOLATILE ORGANICS								
1,1-Dichloroethane	0.08	0.001	none	not available	none	0.0	no	No samples > screening criteria
1,2-Dichloroethene	0.070-0.100	0.001	none	not available	none	0.0	no	No samples > screening criteria
Carbon disulfide	0.8	0.001	none	not available	none	1.2	no	No samples > screening criteria
Chloroform	0.0045	0.001	none	not available	none	0.0	no	No samples > screening criteria
Methylene chloride	0.0044	0.001	none	not available	none	1.2	no	No samples > screening criteria
Phenol	9.6	0.002	none	not available	none	3.2	no	No samples > screening criteria
Vinyl chloride	0.000025	0.001	42 (0.00003 - 0.00048)	not available	42	24.7	yes	42 samples > screening criteria
SEMIVOLATILE ORGANICS								
bis(2-ethylhexyl)phthalate	0.00024	0.002	none	not available	none	0.0	no	No samples > screening criteria
Diethyl phthalate	4.5	0.002	none	not available	none	0.0	no	No samples > screening criteria

[1] This table includes all chemicals that were detected in one or more downgradient samples and for which a preliminary cleanup level was identified.
(SW-08, SW-09, and SD-SW are not downgradient sampling locations.)
[2] Background surface water samples collected at SW-15,SW-17B, SW-18, SW-19, and SW-20 in November 2002.
[3] Value represents a secondary MCL; chemicals that exceed the secondary MCL do not need to be addressed in the Feasibility Study (Ecology 2004) .

[box] **Chemical to be evaluated in the FS report**

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Table 8-3a. Potentially Applicable State and Federal Laws and Preliminary Cleanup Levels for Groundwater (mg/L), Hansville Landfill

Chemical	Surface Water Preliminary Cleanup Level [1]	MCL (Drinking Water)	MTCA Method B (Groundwater Quality)	Preliminary Cleanup Level	Method Detection Limit (MDL) [2]
METALS					
Antimony	0.0056	0.006	0.0064	0.0056	0.001
Arsenic	0.000005	0.01	0.005 [3]	0.000005	0.00005
Barium	1	2	3.2	1	0.003
Cadmium	0.000094	0.005	0.008	0.000094	0.0005
Calcium	none	none	none	none	0.1
Chromium	0.01	0.1	0.048	0.01	0.006
Copper	0.00274	1.3	0.592	0.00274	0.001
Iron	0.3 [5]	0.3 [5]	none	0.3 [5]	0.005
Lead	0.000541	0.015	none	0.000541	0.001
Magnesium	none	none	none	none	0.1
Manganese	2.24 / 0.05 [5]	0.05 [5]	2.24	2.24 / 0.05 [5]	0.0005
Mercury	0.000002	0.002	0.0048	0.000002	0.0002
Nickel	0.016	0.1	0.32	0.016	0.01
Potassium	none	none	none	none	1
Selenium	0.005	0.05	0.08	0.005	0.001
Silver	0.0003 / 0.1 [5]	0.1 [5]	0.08	0.0003 / 0.1 [5]	0.0001
Sodium	none	none	none	none	0.5
Thallium	0.00024	0.002	0.00112	0.00024	0.001
Zinc	0.032 / 5.0 [5]	5 [5]	4.8	0.032 / 5.0 [5]	0.002
CONVENTIONALS					
Ammonia-N	none	none	none	none	0.005
Chloride	250 [5]	250 [5]	none	250 [5]	1
Nitrate-N	10	10	25.6	10	0.01
Sulfate	250 [5]	250 [5]	none	250 [5]	not reported
VOLATILE ORGANICS					
1,1-Dichloroethane	0.8	none	0.8	0.8	0.001
1,2-Dichloroethylene	0.070-0.100	0.070-0.100	0.080-0.160	0.070-0.100	0.001
Chloroform	0.0045	0.08	0.00717	0.0045	0.005
Methylene Chloride	0.0044	0.005	0.00583	0.0044	0.001
Trichlorofluorometha	2.4	none	2.4	2.4	0.001
Vinyl Chloride	0.000025	0.002	0.000029	0.000025	0.00001
SEMIVOLATILE ORGANICS					
bis(2-ethylhexyl)phth	0.00024	none	0.00625	0.00024	0.002
Diethyl phthalate	4.5	none	12.8	4.5	0.002

[1] Surface water PCL from Table 8-2a.
[2] Lowest Method Detection Limit (MDL) for groundwater from Hansville Database.
[3] MTCA Method A cleanup level used for arsenic, per Department of Ecology policy (Ecology 2004).
[4] Federal MCL and MTCA B represent range of "cis" and "trans" isomers.
[5] Value represents a secondary MCL based on aesthetics instead of ingestion.
MCL = Maximum Contaminant Level (Chapter 246-290 WAC)
MTCA = Model Toxics Control Act (Chapter 173-340 WAC)

Table 8-3b. Summary of Chemical Screening for Groundwater, Hansville Landfill

Chemical[1]	Preliminary Cleanup Level (PCL) (mg/L)	Method Detection Limit (MDL)	Number of Downgradient Samples > Preliminary Cleanup Level [Data Range in ( )]	Background Concentration (mg/L) [2]	Number of Downgradient Samples > Preliminary Cleanup Level and > Background	Frequency of Detection (%)	Downgradient Samples > Preliminary Cleanup Level and > Background and FOD > 5%?	Comments
METALS								
Antimony	0.0056	0.001	1 (0.008)			3.8	no	Low frequency of detection
Arsenic	0.000005	0.00005	177 (0.00012-0.037)	0.005	48	96.7	**yes**	48 samples > PCL and background
Barium	1	0.003	none			98.2	no	No samples > screening criteria
Cadmium	0.000094	0.0005	none			0.0	no	No samples > screening criteria
Chromium	0.01	0.006	none			0.0	no	No samples > screening criteria
Copper	0.00274	0.001	38 (0.003 - 0.035)			29.1	**yes**	38 samples > PCL
Iron	0.3 [4]	0.005	30 (0.32-2.9)			62.6	no	PCL is aesthetic secondary MCL
Lead	0.000541	0.001	14 (0.001-0.01)			7.7	**yes**	14 samples > PCL
Manganese	2.24 / 0.05 [4]	0.0005	33 / 106 (2.2-13) / (0.06-13)	o be evaluated in the FS report		83	**yes**	33 samples > MTCA B
Mercury	0.000002	0.0002	none			3.8	no	No samples > screening criteria
Nickel	0.016	0.01	19 (0.02-0.08)			24	**yes**	19 samples > PCL
Selenium	0.005	0.001	none			9.6	no	No samples > screening criteria
Silver	0.0003 / 0.1 [4]	0.0001	5 (0.0004-0.0008)			15.4	**yes**	5 samples > PCL
Thallium	0.00024	0.001	1 (0.002)			1.0	no	Low frequency of detection
Zinc	0.032 / 5.0 [4]	0.002	3 (0.04 - 0.08)			87.5	**yes**	3 samples > PCL
CONVENTIONALS								
Chloride	250 [4]	1	7 (260-470)			97	no	PCL is aesthetic secondary MCL
Nitrate-N	10	0.01	8 (11-18)			67	**yes**	8 samples > PCL
Sulfate	250 [4]	not reported	none			100	no	No samples > screening criteria
VOLATILE ORGANICS								
1,1-Dichloroethane	0.8	0.001	none			18.4	no	no samples > screening criteria
1,2-Dichloroethylene[3]	0.070-0.100	0.001	none			7	no	no samples > screening criteria
Chloroform	0.0045	0.005	none			4.2	no	no samples > screening criteria
Methylene Chloride	0.0044	0.001	none			3.5	no	no samples > screening criteria
Trichlorofluoromethane	2.4	0.001	none			3.5	no	no samples > screening criteria
Vinyl Chloride	0.000025	0.00001	87 (0.00004-0.011)			39.1	**yes**	87 samples > PCL
SEMIVOLATILE ORGANICS								
bis(2-ethylhexyl)phthalate	0.00024	0.002	2 (0.0034 - 0.0042)		2	7.1	**yes**	2 samples > PCL
Diethyl phthalate	4.5	0.002	none			3.6	no	no samples > screening criteria

[1] This table includes all chemicals that were detected in one or more downgradient samples and for which a preliminary cleanup level was identified.

[2] Method A cleanup level for arsenic represents state background of natural arsenic, per Department of Ecology policy (Ecology 2004).

[3] Federal MCL and MTCA B represent range of "cis" and "trans" isomers.

[4] Value represents a secondary MCL ; chemicals that exceed the secondary MCL, do not need to be addressed in the Feasibility Study (Ecology 2004).

MCL = Maximum Contaminant Level (Chapter 246-290 WAC)   MTCA = Model Toxics Control Act (Chapter 173-340 WAC)

[boxed] **Chemical to be evaluated in the FS report**

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Table 8-4a. Potentially Applicable State Guidelines, Laws, and Preliminary Cleanup Levels for Sediment (mg/kg), Hansville Landfill

Chemical	Freshwater Sediment Quality Value [1]	Lowest Apparent Effects Threshold [2]	MTCA Cleanup Level (soil)	Preliminary Cleanup Level (mg/kg)
METALS				
Antimony	none	0.6	32	0.6
Arsenic	57	31.4	20	20
Barium	none	none	5,600	5,600
Beryllium	none	0.46	160	0.46
Cadmium	5.1	2.39	80	2.39
Chromium	260	95	240	95
Copper	390	619	2,960	390
Lead	450	335	250	250
Manganese	none	1,800	11,200	1,800
Mercury	0.41	0.8	24	0.41
Nickel	none	53.1	1,600	53.1
Selenium	none	none	400	400
Silver	6.1	0.545	400	0.545
Thallium	none	none	5.6	5.60
Zinc	410	683	24,000	410

[1] Freshwater Sediment Quality Values from Cubbage et al. 1997
[2] Lowest Apparent Effect Thresholds (LAETs) from Ecology (2003), except manganese from Cubbage et al. (1997).

MTCA = Model Toxics Control Act (Chapter 173-340 WAC). MTCA soil cleanup levels were applied per Ecology requirements.
MTCA Method B soil cleanup levels are used for all metals except arsenic and lead, to which MTCA Method A cleanup levels were applied (per Ecology requirements).

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Table 8-4b. Summary of Chemical Screening Results for Freshwater Sediment, Hansville Landfill

Chemical[1]	Preliminary Cleanup Level (mg/kg)	Number of Downgradient Samples > Preliminary Cleanup Level [2] [Data Range in ( )]	Background Concentrations (mg/kg)[3]	Downgradient Samples > Preliminary Cleanup Level and > Background ?	Comments
METALS					
Antimony	0.6	three samples (0.9-13)	<0.25 to <2.4	yes	1 sample > preliminary cleanup level and > background
Arsenic	20	one sample (28)	2.1 to 11	yes	1 sample > preliminary cleanup level and > background
Barium	5,600	none	46 to 83	no	No samples > preliminary cleanup level
Beryllium	0.46	none	0.07 to <0.5	no	No samples > preliminary cleanup level
Cadmium	2.39	none	<0.27 to <2.4	no	No samples > preliminary cleanup level
Chromium	95	one sample (310)	19 to 120	yes	1 sample > preliminary cleanup level and > background
Copper	390	none	2.3 to 39	no	No samples > preliminary cleanup level
Lead	250	none	3.6 to 25	no	No samples > preliminary cleanup level
Manganese	1,800	two samples (2700-4100)	220 to 890	yes	2 samples > preliminary cleanup level and > background
Mercury	0.41	none	<0.04 to <0.2	no	No samples > preliminary cleanup level
Nickel	53.1	one sample (54)	16 to 37	yes	Triplicate samples SD-10a,b,c all < screening criterion
Selenium	400	none	<0.25 to <1.2	no	No samples > preliminary cleanup level
Silver	0.545	two samples (0.55-1.5)	<0.02 to 0.6	yes	1 sample > preliminary cleanup level and > background
Thallium	5.60	none	<0.24 to <2.4	no	No samples > preliminary cleanup level
Zinc	410	none	5.5 to 95	no	No samples > preliminary cleanup level
VOLATILE ORGANICS					
Methylene Chloride	133	none	not available	no	No samples > preliminary cleanup level

[1] This table includes all chemicals that were detected in one or more downgradient samples and have preliminary cleanup levels.
SD-08, SD-09, SD-11 through SD-16, and SD-SB are not downgradient sampling locations.
[2] Multiple replicated samples > preliminary cleanup level are only counted as one occurrence.
[3] Background samples were collected at Stations SD-11, SD-12, SD-14, SD-15, and SD-16 in April 1997.

[Boxed] **Chemical to be evaluated in the FS report**

Table 8-5. Chemicals from the Screening Process to be Evaluated in the Feasibility Study, Hansville Landfill RI

Chemicals Carried into the Feasibility Study	Groundwater	Surface Water	Sediment
Antimony			X
Arsenic	X	X	X
Bis(2-ethylhexyl)phthalate	X		
Chromium			X
Copper	X	X	
Lead	X		
Manganese	X		X
Nickel	X		X
Nitrate	X		
Silver	X		X
Vinyl Chloride	X	X	
Zinc	X	X	

9. CHEMICAL FATE AND TRANSPORT EVALUATION

9.1 PURPOSE AND OBJECTIVES

The purpose of the fate and transport evaluation is to describe the behavior of chemicals originating from waste disposal areas at the Landfill during their migration from primary and secondary sources to potential receptors along pathways that exist at the Site. This section describes the conceptual site model, the distribution of chemicals, and chemical fate along migration pathways.

9.2 CONCEPTUAL SITE MODEL

The conceptual site model for the Site (Figure 9-1) describes the occurrence and migration of chemicals from the source areas at the Landfill to potential human health and ecological receptors. It should be noted that the conceptual site model does not differentiate between pre- and post-closure conditions at the Landfill. While the potential contaminant sources and release mechanisms are described for both pre-closure and post-closure conditions, some of the source and release mechanisms have been significantly reduced or eliminated by the source control activities (landfill closure, engineered cap, and landfill gas extraction and flaring system) already constructed at the Landfill.

9.2.1 Primary Contaminant Sources

There are three potential primary contaminant sources at the Landfill: the solid waste disposal area, the septage disposal area, and the demolition waste disposal area. The history and types of materials disposed in these locations are described in Chapter 2, Current Property Features and Conditions, and Chapter 3, Waste Source Investigation. These three disposal areas of the Landfill received mixed municipal solid waste, septic tank pumpings, and demolition waste, respectively. Waste disposal occurred at the Landfill from 1962 through June 1989, as described in Chapter 3.

9.2.2 Release Mechanisms for Primary Contaminant Sources

In general there are three primary release mechanisms for potential transport of chemicals from the primary contaminant sources, these include: landfill leachate, landfill gas, and surface water runoff. Each of these potential mechanisms is described below.

9.2.2.1 Infiltration/Leachate Production

Leachate is formed at waste disposal areas through contact of waste with water by means of the following mechanisms: precipitation on exposed waste materials during active filling operations; infiltration into buried waste materials; contact of buried waste materials with groundwater; and downward percolation of water contained in the waste materials (especially septage waste, which contains a high percentage of water). Leachate was most likely formed during the operation of the Landfill by all of these mechanisms except contact with groundwater, since the bottom of the landfill materials is not in contact with groundwater.

Leachate is generally comprised of a variety of organic and inorganic compounds leached from the waste within a landfill as precipitation percolates downward through the waste fill. As infiltrating water percolates within a typical solid waste landfill, the most mobile chemical elements, such as chloride, sodium, nitrate, and potassium, are dissolved from the waste into the leachate. Oxygen in the air and in the percolating water chemically degrades some of the organic matter into weak acids. These acids can dissolve additional chemical constituents from the waste material, and can dissolve minerals in the soils in contact with the landfill and soils used within the landfill itself (daily and intermediate cover material).

Once the oxygen in the water and air within a landfill has been chemically used up by aerobic decomposition, anaerobic conditions occur. Under anaerobic conditions, methane, carbon dioxide, and hydrogen sulfide, as well other intermediate degradation compounds, are produced within the waste. These intermediate compounds and other organic compounds result in high concentrations of organic materials in the leachate. Leachate at this stage is characterized by high biological and chemical oxygen demand. Metals that are normally immobile can be released to leachate at this stage. Migration of leachate through the vadose zone and into groundwater may also result in the mobilization of some metals from the natural soils and the aquifer matrix.

The mechanisms for transfer of VOCs (such as vinyl chloride) in landfill gas to groundwater is briefly described in Section 4.2.3, Potential for Groundwater Contamination and Section 9.2.2.2, Landfill Gas. These transfer mechanisms can also occur from contact of landfill gas and the liquid leachate within a landfill.

After disposal ceased at the Hansville Landfill, an engineered cover system was installed in 1989 over the on-site disposal areas (solid waste, demolition waste, and septage waste). This cover system was designed to at least meet the requirements of Chapter 173-304 WAC and to achieve a 99% reduction of infiltration and greatly reduce infiltration of precipitation and generation of leachate at the Landfill (see Sections 2.2.1.3, Description of Final Cover System, and 5.4.6, Estimates of Leachate Generation). It should be noted that a 60 ml HDPE liner was used to close the Landfill which exceeded the MFS requirement of 50 ml. Gravity drainage of leachate within the waste disposal areas will continue at a decreasing rate over time, until drainable moisture is exhausted, as discussed below in Section 9.2.3, Secondary Contaminant Sources.

The leachate generation predictions from the disposal areas at the Landfill, generated using the Hydrologic Evaluation of Landfill Performance (HELP) model, provide an estimate of potential infiltration and leachate generation. While the HELP model is reasonably accurate, the use of a geomembrane in the cover system at the Landfill introduces an inherent uncertainty. The HELP model requires an assumed number of geomembrane flaws, pinhole density, and liner placement quality, all of which are subjective input to the model. The HELP model also does not account for the consumption of water by biological processes in a municipal landfill, which may diminish the volume of infiltration that is actually available for leachate production (EPA 1994a).

Once a designed geomembrane cap/cover system is placed on a closed landfill, it becomes effective in reducing infiltration into the landfill, thus reducing the generation of leachate. As noted above, the designed capping system installed over the three disposal areas at the Hansville Landfill is anticipated to provide 99% reduction in infiltration over that of an uncapped disposal area. However, residual leachate saturation within the disposal areas will continue to drain over a number of years until a steady-state condition is reached.

Estimates of post-closure leachate generation can be checked at landfills with leachate collection systems to compare actual measurements with model projections. Although the Hansville Landfill does not have such a system, a post-closure leachate evaluation prepared by Parametrix for the Inman Road Landfill in Skagit County provides useful insights. A geomembrane cap was installed at the Inman site in 1993 and the leachate generation rate was predicted to decrease to 15% of the pre-closure amount in the first 5 years (Parametrix 1992).

Since this landfill has a bottom liner, verification of the modeling was possible, and the landfill operator reports that the leachate volume is tracking with the model (Arndt 1997).

A similar gradual reduction in leachate generation for the Landfill was expected following completion of closure and capping in 1988/1989, with leachate volumes reaching their ultimate steady-state values over a period of approximately 15 years (see Figure 5-15). In an attempt to determine if residual leachate could be detected and sampled within the solid waste disposal area, soundings were taken in the in-refuse gas extraction wells in 1992 and in early November 1997. These wells penetrate approximately 80% to 90% of the depth of refuse. However, no leachate was detected in the gas extraction wells in either attempt. Therefore, no leachate sampling data were obtained for the RI.

9.2.2.2 Landfill Gas

As described in Chapter 4, Landfill Gas Investigation, landfill gas is formed by the decomposition of municipal refuse. Landfill gas is principally generated in the 13-acre solid waste disposal area of the Landfill, and to a much lesser extent in the demolition waste and septage waste disposal areas. This is confirmed by the monitoring of gas probes at the Landfill, which have historically detected landfill gas only in the immediate vicinity of the solid waste disposal area. Landfill gas is primarily composed of methane and carbon dioxide in typical proportions of 55% and 40%, respectively, and can include VOCs present in the waste materials or produced through the natural decomposition of waste materials (see Figure 4-1). Vinyl chloride, a VOC, is a chemical identified in landfill gas at the Landfill.

Landfill gas that migrates through the vadose zone may contact groundwater. The dissolution of vinyl chloride in groundwater occurs in accordance with Henry's Law and is a function of the concentration of vinyl chloride in the gas, the gas pressure at the groundwater surface, and the existing concentration of vinyl chloride in the groundwater. As an example, at sites studied by Prosser and Janechek (1995), a landfill gas vinyl chloride concentration of 1 part per million by volume (ppmv) at atmospheric pressure, was found to result in an equilibrium concentration of vinyl chloride in groundwater of 0.0058 mg/L.

The concentration of vinyl chloride detected in the August 1996 VOC sampling of the landfill gas at the flare facility at the Landfill was 0.46 ppmv, and the highest detected concentration of vinyl chloride during the four RI groundwater sampling events was 0.011 mg/L at monitoring well MW-6, adjacent to the solid waste disposal area. The comparable proportions of vinyl chloride in landfill gas and groundwater observed in the Hansville data and the Prosser and Janechek study indicate that contact of landfill gas with groundwater is a potential mechanism for introduction of vinyl chloride into groundwater at the Landfill.

Prior to the installation of the landfill gas extraction and flaring system at the Landfill, landfill gas had migrated into the vadose zone under and around the solid waste disposal area. This provided a potential source of vinyl chloride to groundwater through direct contact with landfill gas. However, the operation of the active landfill gas extraction and flaring system significantly reduced or eliminated the direct contact of landfill gas with groundwater.

The monitoring of gas probes and gas extraction wells during the RI study period indicates that landfill gas migration beyond the footprint of the solid waste disposal area is unlikely while the landfill gas extraction and flaring system is operating (see Chapter 4, Landfill Gas Investigation). However, it is possible that the presence of vinyl chloride in groundwater may be at least partially attributable to a combination of direct contact of landfill gas with groundwater directly beneath the Landfill, as well as residual leachate drainage within the solid waste disposal area and secondary sources/release mechanisms discussed in the following sections.

9.2.2.3 Surface Water Runoff

During the operation of the Landfill, surface water runoff from exposed disposal areas flowed down slope from these areas. Given the high permeability of the sandy surficial soils, some of this overland flow from the disposal areas likely infiltrated into the ground. Surface water runoff from exposed waste was eliminated when the Landfill was capped in 1989.

9.2.3 Secondary Contaminant Sources

Secondary contaminant sources are potential contaminant sources outside of the envelope of the three disposal areas (primary contaminant sources). In general, they are the result of potential past contaminant releases from the primary contaminant source.

The conceptual model for the Site (see Figure 9-1) identifies two principal secondary contaminant sources: one related to historical leachate percolation and the other related to landfill gas. Secondary sources related to leachate percolation apply to all three disposal areas at the Landfill and secondary sources related to landfill gas apply only to the solid waste disposal area.

9.2.3.1 Leachate Related Secondary Contaminant Sources

Soils in the unsaturated (vadose) zone beneath each of the three disposal areas at the Landfill received percolating leachate during the operational life of the Landfill. After the three disposal areas at the Landfill were capped, leachate production decreased and continues to decrease, as discussed in Section 9.2.2.1.

As the leachate percolated through the vadose zone beneath each disposal area during operation of the Landfill, organic and inorganic chemicals within the leachate would have partitioned between the liquid, solid, and gas phases, depending upon the physical properties of the chemical, the mineralogy of the soil (in particular the organic carbon content), and the geochemical conditions (reducing or oxidizing). Subsequent infiltration may have desorbed some of the chemicals from the solid phase and/or mixed with residual leachate in the pore water.

9.2.3.2 Landfill Gas Related Secondary Contaminant Sources

If landfill gas migrates into the soils surrounding or beneath a landfill, chemicals within the gas can be transferred into the soil matrix. Even though the landfill gas is removed from the soil column by an active gas extraction system (as with the Landfill), chemicals can remain behind in the soil. This may provide a potential secondary contaminant source.

9.2.4 Release Mechanisms for Secondary Contaminant Sources

9.2.4.1 Residual Leachate in the Vadose Zone

Residual leachate from historical leachate percolation, likely to be present in the vadose zone beneath the three on-site disposal areas, was identified as a potential secondary source of groundwater contamination at the Landfill. As leachate percolates through the vadose zone beneath a disposal area, a portion of the dissolved contaminants in the leachate are retained in the soils (adsorbed) through one of several mechanisms. These mechanisms include physical, chemical, and exchange processes. Of these three mechanisms, chemical and exchange processes tend to be more permanent and less likely to result in the future release of the contaminant, whereas physical adsorption is reversible with a decrease in concentration, and the material is desorbed to the same extent that it was originally adsorbed (Sawyer and McCarty 1978).

VOCs can also be released into the vadose zone from leachate residual. If the concentration of a particular VOC in the soil pore air decreases compared with the initial condition, the VOC will try to re-attain equilibrium between the gas and liquid phase by moving out of the liquid phase. Movement of the VOC away from the residual is controlled by diffusion and pressure-driven gradients (advection) in the vadose zone soil gas.

9.2.4.2 Anaerobic Condition Resulting From Leachate Percolation

The biological decomposition of leachate as it percolates through the vadose zone beneath the disposal areas at the Landfill tends to consume the oxygen that would be available in the vadose zone. Additionally, the Landfill cover system prevents the infiltration and percolation of surface water that would normally be saturated with oxygen and would tend to maintain aerobic conditions in the groundwater.

Changes from aerobic to anaerobic conditions affect the redox state of the soil/water system. In particular, metals that may form relatively insoluble complex oxides and hydroxides under oxidizing conditions (such as iron and manganese) are converted to more soluble ferrous and manganous hydroxides under reducing conditions. The result is that naturally occurring metals may be leached from the vadose and saturated zones, resulting in elevated concentrations of these metals in groundwater. The correlation between low dissolved oxygen in the groundwater and high concentrations of manganese is demonstrated at several wells within the RI Study Area, including MW-6, MW-8, MW-8D, MW-12I, MW-13D, and MW-14.

9.2.4.3 Landfill Gas Condensate

Landfill gas is generated within a landfill as a result of the decomposition of organic matter under anaerobic conditions. This decomposition process results in the generation of heat, and the temperature within a landfill typically ranges from 80 to over 100° F. The landfill gas becomes saturated with water vapor at this temperature. As the gas migrates outside the limits of a landfill, where the temperature is generally cooler, the gas releases condensate into the soil pore spaces. This condensate, which includes VOCs at concentrations approaching equilibrium with concentrations in landfill gas, can migrate to groundwater.

The monitoring of gas probes and gas extraction wells at the Hansville Landfill indicates that landfill gas is no longer migrating beyond the Landfill, thus eliminating the production of condensate outside the Landfill.

9.2.4.4 Landfill Gas Contamination of Vadose Zone

Landfill gas migration in the vicinity of the solid waste disposal area at the Landfill has occurred in the past. Concentrations measured in gas wells immediately adjacent to the solid waste disposal area in 1991, just prior to startup of the active gas extraction and flaring system, showed methane concentrations approaching 80% by volume (N-1D). Methane concentrations at perimeter gas probes, located 100 to 200 ft from the solid waste disposal area, ranged to just over 20% methane.

As landfill gas migrated beyond the boundaries of the solid waste (including beneath the disposal area), it likely came into contact with residual soil moisture. Assuming that sufficient contact time was provided, the VOCs in the landfill gas would have come to equilibrium with this soil moisture in accordance with Henry's Law. As discussed in Section 9.2.2.2, Primary Contaminant Sources/Landfill Gas, the equilibrium concentration of VOCs in the soil pore water is a function of partial pressure and solubility. In addition, as the landfill gas migrates through the soil, VOCs can adhere directly to the soil matrix in either the vapor or liquid phase. As rainwater or other liquids (leachate) infiltrate and percolate through the soil, they reach equilibrium with the VOCs present in the soil and may eventually reach groundwater (Prosser and Janechek 1995).

9.2.4.5 Carbonic Acid from Landfill Gas and Oxygen Displacement

As discussed in Section 9.2.2.2, Primary Contaminant Sources/Landfill Gas, landfill gas typically contains approximately 40% carbon dioxide by volume. Carbon dioxide dissolves in water to form carbonic acid and reduces pH. The high concentrations of carbon dioxide during the early period of gas migration at the Landfill would have likely resulted in the formation of carbonic acid, and in conjunction with the displacement of oxygen, could have resulted in reducing conditions in the vadose zone surrounding the solid waste disposal area.

One indicator of the production of carbonic acid is increased concentrations of bicarbonate and carbonate (Boulding 1995). A review of sampling data from the RI study period shows that bicarbonate is significantly above upgradient levels at several monitoring wells that are impacted by manganese, iron, and arsenic. As noted above in Section 9.2.4.2, Anaerobic Condition Resulting from Leachate Percolation, the speciation and hence mobility of many metals is strongly influenced by the redox and pH conditions. In particular, low pH and reducing conditions increase the mobility of iron, manganese, and arsenic. Thus the potential for leaching of these metals from vadose zone soils and migration to the groundwater is enhanced.

9.3 DISTRIBUTION OF REPRESENTATIVE CHEMICALS

The preceding section (Section 9.2, Conceptual Site Model) describes the potential primary and secondary contaminant sources for the Hansville Landfill and the possible contaminant release mechanisms that may impact groundwater, surface water, and sediment downgradient of the Landfill. The possible contaminant source and release mechanisms were described for both pre-closure and post-closure conditions.

The RI has been conducted under the post-closure conditions, with source control/remediation measures already implemented at the Landfill (i.e., landfill closure, engineered cap/cover system, and active landfill gas extraction and flaring system). Therefore, the chemicals found in groundwater, surface water, and sediments during the four initial comprehensive sampling events of the RI should represent a “worst case” situation under current conditions. Both leachate and landfill gas generation should continue to decrease over time; thus chemicals found in groundwater, surface water, and sediment should also continue to decrease.

Chemicals in groundwater, surface water, and sediment that emerged from the chemical screening and will be considered in the FS were described in Chapter 8 and summarized in Table 8-5. Of the twelve chemicals listed in Table 8-5 (nine metals, bis(2-ethylhexyl)phthalate, vinyl chloride, and nitrate), five were selected as most representative of landfill impacts: arsenic, manganese, nitrate, vinyl chloride, and specific conductance, and are referred to collectively as representative chemicals. Arsenic was selected because it occurs naturally in the groundwater, surface water, and sediments in the area, and can experience changes in concentrations by contact with landfill leachate. The other chemicals have provided consistent indications of impacts from the Landfill since monitoring began in the late 1980s and have been tested during all sampling events from 1996 to present. This section describes the distribution of these representative chemicals along the migration pathways defined during the RI.

The distributions of vinyl chloride, arsenic, manganese, nitrate, and specific conductance in groundwater and surface water during seasonal low water-table conditions in the RI sampling period and a recent year of sampling (November 1996 and October 2003, respectively) are shown on Figures 9-2 through 9-11. The concentrations measured during low-water table conditions during each period were selected to minimize the effect of seasonal variations so that changes that have occurred over time are more apparent. The highest concentration of each constituent at each well cluster location (adjacent shallow and deep wells) is contoured; therefore, the maps represent groundwater quality throughout the saturated thickness of the upper aquifer. Water quality data for surface water stations are also included in the contouring, since the source of flow for the streams sampled downgradient of the Landfill is groundwater.

9.3.1 Vinyl Chloride

Vinyl chloride was detected in August 1996 in the inlet to the main landfill gas flare at the Landfill at a concentration of 460 ppbv by volume (see Table 4-1). The vinyl chloride concentration at the flare was measured again in June 2004 and found to be 50 ppbv, an approximately 10-fold decrease. As described in Chapter 4, Landfill Gas Investigation, the landfill gas control system is effectively preventing migration of gas out of the refuse, and no landfill gas components (including vinyl chloride) were detected in the perimeter landfill gas probes in either 1996 or 2004.

The chemical screening (Chapter 8) indicated that vinyl chloride exceeded preliminary cleanup levels in groundwater and surface water and will be further evaluated in the Feasibility Study. Vinyl chloride was detected in groundwater in November 1996 (Figure 9-2) at maximum concentrations of 0.0066 mg/L to 0.011 mg/L in monitoring wells within 200 ft of the Landfill (MW-4, MW-6, and MW-14). Lower concentrations were detected in November 1996 at wells located at a distance downgradient from the Landfill such as at MW-12I (0.0036 mg/L), located approximately 1,040 ft southwest of the Landfill. The preliminary cleanup level for vinyl chloride in groundwater is 0.000025 mg/L (see Table 8-3a).

In the creeks west of the Landfill that are formed by groundwater seepage from the upper aquifer, vinyl chloride was detected in November 1996 (Figure 9-2) only at stations on the upper reaches of two Middle Creek tributaries. The concentrations detected were 0.00048 mg/L at SW-1 (head of main tributary), and 0.00026 mg/L at SW-4 (headwaters of north tributary). Vinyl chloride was not detected at stations on Middle Creek downstream from SW-1 or SW-4, or in any of the sediment samples from these creeks.

As shown on Figure 9-3, vinyl chloride concentrations in both groundwater and surface water have shown substantial decreases since 1996. The highest groundwater concentrations detected in October 2003 were 0.00125 mg/L at wells MW-6 and MW-14 near the Landfill, and 0.0013 mg/L in well MW-12I further downgradient from the Landfill. The highest detected concentrations in surface water were 0.00008 mg/L in SW-4 and 0.00002 mg/L in SW-1. Vinyl chloride was not detected in any other surface water stations in October 2003. These decreases represent an approximately three to nine-fold decrease in groundwater concentrations, and an approximately three to 24-fold decrease in surface water concentrations.

9.3.2 Arsenic

The chemical screening (Chapter 8) indicated that arsenic exceeded the screening criteria in groundwater, surface water, and sediment, and will be further evaluated in the FS. However, data from the upgradient monitoring well (MW-5), the background surface water stations, and the background sediment stations confirm that arsenic occurs naturally in groundwater, surface water, and sediments in the Study Area. The natural trends and occurrence of arsenic obscure quantification of impacts attributable to the Landfill.

As shown on Figures 9-4 and 9-5, arsenic was detected in all monitoring wells except MW-1, both upgradient and downgradient of the Landfill. The highest arsenic concentrations, 0.011 mg/L and 0.021 mg/L, during November 1996 (Figure 9-4) occurred in wells MW-6 and MW-14, respectively, adjacent to the solid waste disposal area. The October 2003 arsenic concentrations (Figure 9-5) show that arsenic concentrations and their distribution in the site vicinity have not changed substantially since November 1996. The concentration measured at MW-14 in October 2003 (Figure 9-5) was also 0.021 mg/L, although the concentration measured in MW-6 was slightly lower at 0.0062 mg/L. One sediment sample (SD-06) slightly exceeded the preliminary cleanup level for arsenic (value of 28 mg/kg versus preliminary cleanup level of 20 mg/kg). Due to the natural occurrence of arsenic, mapping of this chemical does not provide useful indications of the extent of impacts from waste disposal areas at the Landfill.

9.3.3 Manganese

The chemical screening (Chapter 8) indicated that manganese exceeded the screening criteria in groundwater and sediment and will be evaluated further in the FS. Concentrations of manganese (Figures 9-6 and 9-7) are highest in wells MW-6 and MW-14 adjacent to the solid waste disposal area and decrease downgradient of the Landfill. As shown on Figures 9-6 and 9-7, manganese concentrations immediately downgradient of the Landfill in well MW-14 and in well MW-12I (further downgradient along that flow path) have not changed substantially since 1996. The respective concentrations measured in MW-14 and MW-12I were 5.8 mg/L and 0.075 mg/L in November 1996, and 6.0 mg/L and 0.088 mg/L in October 2003. However, concentrations in SW-1 further along this flowpath decreased from 0.03 mg/L in November 1996, to less than 0.0005 mg/L in October 2003.

In the central and northern portion of the Landfill Property, manganese concentrations in groundwater and surface water have decreased since the RI sampling period. For example, October 2003 manganese concentrations were lower compared to the concentrations measured in November 1996 in wells MW-6 (a decrease from 4.3 mg/L to 1.2 mg/L) and MW-13D (a decrease from 0.27 mg/L to 0.09 mg/L) and in surface water station SW-4 (a decrease from 0.024 mg/L to 0.015 mg/L). The preliminary cleanup level for manganese is 2.24 mg/L.

Two sediment samples (SD-1 and SD-6) exceeded the preliminary cleanup level for manganese (values of 4,100 mg/kg and 2,700 mg/kg, respectively, compared to the preliminary cleanup level of 1,800 mg/kg).

9.3.4 Nitrate

The chemical screening (Chapter 8) indicated that nitrate exceeded the screening criteria in groundwater and will be evaluated further in the FS. Nitrate in groundwater at concentrations exceeding the preliminary cleanup level of 1.6 mg/L was measured in November 1996 in on-site wells MW-2 and MW-7 and off-site wells MW-8D, MW-9, and MW-12 (Figure 9-8). Most of these stations are downgradient of the former demolition and septage disposal areas, both potential sources of nitrate. Nitrate concentrations in the northern part of the Site have decreased substantially since November 1996 (Figure 9-9). The concentration of nitrate in MW-7 was 18 mg/L in November 1996, compared to 1 mg/L in October 2003.

Nitrate concentrations in surface water have typically been less than 1 mg/L at most stations. The highest surface water concentrations of nitrate in November 1996 were consistently found at station SW-7 in Creek A (Figure 9-8), which is hydraulically connected to and downgradient from MW-7 and the septage waste disposal areas. The concentrations of nitrate in SW-7 have decreased substantially since November 1996 (from 1.8 mg/L in November 1996 to 0.46 mg/L in October 2003).

Nitrate does not typically accumulate in sediment and screening criteria for nitrate in sediment do not exist; therefore, nitrate was not tested in sediment.

9.3.5 Specific Conductance

Specific conductance is not a chemical, but is an indicator of total dissolved solids. Therefore, this parameter does not have a preliminary cleanup level. In November 1996, specific conductance was highest in wells in the northern portion of the Site (2,000 μmhos/cm at well MW-2, see Figure 9-10). Relatively high measurements of specific conductance were also found immediately downgradient from the Landfill at wells MW-6 and MW-14 (971 and 728 μmhos/cm, respectively) and at well MW-12I (988 μmhos/cm), further downgradient along that flow path. Specific conductance has decreased substantially in these wells since November 1996 (see Figure 9-11), and the highest value measured in October 2003 was 528 μmhos/cm at well MW-6.

Specific conductance has also decreased in surface water stations since November 1996. For example, the highest specific conductance observed in November 1996 was 864 μmhos/cm in SW-4, and specific conductance at this station was measured at 563 μmhos/cm in October 2003.

Specific conductance is a water quality parameter and was therefore not tested in sediment.

9.3.6 Distribution of Chemicals in Vicinity of the Siltation Basin

The isoconcentration maps for November 1996 show an apparent anomaly at monitoring well MW-1. Concentrations of vinyl chloride, arsenic, and manganese, and specific conductance measurements in this well are notably less than those reported for nearby wells MW-14 and MW-6 (located adjacent to the solid waste disposal area) and for nearest off-property downgradient wells (MW-8/8D and MW-13/13D, and MW-9). A likely explanation for this anomaly is the influence of the siltation basin adjacent to MW-1, which allows stormwater runoff from the capped waste disposal areas to percolate into the ground and create a seasonal recharge mound on the water table (see Section 5.4.3, Groundwater Flow Directions and Velocities). This recharge would tend to dilute chemical constituents expected to be present in the upper aquifer at well MW-1.

9.3.7 Vertical Distribution of Chemicals

The vertical distribution of elevated parameters in the upper aquifer downgradient of the disposal areas is consistent with vertical gradients observed at RI monitoring well locations (see Section 5.4.2.3, Properties of Hydrostratigraphic Units). In downgradient wells adjacent to the disposal areas (MW-2, MW-6, and MW-14), the highest concentrations of parameters occur near the top of the upper aquifer. Downward vertical gradients southwest of the disposal areas result in higher concentrations of parameters near the bottom of the upper aquifer at monitoring wells MW-8D, MW-13D, MW-9. The transition to upward vertical gradients in the vicinity of the stream heads (points of groundwater discharge to surface water) may be the cause of higher concentrations of parameters that occur in the middle of the aquifer, as at MW-12I.

9.4 TRENDS IN REPRESENTATIVE CHEMICALS OVER TIME

Changes in the measured concentrations of vinyl chloride, arsenic, manganese, nitrate, and specific conductance are shown in Figures 9-12a and b through 9-16a and b for representative wells and surface water stations along each of the two flow paths described in Section 5.4.3.2 (MW-14 to SW-1, and MW-2 to SW-2). Non-detected values are plotted at one-half the detection limit. Concentrations in upgradient well MW-5 are also shown for each flowpath for arsenic, manganese, nitrate, and specific conductance. The figures show milestones in the history of the project, including completion of the final landfill cover in 1990, installation of the active landfill gas extraction system in 1991, completion of the gas system modifications in 1994, initial RI sampling events in 1996 and 1997, Ecology-directed monitoring through January of 2004, and modifications to the landfill gas system in 2003.

Most of the chemicals show decreases in groundwater concentrations over time, as illustrated by Figures 9-12 through 9-16. These trends reflect the following conditions:

- Decreasing rates of landfill gas and leachate production since the disposal areas at the Landfill were capped in 1989.
- Effectiveness of the landfill gas extraction and flaring system in controlling landfill gas and reducing contact of landfill gas with groundwater.
- Attenuation of chemicals dissolved in groundwater by natural processes (physical, chemical, and biological), as the groundwater flows downgradient and discharges to the creeks west of the Landfill.

The trends observed in the concentrations of each chemical are described in the following sections.

9.4.1 Vinyl Chloride

Concentrations of vinyl chloride along the MW-14 to SW-1 flow path have been substantially reduced in both wells and surface water stations since the landfill gas extraction system was installed in 1991. In wells MW-6 and MW-14, vinyl chloride concentrations have been reduced from about 0.01 mg/L in 1997 to between 0.001 and 0.002 mg/L in the last few years. The high values measured in January 2004 were anomalous; subsequent Ecology-directed sampling has continued to show values between 0.001 and 0.002 mg/L since January 2004. In surface water station SW-1, vinyl chloride concentrations have been reduced from about 0.001 mg/L to less than 0.00001 mg/L.

Along the MW-2 to SW-4 flow path, vinyl chloride concentrations have also shown substantial decreases. Concentrations in MW-2 responded rapidly to the 1991 installation of the landfill gas extraction system, decreasing from highs of about 0.01 mg/L in 1992 and 1993 to less than 0.0001 mg/L by 1995. Concentrations of vinyl chloride in SW-4 have also shown an overall steady downward trend and are now typically between 0.00001 mg/L and 0.0001 mg/L.

9.4.2 Arsenic

Arsenic trends in both groundwater and surface along both flow paths have generally fluctuated within stable ranges since implementation of the Landfill improvements. This includes the upgradient well MW-5.

9.4.3 Manganese

Concentrations of manganese along the MW-14 to SW-1 flow path have been substantially reduced in some wells and surface water stations since the installation of the final cover system in 1990. In well MW-6, manganese concentrations have decreased steadily from a high of about 10 mg/L in 1992 and 1993, to about 1 mg/L during 2003. In surface water station SW-1, manganese concentrations have been reduced from about 0.1 mg/L to less than 0.001 mg/L during the same period.

Along the MW-2 to SW-4 flow path, manganese concentrations have also shown decreases. Concentrations in well MW-13D decreased from a high of 0.3 mg/L during 1996 to less than 0.1 mg/L in 2003. Concentrations of manganese in SW-4 have also shown an overall steady downward trend from highs of about 0.04 mg/L to the current concentrations that are less than 0.01 mg/L.

9.4.4 Nitrate

Along the MW-14 to SW-1 flow path, nitrate in groundwater has fluctuated over time without clear trends. Nitrate in surface water station SW-1 has shown slight increases since landfill closure, from concentrations of less than 0.01 mg/L during the initial RI sampling events in 1996 and 1997 to concentrations between about 1 and 4 mg/L in recent years.

Along the MW-2 to SW-4 flow path, nitrate in surface water station SW-4 has shown slight increases since completion of the Landfill improvements from concentrations slightly less than 1 mg/L during the initial RI sampling events in 1996 and 1997, to concentrations of between about 1 and 3 mg/L in the past few years.

9.4.5 Specific Conductance

Along the MW-14 to SW-1 flow path, specific conductance has decreased in all wells since the landfill closure in 1990. For example, specific conductance measurements in wells MW-6 and MW-14 have decreased from respective highs of about 2,000 µmhos/cm and 800 µmhos/cm, prior to and during 1996, to about 600 µmhos/cm and 400 µmhos/cm, in the past few years. Specific conductance measurements in surface water station SW-1 have remained relatively stable between 300 and 400 µmhos/cm since the initial RI sampling events in 1996 and 1997.

Along the MW-2 to SW-4 flow path, specific conductance has decreased in all wells and in surface water station SW-4 since landfill closure. For example, specific conductance in MW-2 decreased from greater than 5,000 µmhos/cm in the 1980's to between 1,000 and 2,000 µmhos/cm during the initial RI sampling events in 1996 and 1997. In further downgradient well MW-13D, specific conductance measurements decreased from over 1,000 µmhos/cm during 1996 and 1997, to about 300 µmhos/cm in the past few years. Specific conductance measurements in surface water station SW-4 have decreased from about 800 µmhos/cm during 1996 to about 500 µmhos/cm in the past few years.

9.5 CHEMICAL FATE ALONG MIGRATION PATHWAYS

The fate of chemicals identified in groundwater, surface water, and sediments earlier in this chapter is discussed in following sections.

9.5.1 Vinyl Chloride

Vinyl chloride is a product of decomposition of chlorinated solvents by bacteria in environments where oxygen is not present (anaerobic conditions). The typical dechlorination sequence is as follows: tetrachloroethylene (PCE), trichloroethylene (TCE), dichloroethylene (DCE), and vinyl chloride (Freedman and Gossett 1989). Vinyl chloride can result from decomposition of cleaning products containing chlorinated solvents that are found in municipal refuse. Other potential sources of vinyl chloride include refrigerants, floor tiles, drugs, cosmetic products, and plastics. Due to its chemical properties, vinyl chloride tends to exist in a gas phase and is soluble in water.

Vinyl chloride has been identified in the landfill gas extracted from the solid waste disposal area at the Hansville Landfill. With the installation and operation of the active landfill gas extraction and flaring system in 1991, the pathway for off-site migration of vinyl chloride with landfill gas has been greatly reduced or eliminated. As discussed in Chapter 4, Landfill Gas Investigation, data from perimeter gas probes confirm that landfill gas migration has been contained at the perimeter of the Landfill and that lateral gas migration is not detected.

Vinyl chloride and its precursors dichloroethane and dichloroethene have been identified in groundwater monitoring wells around the Landfill since 1988. Vinyl chloride volatilizes readily when exposed to atmospheric pressure, but is reported to be stable in groundwater with an estimated half-life ranging from 8 weeks to 8 years (Howard et al. 1991). Although vinyl chloride is resistant to breakdown under anaerobic conditions, it will readily biodegrade under aerobic conditions. Vinyl chloride has a low octanol-water partition coefficient, and thus is not significantly retarded relative to groundwater flow.

Vinyl chloride has been transported by groundwater discharge from the upper aquifer to the upper reaches of streams west of the Landfill. Due to the volatile nature of vinyl chloride, it dissipates to the atmosphere during flow down the stream channels, was not detected at downstream stations below SW-2 and SW-4 on Middle Creek, and was not detected in any RI sediment samples. In the atmosphere, vinyl chloride is broken down by ultraviolet light.

9.5.2 Arsenic and Manganese

Leachable metals contained in refuse, demolition debris, or septage disposed at the Landfill may have been present in leachate generated during landfill operation (see Section 9.2.2.1, Infiltration/Leachate Production and Section 9.2.2.2, Landfill Gas). Naturally occurring metals (such as manganese, arsenic, and iron) in soils beneath the disposal areas and in the upper aquifer can also be mobilized during percolation of leachate through the unsaturated zone and migration of leachate-impacted groundwater in the upper aquifer.

As the chemical equilibrium of the groundwater changes with distance from the Landfill disposal areas, largely due to mixing with uncontaminated groundwater and changes in dissolved gas concentrations, pH and REDOX potential, metals have the potential to come out of solution and adsorb onto the aquifer matrix. Both arsenic and manganese are more mobile under reducing conditions close to the waste disposal areas, and become less mobile away from the Landfill as reducing conditions diminish. Transport of metals in groundwater can therefore be retarded over time with increasing distances from the waste disposal areas.

Metals dissolved in groundwater are transported to surface water in the streams that originate as groundwater flow west of the Landfill. These metals can be transported downstream as dissolved components in surface water or can adsorb to sediments and particulate matter in the creek beds. Subsequent migration of metals in sediments can then occur under the influence of surface water flow.

9.5.3 Nitrate

Septage pumpings are generally high in ammonia. Anaerobic conditions, which frequently occur in buried waste, favor conversion of ammonia to nitrate (NO_3). Nitrate is very soluble and highly mobile. Nitrate in the vicinity of the sources (former demolition disposal area and septage disposal area) likely undergoes some degree of biological denitrification, converting nitrate to nitrogen gas. However, as groundwater moves away from the source, the biological activity likely decreases as a result of dilution and oxygenation. Nitrate in the groundwater is likely transported through the aquifer with little attenuation by biological processes, sorption to soils, or other mechanisms.

9.6 BOUNDARIES OF LANDFILL IMPACTS

Information presented in Chapter 5 (Groundwater Investigation) and the preceding sections of Chapter 9 provide sufficient information to bound the area of impacts from the Hansville Landfill. The groundwater flow system characterization (Chapter 5) confirmed that groundwater in the upper aquifer is separated from the deeper regional aquifer by the laterally extensive clays of the Kitsap formation. Groundwater in the upper aquifer flows to the west and southwest and discharges to headwaters of creeks downgradient of the Landfill that provide a direct means of evaluating groundwater discharge concentrations.

The distribution of and trends in representative chemicals (Sections 9.3 and 9.4) demonstrate that chemical concentrations in groundwater and surface water have decreased over time, and that the extent of the Landfill impacts are stable or decreasing. This information is consistent with the conceptual model presented in Section 9.2, and analysis of chemical fate along migration pathways presented in Section 9.5. These data indicate that the remedial actions (landfill closure, engineered cap/cover system, and active landfill gas extraction and flaring system) are working as designed, and that Landfill impacts will continue to decrease over time.

Figure 9-17 shows the estimated extent of groundwater and surface water impacts from the Landfill, based on the distribution of representative chemicals presented in Section 9.3. This area is roughly bounded by the Landfill Property boundary on the east, the observed extent of groundwater impacts on the north (monitoring well MW-7 and surface water station SW-7) and south (monitoring well MW-11 and surface water station SW-3), the outcrop of the Kitsap Formation, and documented extent of downstream surface water impacts on the west. The extent of impacts will be used in the Feasibility Study to assess remedial options and the extent of institutional controls that may be required as part of the final selected remedy at the Site.

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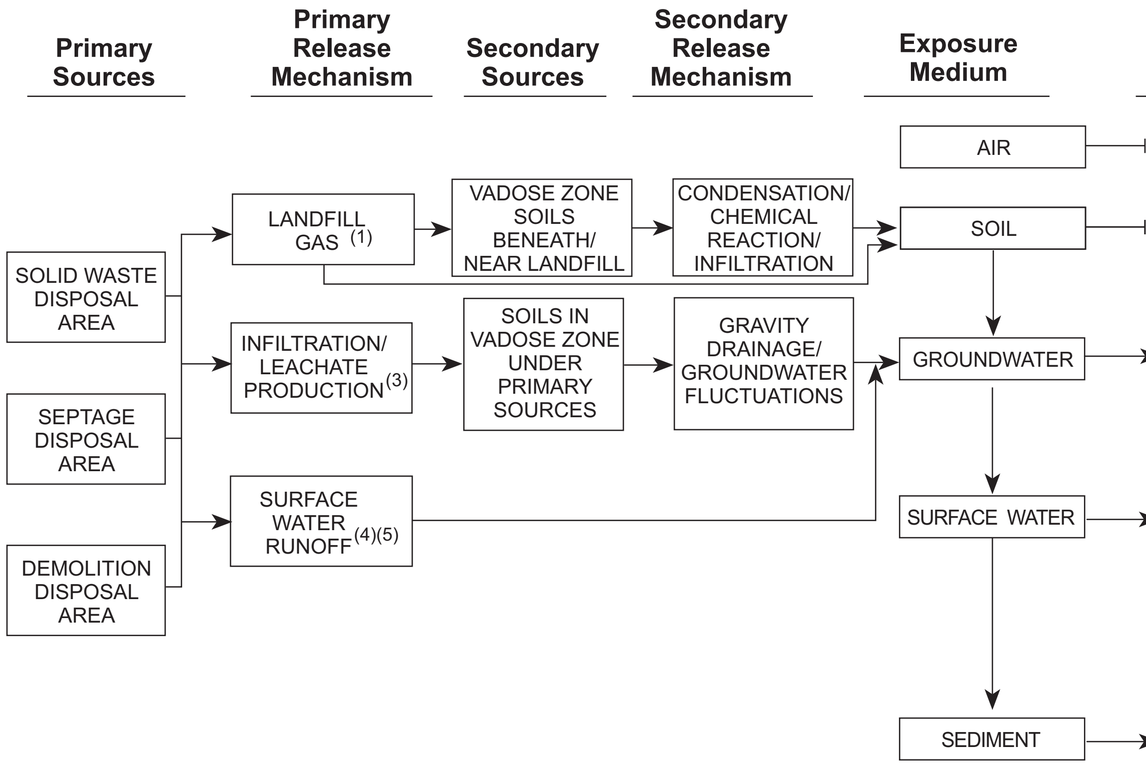

Exposure Medium	Exposure Pathway	Human Onsite Current	Human Onsite Future	Human Offsite Current	Human Offsite Future	Biota (2) Terrestrial Current	Biota (2) Terrestrial Future	Biota (2) Aquatic Current	Biota (2) Aquatic Future
AIR	(1)								
SOIL	(1)								
GROUNDWATER	Ingestion	○	●	○	●	NA	NA	NA	NA
	Inhalation (VOCs)	○	○	□	□	NA	NA	NA	NA
	Dermal Contact	○	○	□	□	NA	NA	NA	NA
SURFACE WATER	Ingestion	NA	NA	●	●	●	●	●	●
	Inhalation (VOCs)	NA	NA	□	□	□	□	NA	NA
	Dermal Contact	NA	NA	●	●	□	□	●	●
	Gill Uptake	NA	NA	NA	NA	NA	NA	●	●
	Food Chain	NA	NA	○	○	□	□	□	□
SEDIMENT	Ingestion	NA	NA	●	●	●	●	●	●
	Inhalation (VOCs)	NA	NA	NA	NA	NA	NA	NA	NA
	Dermal Contact	NA	NA	●	●	□	□	●	●
	Gill Uptake	NA	NA	NA	NA	NA	NA	NA	NA
	Food Chain	NA	NA	○	○	□	□	□	□

Parametrix Hansville Landfill FS 555-2966-002/02(01) 11/05 (B)

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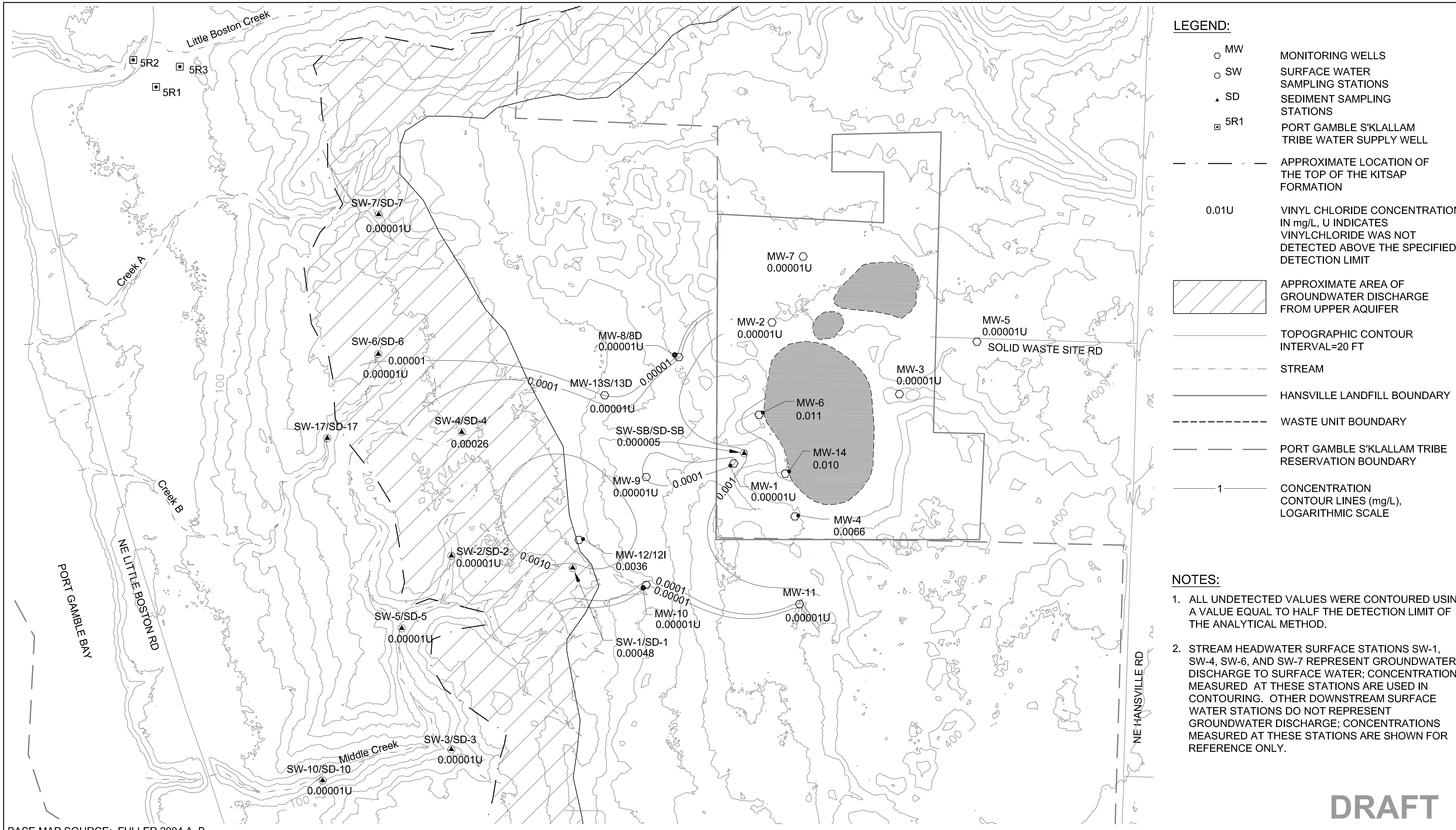
Notes: NA = Not Applicable

(1) Historical release mechanism was controlled by installation of landfill gas control system in 1991.
(2) WAC 173-340 provides no framework for ecological risk assessment. General exposure pathways for biota are identified.
(3) Historical release mechanism was greatly reduced by installation of geomembrane cap in 1989.
(4) Historical release mechanism was eliminated by installation of geomembrane cap in 1989.
(5) Surface water rapidly percolates into the various soils at the site; no streams exist on-site.

● Complete Exposure Pathway
○ Incomplete Exposure Pathway
□ Complete but Minor Exposure Pathway

Figure 9-1
Conceptual Site Model
Hansville Landfill RI/FS



NOTES:

1. ALL UNDETECTED VALUES WERE CONTOURED USING A VALUE EQUAL TO HALF THE DETECTION LIMIT OF THE ANALYTICAL METHOD.

2. STREAM HEADWATER SURFACE STATIONS SW-1, SW-4, SW-6, AND SW-7 REPRESENT GROUNDWATER DISCHARGE TO SURFACE WATER; CONCENTRATIONS MEASURED AT THESE STATIONS ARE USED IN CONTOURING. OTHER DOWNSTREAM SURFACE WATER STATIONS DO NOT REPRESENT GROUNDWATER DISCHARGE; CONCENTRATIONS MEASURED AT THESE STATIONS ARE SHOWN FOR REFERENCE ONLY.

Parametrix DATE: 03/22/06 2:30pm FILE: K2966002P01T02-F09-02

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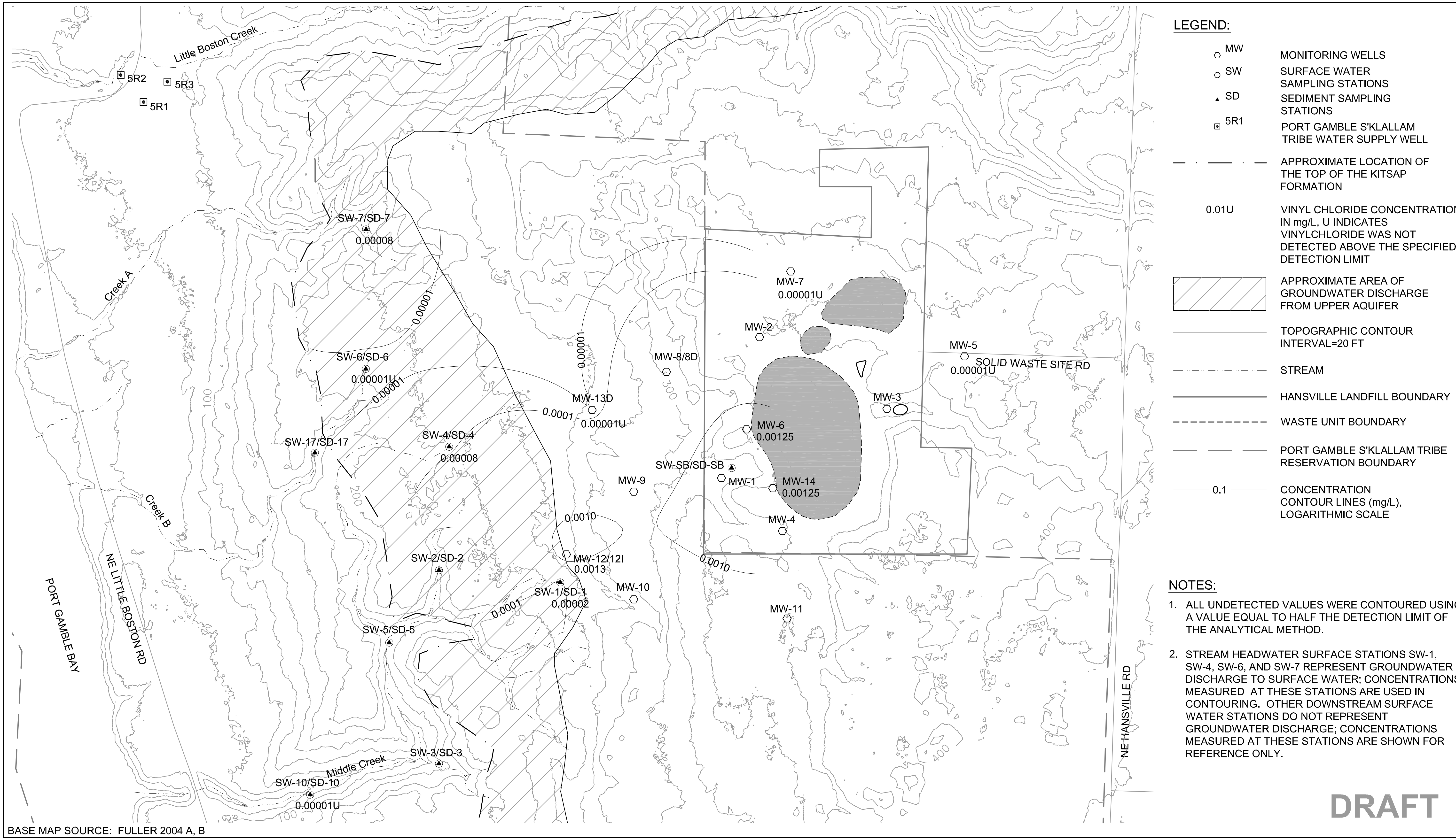
VERTICAL DATUM: NAVD 83

Figure 9-2
Isoconcentration Map for Vinyl Chloride, November 1996
Hansville Landfill RI/FS



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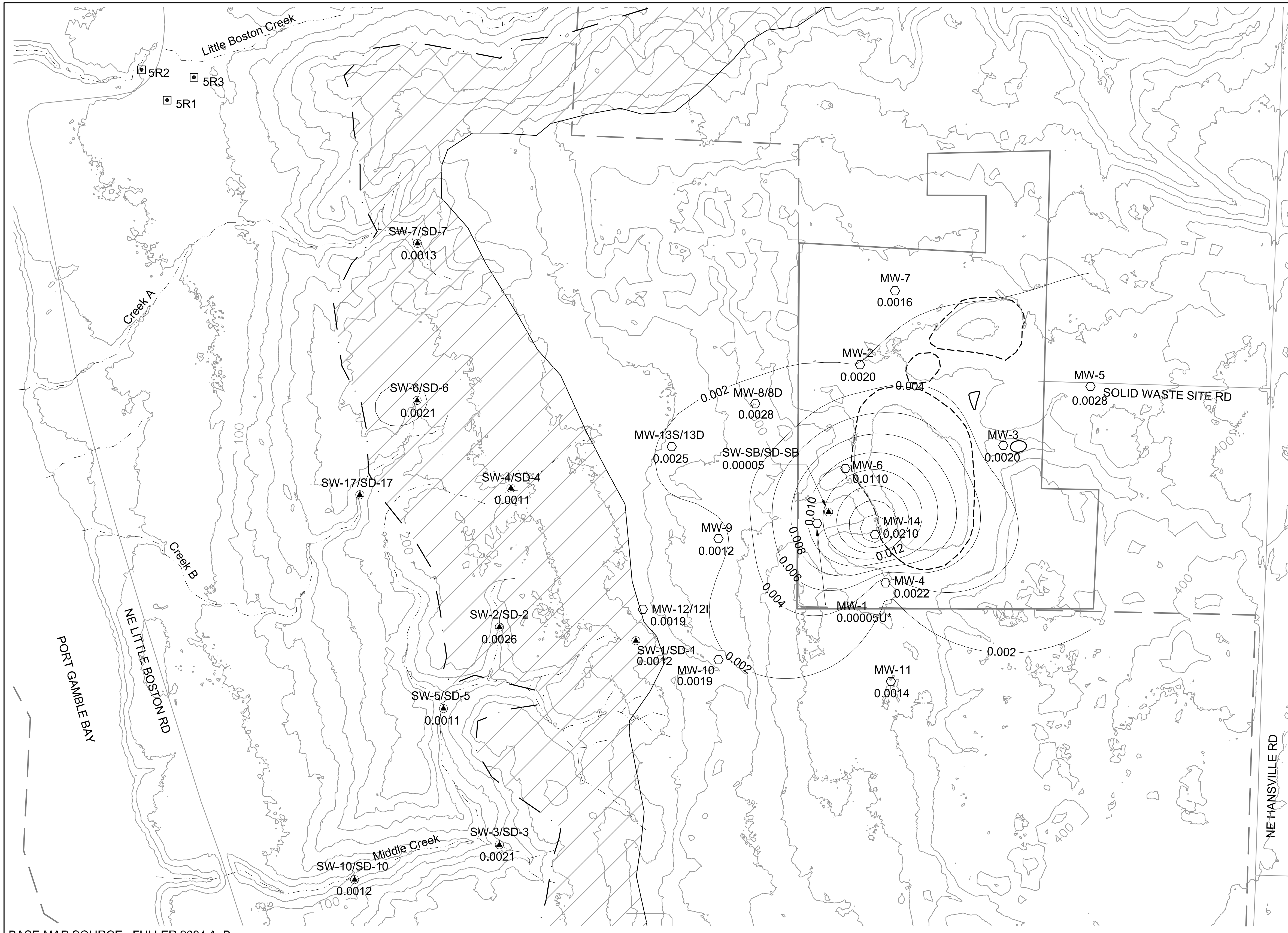
SCALE IN FEET

VERTICAL DATUM: NAVD 83

Figure 9-3
Isoconcentration Map for Vinyl Chloride, October 2003
Hansville Landfill RI/FS



LEGEND:

MW	MONITORING WELLS
SW	SURFACE WATER SAMPLING STATIONS
SD	SEDIMENT SAMPLING STATIONS
5R1	PORT GAMBLE S'KLALLAM TRIBE WATER SUPPLY WELL
	APPROXIMATE LOCATION OF THE TOP OF THE KITSAP FORMATION
0.0028	ARSENIC CONCENTRATION (mg/L), U INDICATES ARSENIC WAS NOT DETECTED ABOVE THE SPECIFIED DETECTION LIMIT
	APPROXIMATE AREA OF GROUNDWATER DISCHARGE FROM UPPER AQUIFER
	TOPOGRAPHIC CONTOUR INTERVAL=20 FT
	STREAM
	HANSVILLE LANDFILL BOUNDARY
	WASTE UNIT BOUNDARY
	PORT GAMBLE S'KLALLAM TRIBE RESERVATION BOUNDARY
0.004	CONCENTRATION CONTOUR LINES (mg/L)

* CONCENTRATION AT MW-1 IS ANOMALOUSLY LOW (SEE SECTION 9.3.5.) AND IS NOT INCLUDED IN CONTOURING

NOTES:

1. ALL UNDETECTED VALUES WERE CONTOURED USING A VALUE EQUAL TO HALF THE DETECTION LIMIT OF THE ANALYTICAL METHOD.
2. STREAM HEADWATER SURFACE STATIONS SW-1, SW-4, SW-6, AND SW-7 REPRESENT GROUNDWATER DISCHARGE TO SURFACE WATER; CONCENTRATIONS MEASURED AT THESE STATIONS ARE USED IN CONTOURING. OTHER DOWNSTREAM SURFACE WATER STATIONS DO NOT REPRESENT GROUNDWATER DISCHARGE; CONCENTRATIONS MEASURED AT THESE STATIONS ARE SHOWN FOR REFERENCE ONLY.

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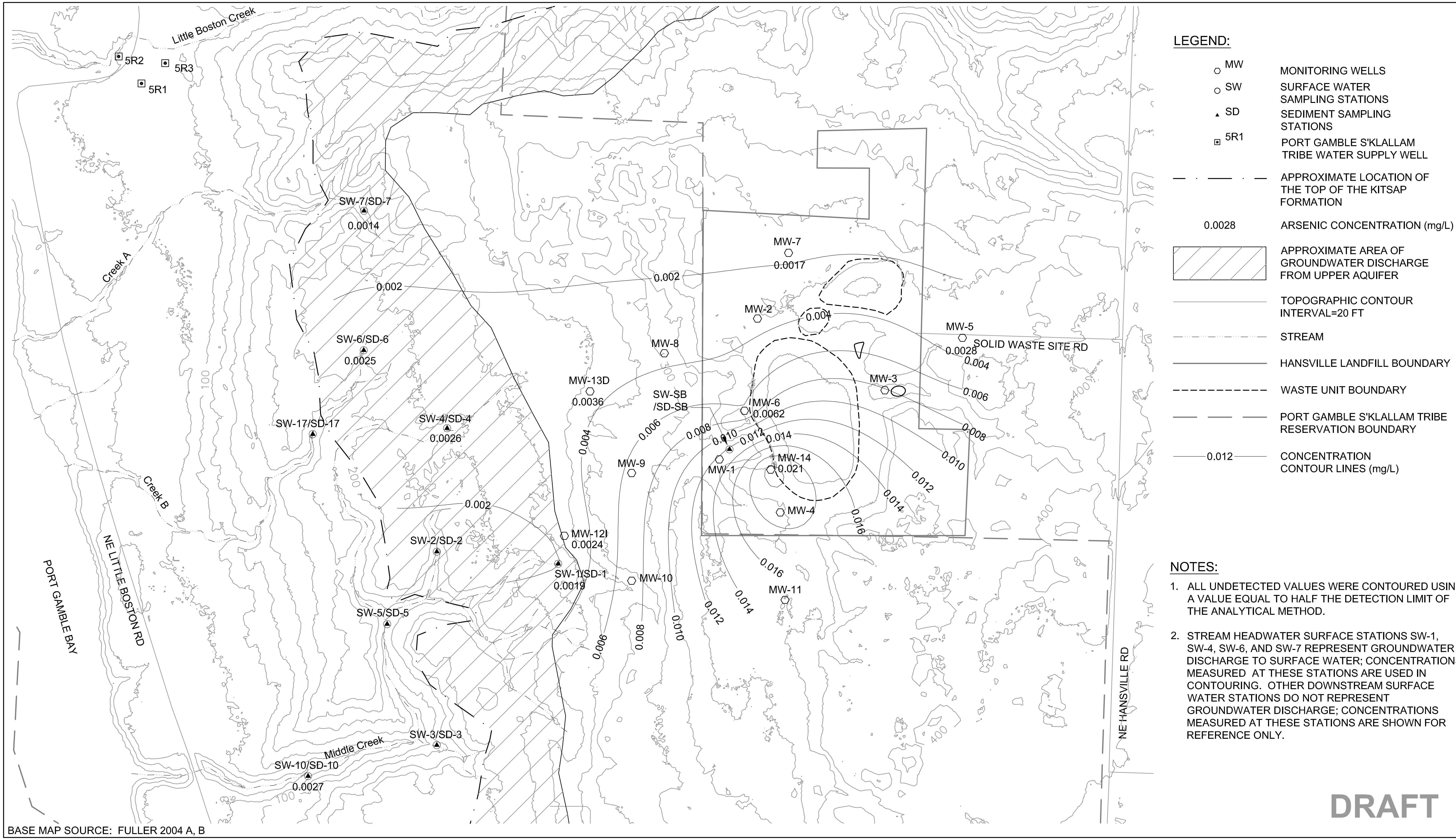
VERTICAL DATUM: NAVD 83

Figure 9-4
Isoconcentration Map for Arsenic, November 1996
Hansville Landfill RI/FS



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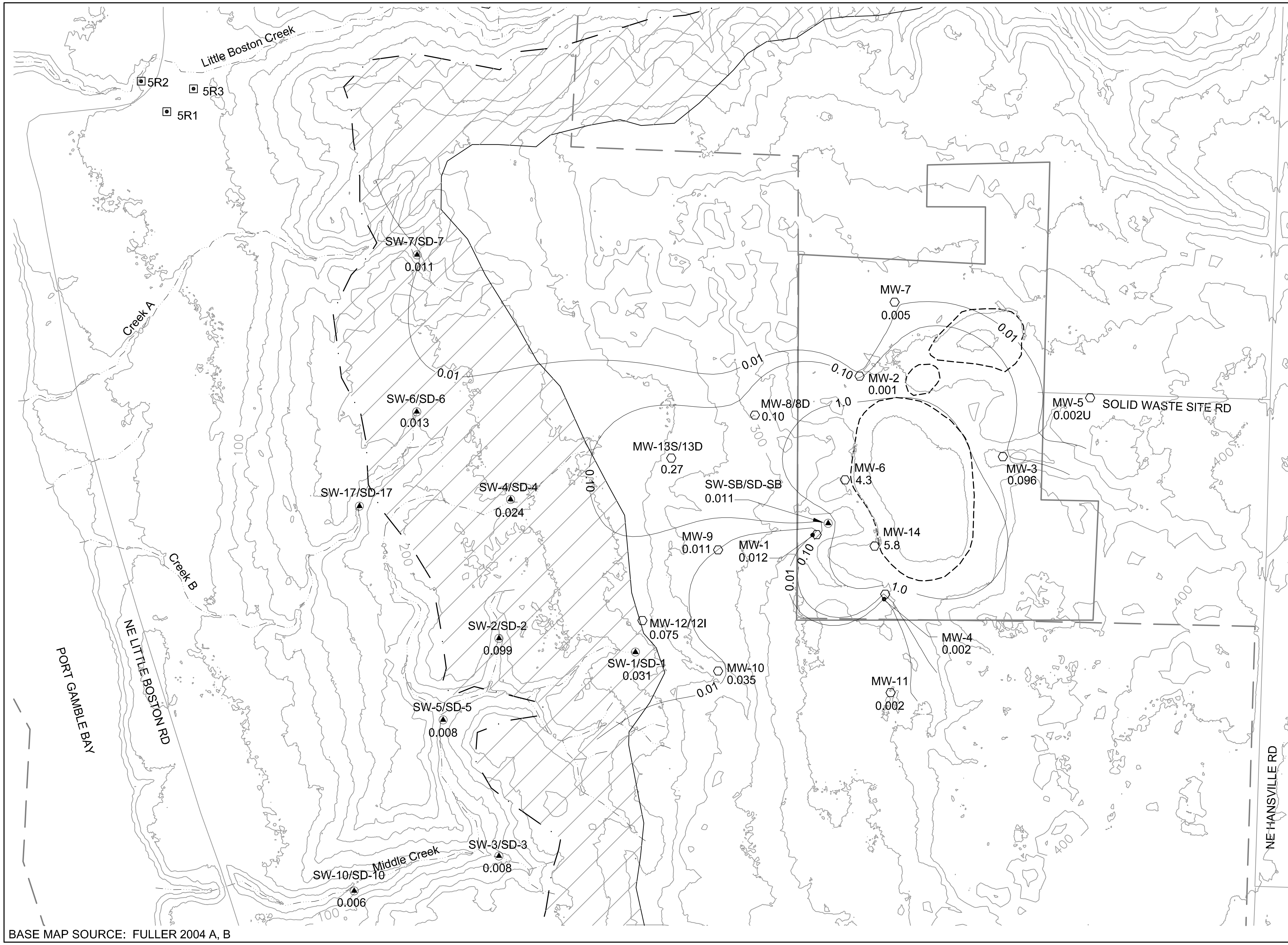
0 600 SCALE IN FEET

VERTICAL DATUM: NAVD 83

Figure 9-5
Isoconcentration Map for Arsenic, October 2003
Hansville Landfill RI/FS



LEGEND:

- MW MONITORING WELLS
- SW SURFACE WATER SAMPLING STATIONS
- SD SEDIMENT SAMPLING STATIONS
- 5R1 PORT GAMBLE S'KLALLAM TRIBE WATER SUPPLY WELL
- APPROXIMATE LOCATION OF THE TOP OF THE KITSAP FORMATION
- 0.002U MANGANESE CONCENTRATION (mg/L) U INDICATED MANGANESE WAS NOT DETECTED ABOVE THE SPECIFIED DETECTION LIMIT
- APPROXIMATE AREA OF GROUNDWATER DISCHARGE FROM UPPER AQUIFER
- TOPOGRAPHIC CONTOUR INTERVAL=20 FT
- STREAM
- HANSVILLE LANDFILL BOUNDARY
- WASTE UNIT BOUNDARY
- PORT GAMBLE S'KLALLAM TRIBE RESERVATION BOUNDARY
- 1.0 CONCENTRATION CONTOUR LINES (mg/L), LOGARITHMIC SCALE

NOTES:

1. ALL UNDETECTED VALUES WERE CONTOURED USING A VALUE EQUAL TO HALF THE DETECTION LIMIT OF THE ANALYTICAL METHOD.
2. STREAM HEADWATER SURFACE STATIONS SW-1, SW-4, SW-6, AND SW-7 REPRESENT GROUNDWATER DISCHARGE TO SURFACE WATER; CONCENTRATIONS MEASURED AT THESE STATIONS ARE USED IN CONTOURING. OTHER DOWNSTREAM SURFACE WATER STATIONS DO NOT REPRESENT GROUNDWATER DISCHARGE; CONCENTRATIONS MEASURED AT THESE STATIONS ARE SHOWN FOR REFERENCE ONLY.

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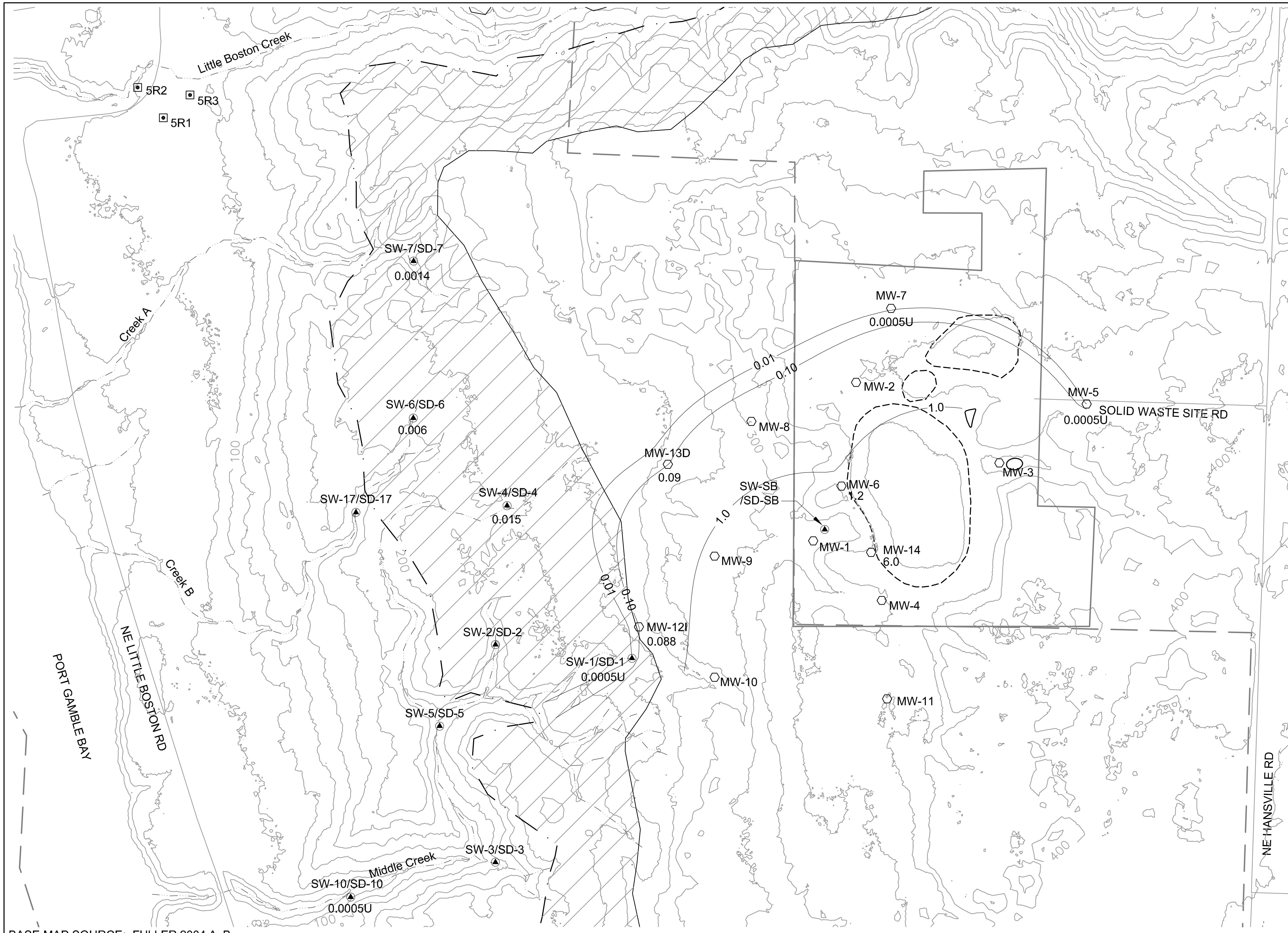
SCALE IN FEET

VERTICAL DATUM: NAVD 83

Figure 9-6
Isoconcentration Map for Manganese, November 1996
Hansville Landfill RI/FS



LEGEND:

- MW — MONITORING WELLS
- SW — SURFACE WATER SAMPLING STATIONS
- SD — SEDIMENT SAMPLING STATIONS
- 5R1 — PORT GAMBLE S'KLALLAM TRIBE WATER SUPPLY WELL
- APPROXIMATE LOCATION OF THE TOP OF THE KITSAP FORMATION
- 0.0005U — MANGANESE CONCENTRATION (mg/L), U INDICATES MANGANESE WAS NOT DETECTED ABOVE THE SPECIFIED DETECTION LIMIT
- APPROXIMATE AREA OF GROUNDWATER DISCHARGE FROM UPPER AQUIFER
- TOPOGRAPHIC CONTOUR INTERVAL=20 FT
- STREAM
- HANSVILLE LANDFILL BOUNDARY
- WASTE UNIT BOUNDARY
- PORT GAMBLE S'KLALLAM TRIBE RESERVATION BOUNDARY
- 1.0 — CONCENTRATION CONTOUR LINES (mg/L), LOGARITHMIC SCALE

NOTES:

1. ALL UNDETECTED VALUES WERE CONTOURED USING A VALUE EQUAL TO HALF THE DETECTION LIMIT OF THE ANALYTICAL METHOD.
2. STREAM HEADWATER SURFACE STATIONS SW-1, SW-4, SW-6, AND SW-7 REPRESENT GROUNDWATER DISCHARGE TO SURFACE WATER; CONCENTRATIONS MEASURED AT THESE STATIONS ARE USED IN CONTOURING. OTHER DOWNSTREAM SURFACE WATER STATIONS DO NOT REPRESENT GROUNDWATER DISCHARGE; CONCENTRATIONS MEASURED AT THESE STATIONS ARE SHOWN FOR REFERENCE ONLY.

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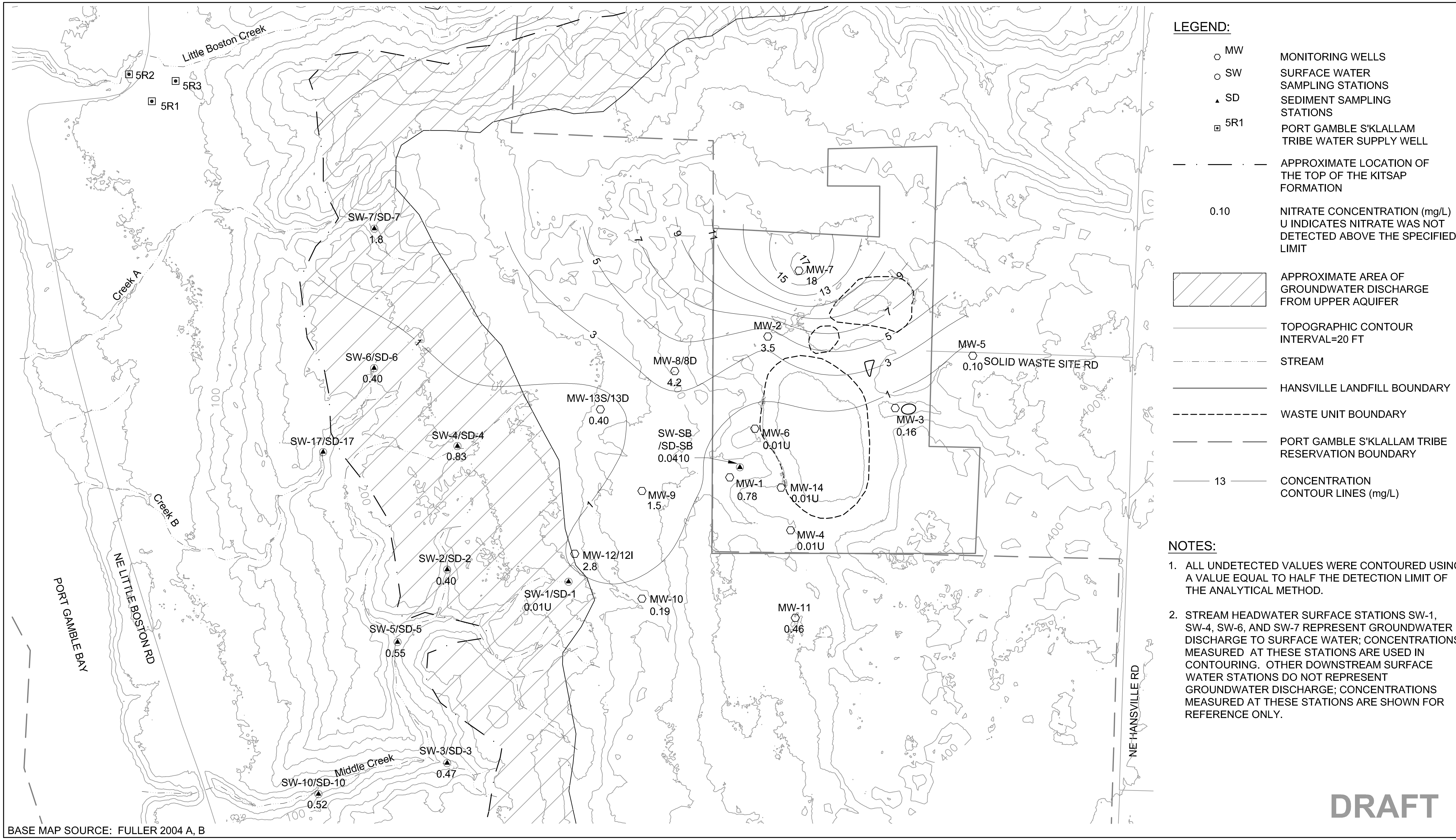
SCALE IN FEET

VERTICAL DATUM: NAVD 83

Figure 9-7
Isoconcentration Map for Manganese, October 2003
Hansville Landfill RI/FS



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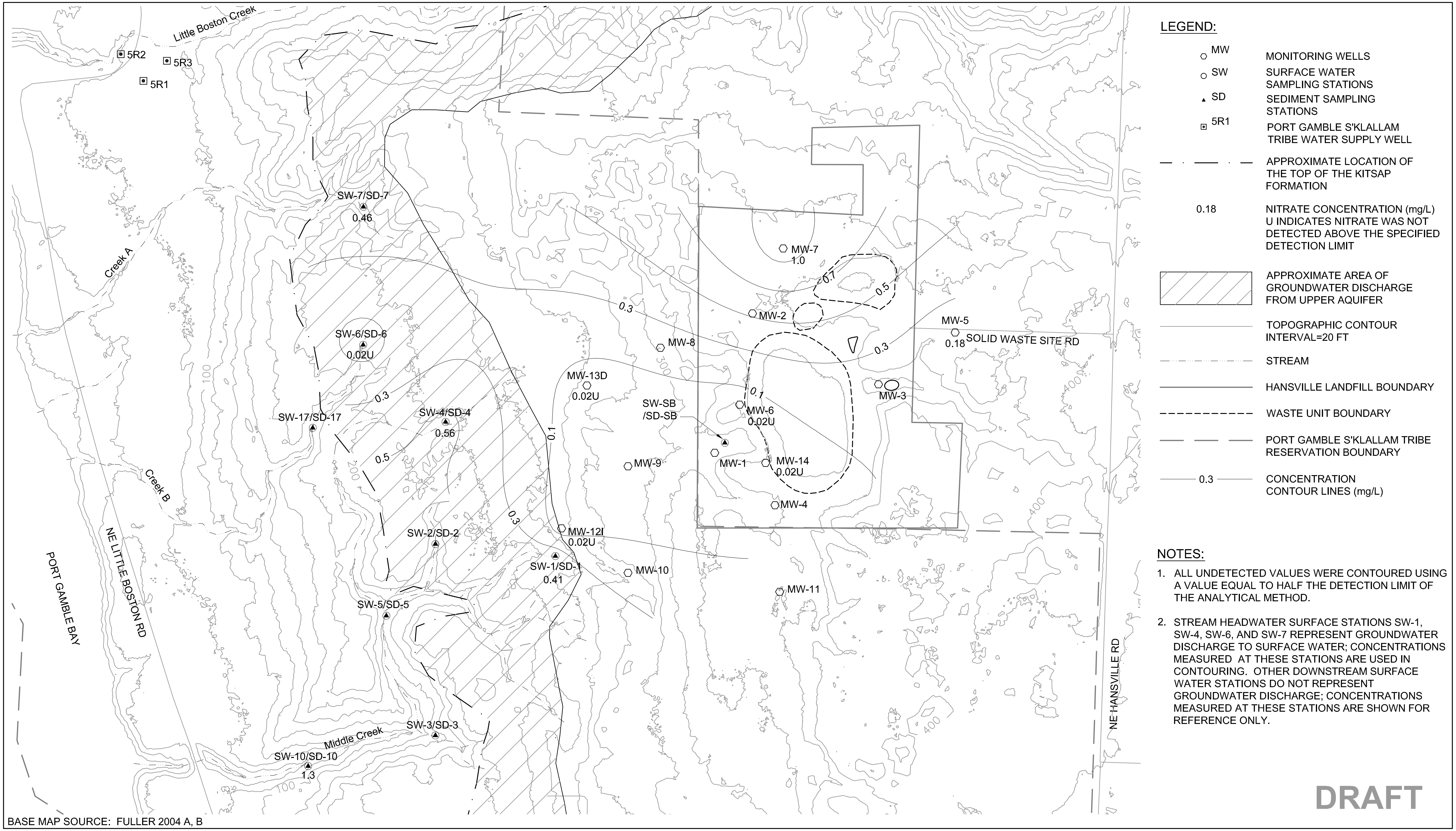
0 600

SCALE IN FEET

VERTICAL DATUM: NAVD 83

Figure 9-8
Isoconcentration Map for Nitrate, November 1996
Hansville Landfill RI/FS



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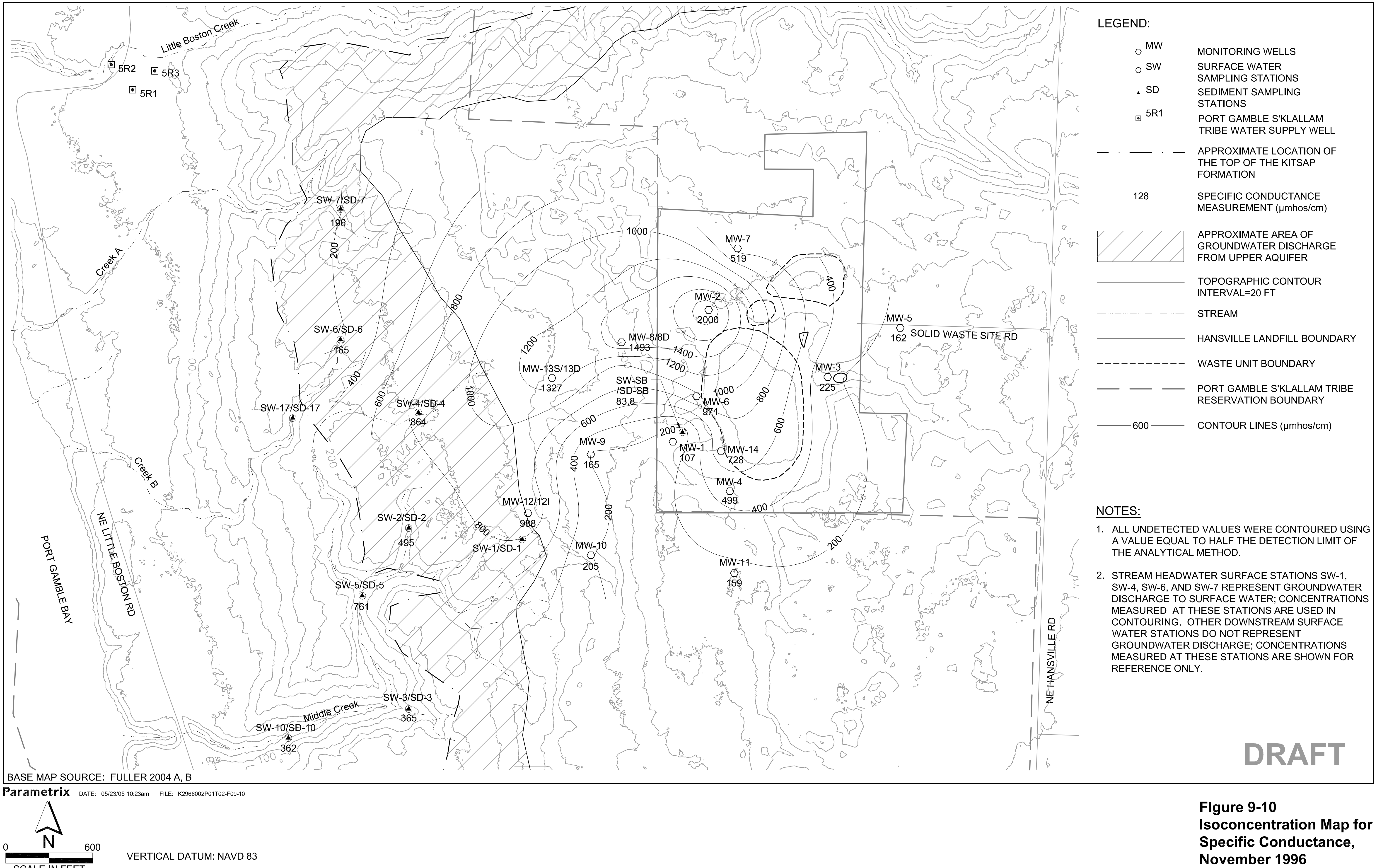
N 0 600 SCALE IN FEET

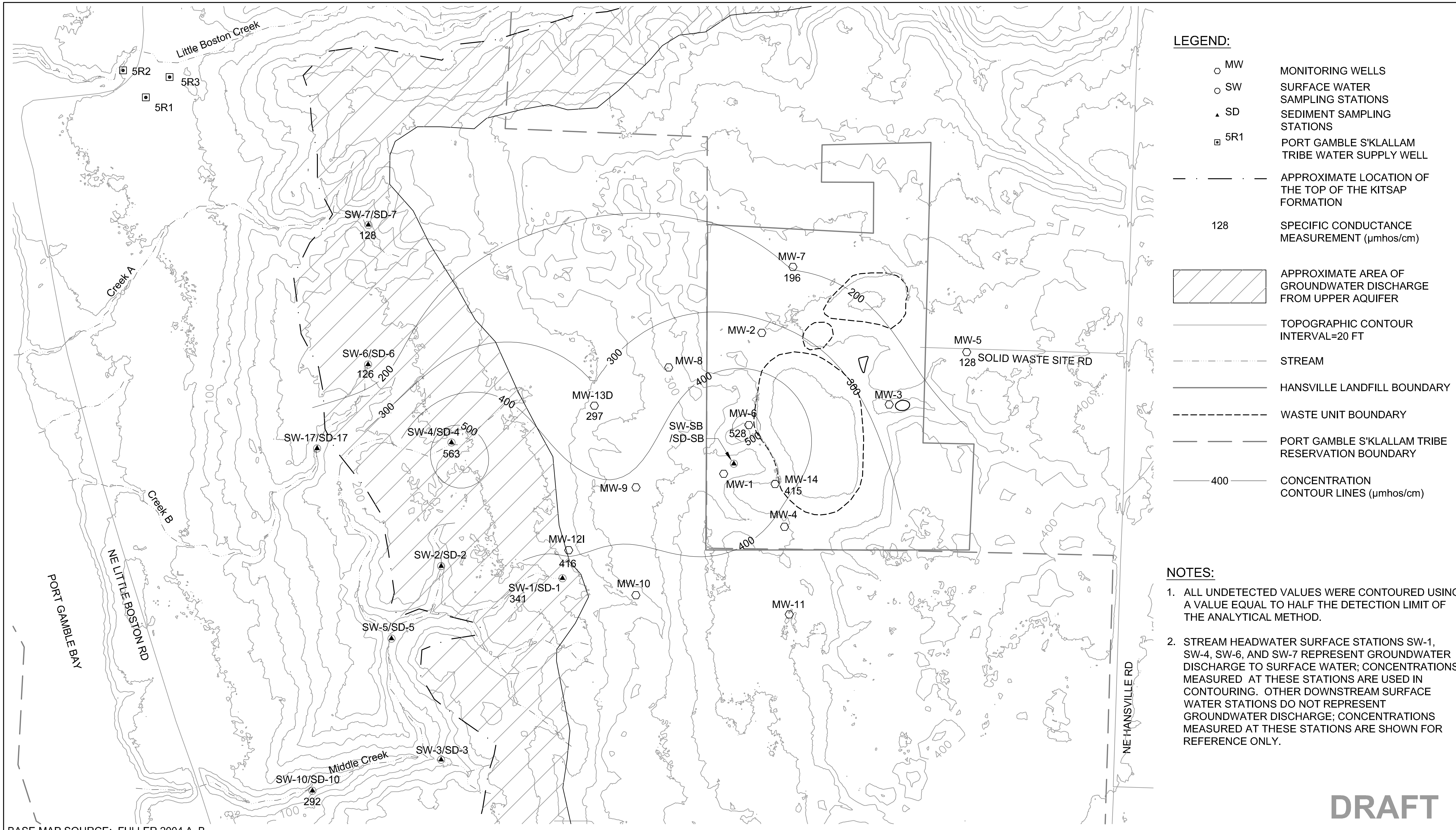
VERTICAL DATUM: NAVD 83

Figure 9-9
Isoconcentration Map for Nitrate, October 2003
Hansville Landfill RI/FS



Parametrix DATE: 05/23/05 10:23am FILE: K2966002P01T02-F09-10

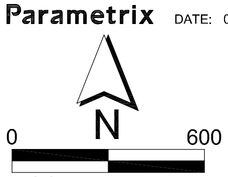
Figure 9-10
Isoconcentration Map for Specific Conductance, November 1996
Hansville Landfill RI/FS



NOTES:

1. ALL UNDETECTED VALUES WERE CONTOURED USING A VALUE EQUAL TO HALF THE DETECTION LIMIT OF THE ANALYTICAL METHOD.
2. STREAM HEADWATER SURFACE STATIONS SW-1, SW-4, SW-6, AND SW-7 REPRESENT GROUNDWATER DISCHARGE TO SURFACE WATER; CONCENTRATIONS MEASURED AT THESE STATIONS ARE USED IN CONTOURING. OTHER DOWNSTREAM SURFACE WATER STATIONS DO NOT REPRESENT GROUNDWATER DISCHARGE; CONCENTRATIONS MEASURED AT THESE STATIONS ARE SHOWN FOR REFERENCE ONLY.

Parametrix DATE: 08/31/05 2:50pm FILE: K2966002P01T02-F09-11



VERTICAL DATUM: NAVD 83

Figure 9-11
Isoconcentration Map for Specific Conductance, October 2003
Hansville Landfill RI/FS

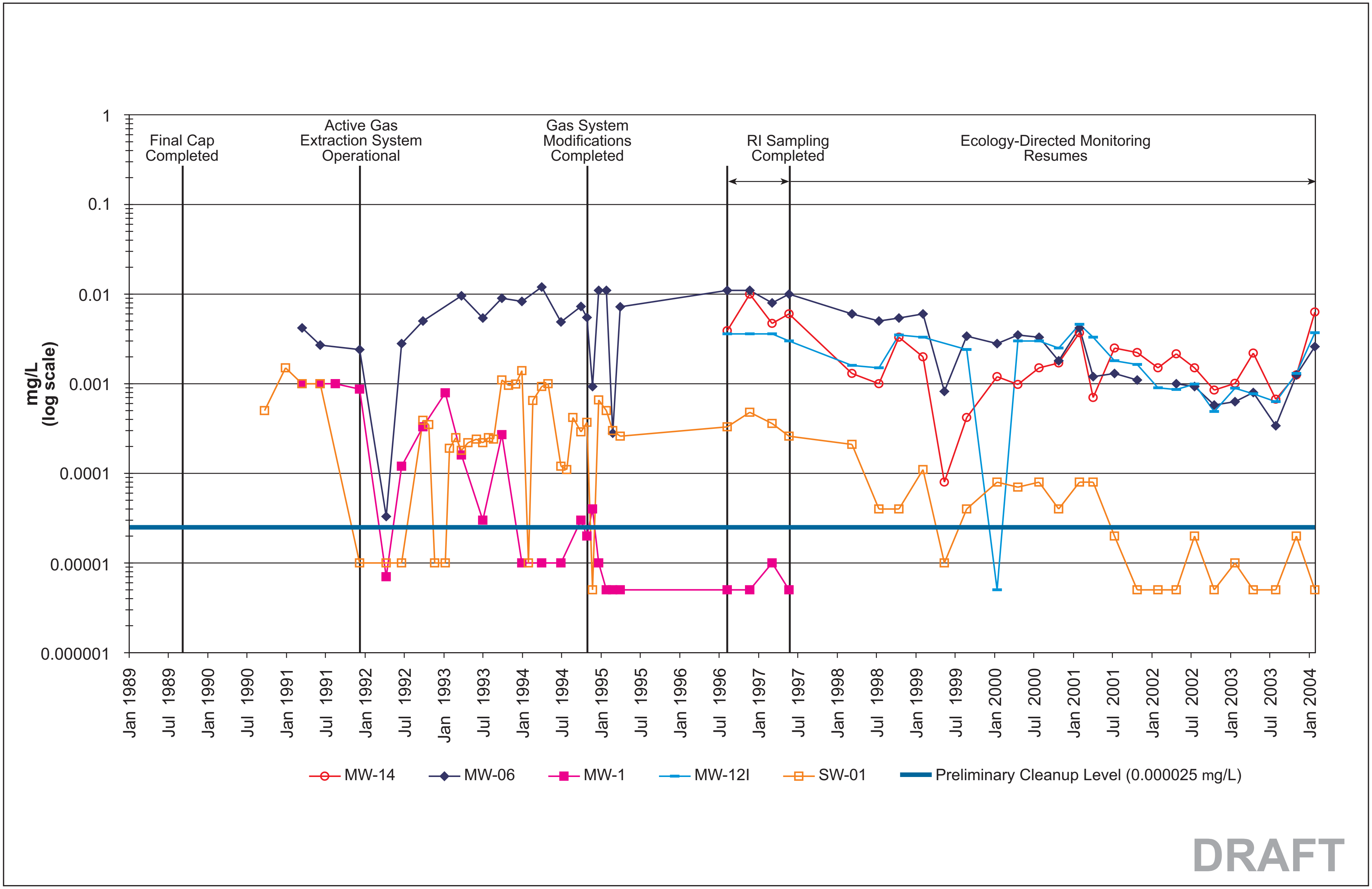


Figure 9-12a
Time-Series Plot of Vinyl Chloride in Groundwater and Surface Water for the MW-14 to SW-01 Flow Path
Hansville Landfill RI/FS

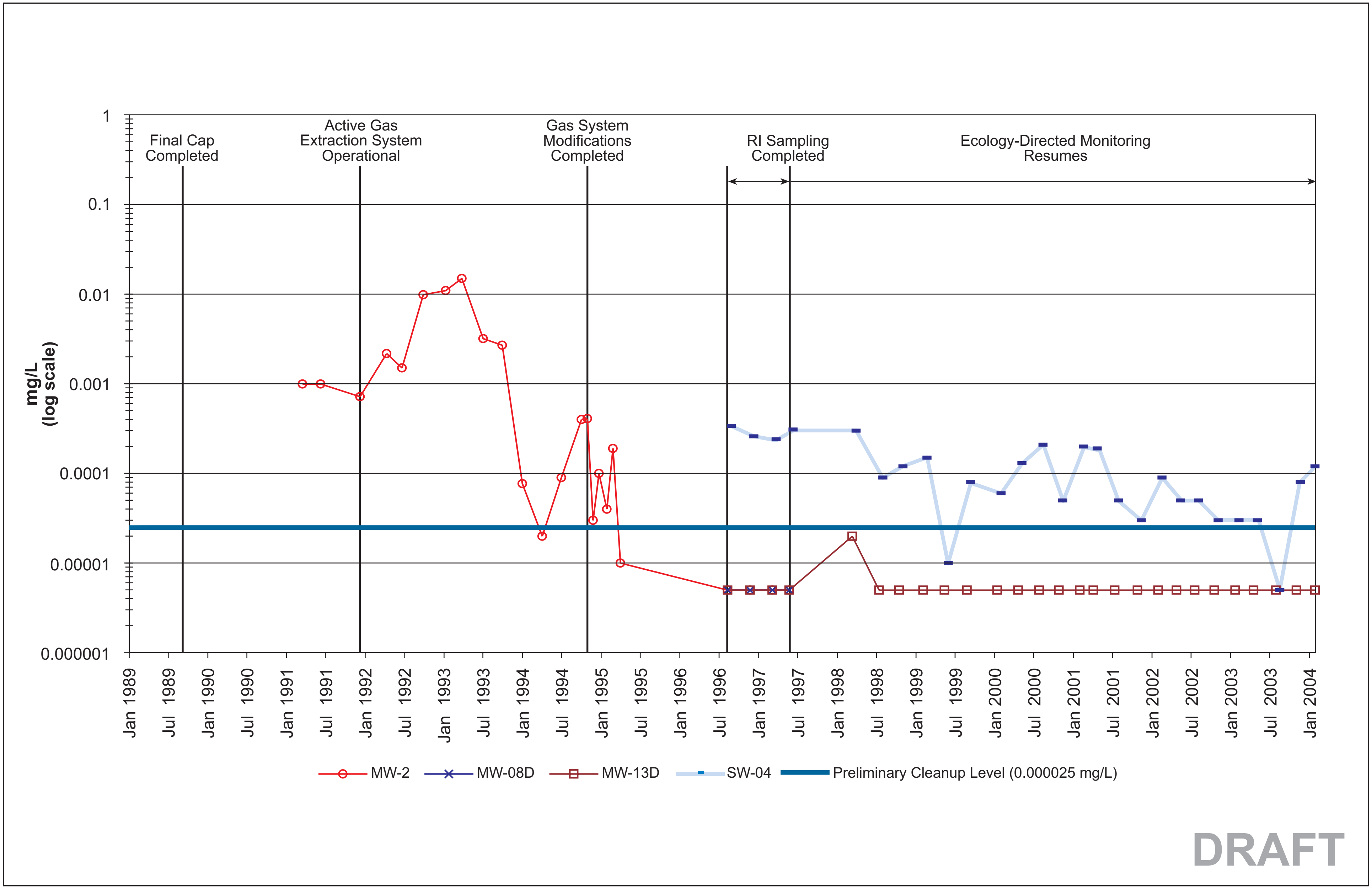


Figure 9-12b
Time-Series Plot of Vinyl Chloride in Groundwater and Surface Water for the MW-02 to SW-04 Flow Path
Hansville Landfill RI/FS

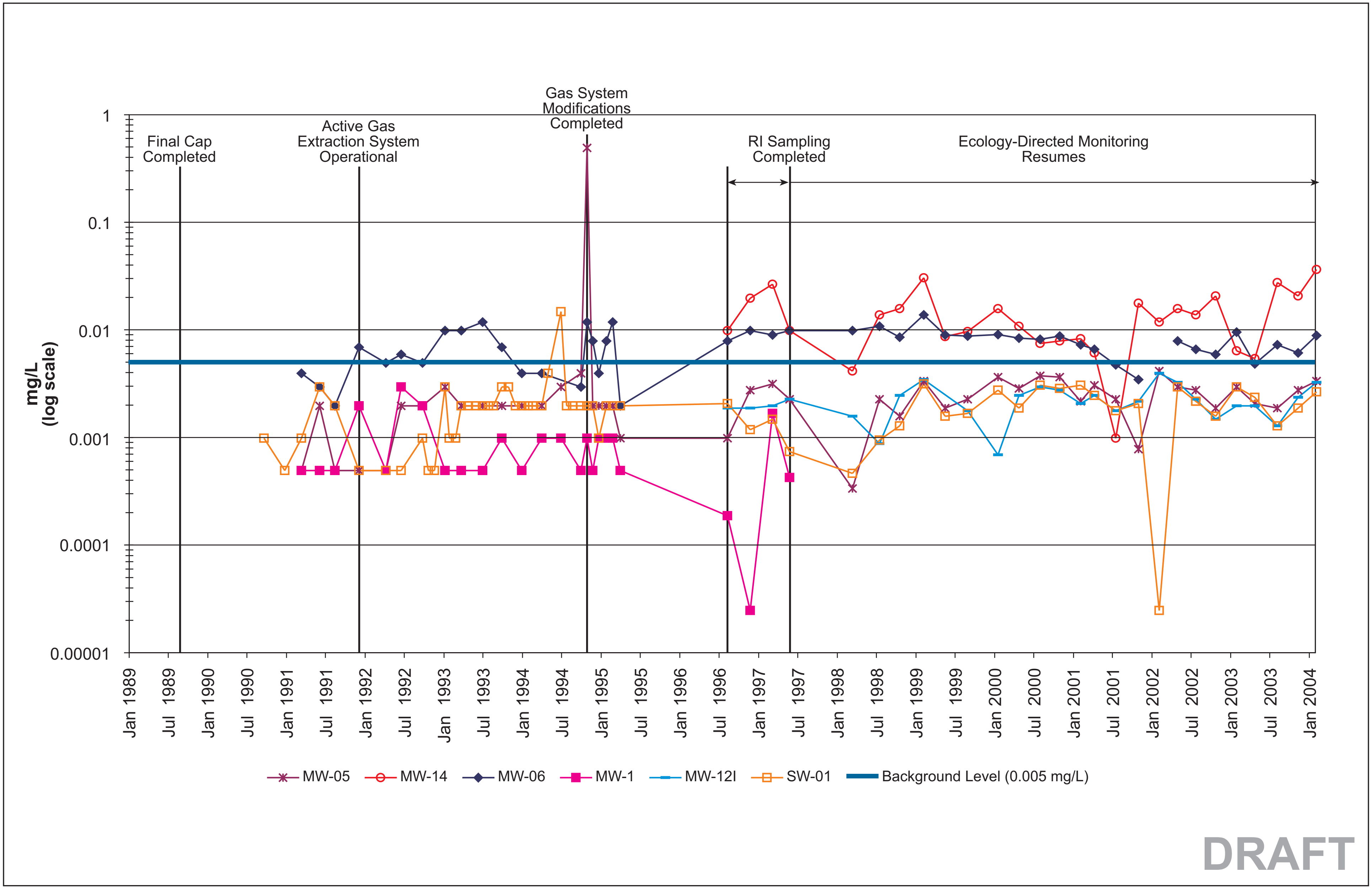


Figure 9-13a
Time-Series Plot of Arsenic in Groundwater and Surface Water for the MW-14 to SW-01 Flow Path
Hansville Landfill RI/FS

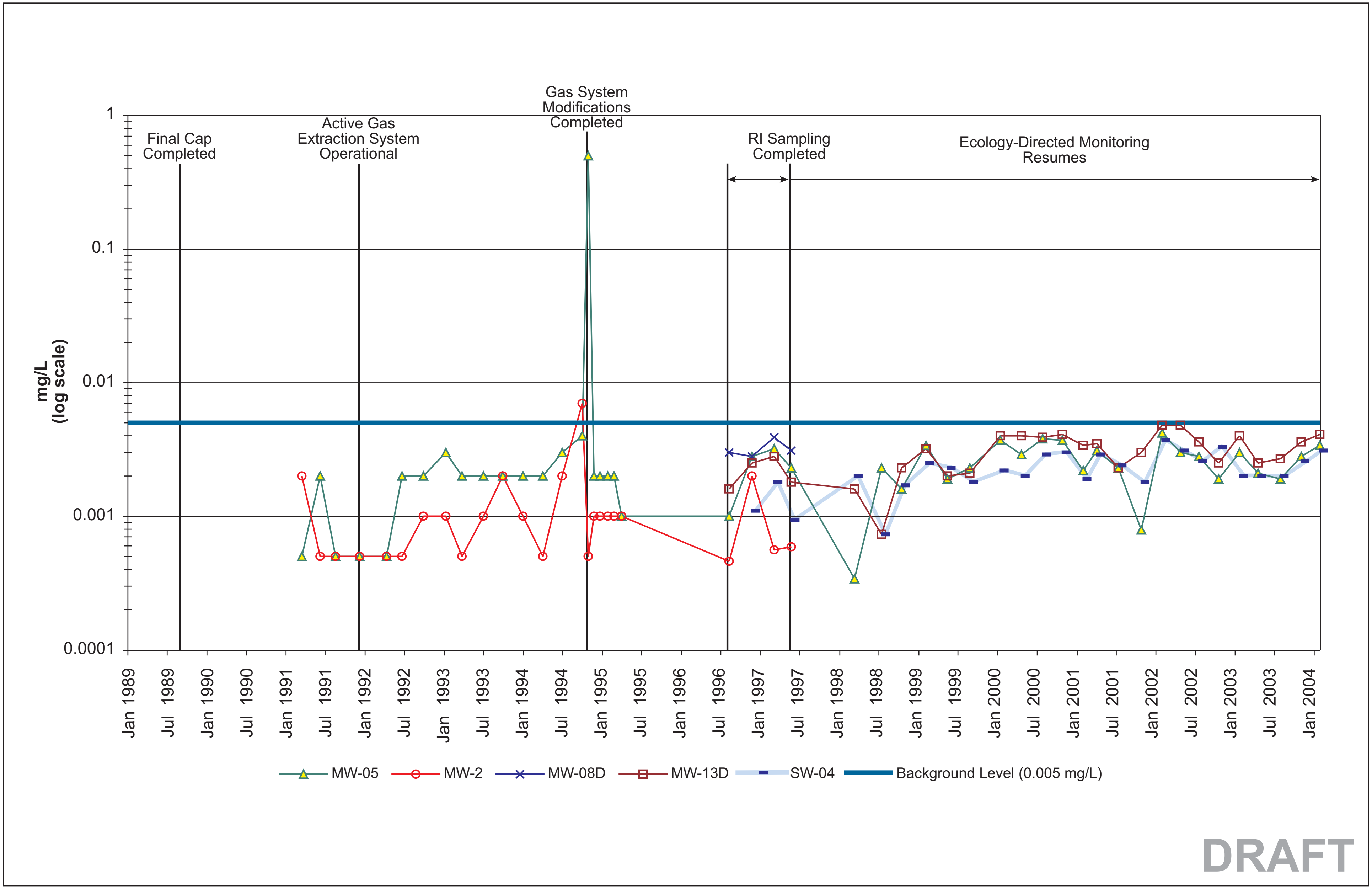


Figure 9-13b
Time-Series Plot of Arsenic in Groundwater and Surface Water for the MW-02 to SW-04 Flow Path
Hansville Landfill RI/FS

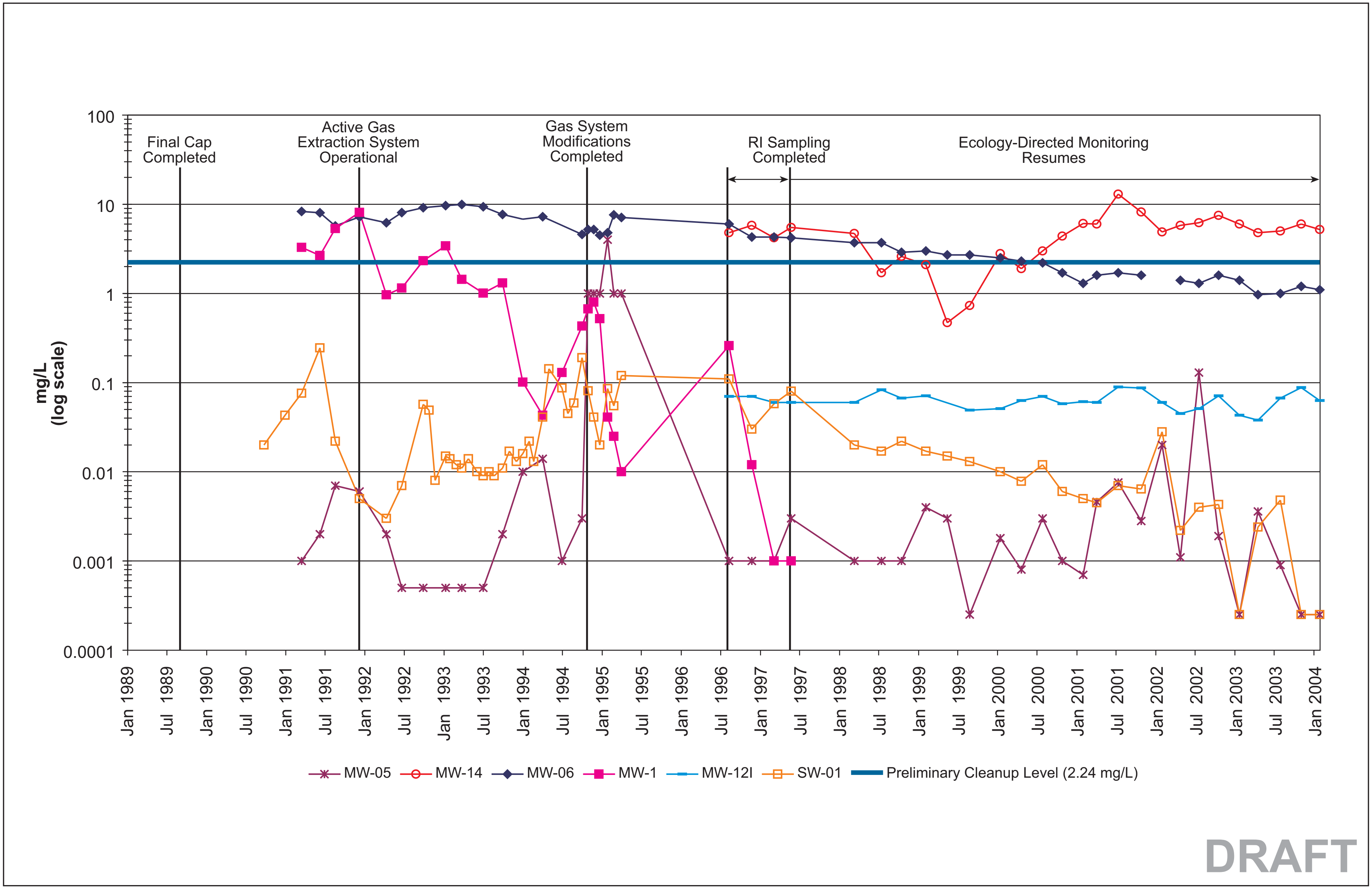


Figure 9-14a
Time-Series Plot of Manganese in Groundwater and Surface Water for the MW-14 to SW-01 Flow Path
Hansville Landfill RI/FS

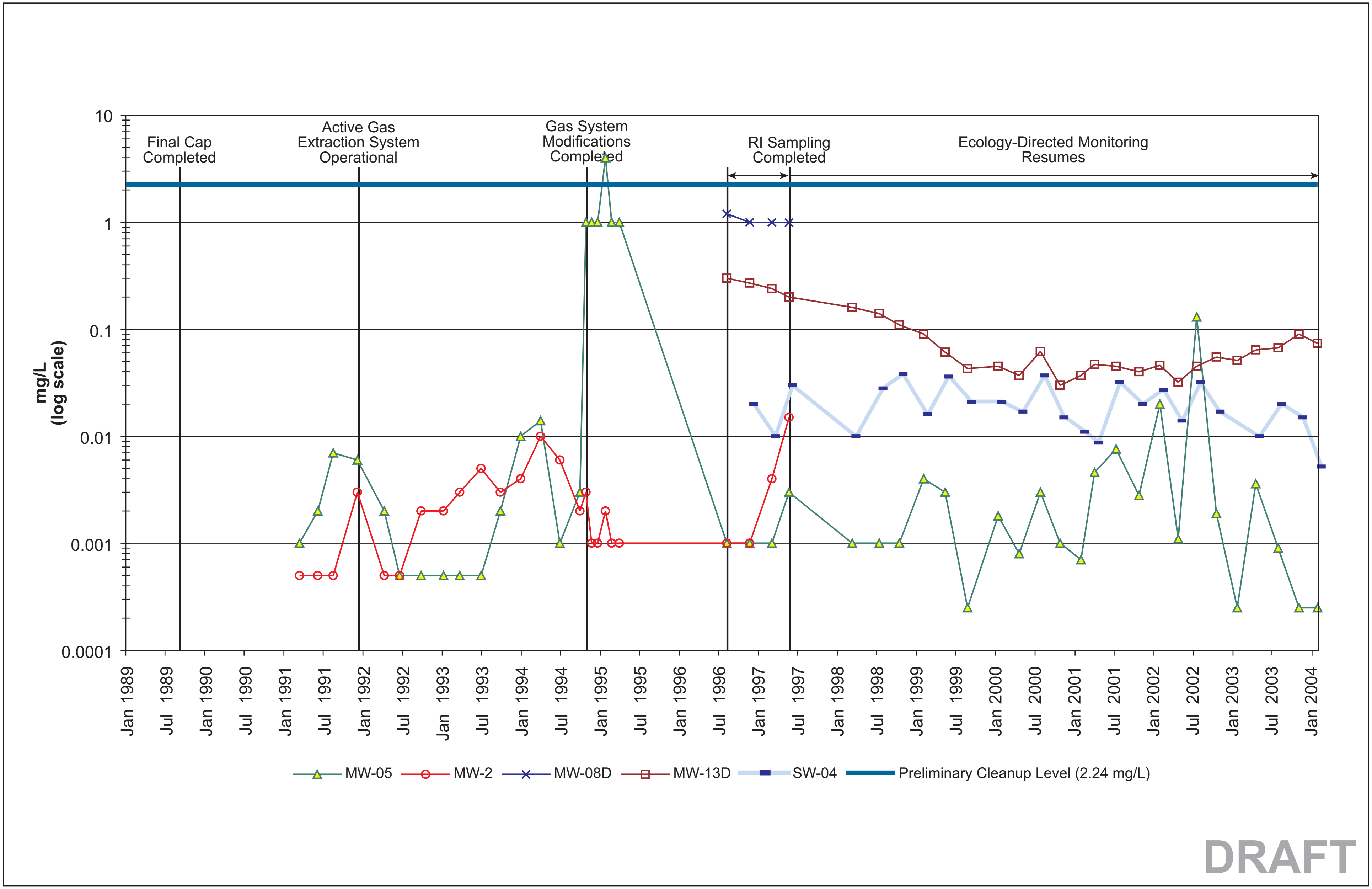


Figure 9-14b
Time-Series Plot of Manganese in Groundwater and Surface Water for the MW-02 to SW-04 Flow Path
Hansville Landfill RI/FS

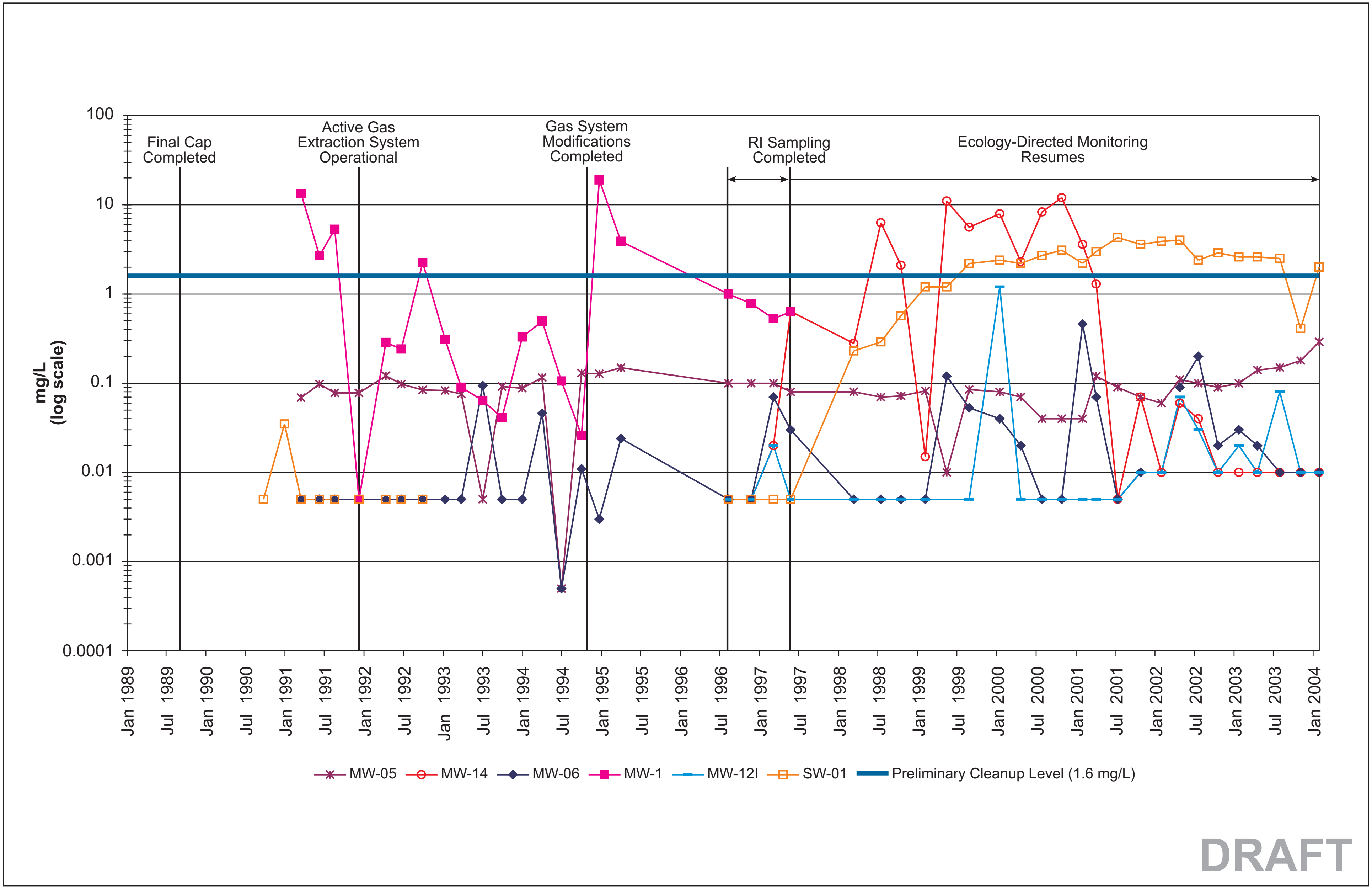


Figure 9-15a
Time-Series Plot of Nitrate in Groundwater and Surface Water for the MW-14 to SW-01 Flow Path
Hansville Landfill RI/FS

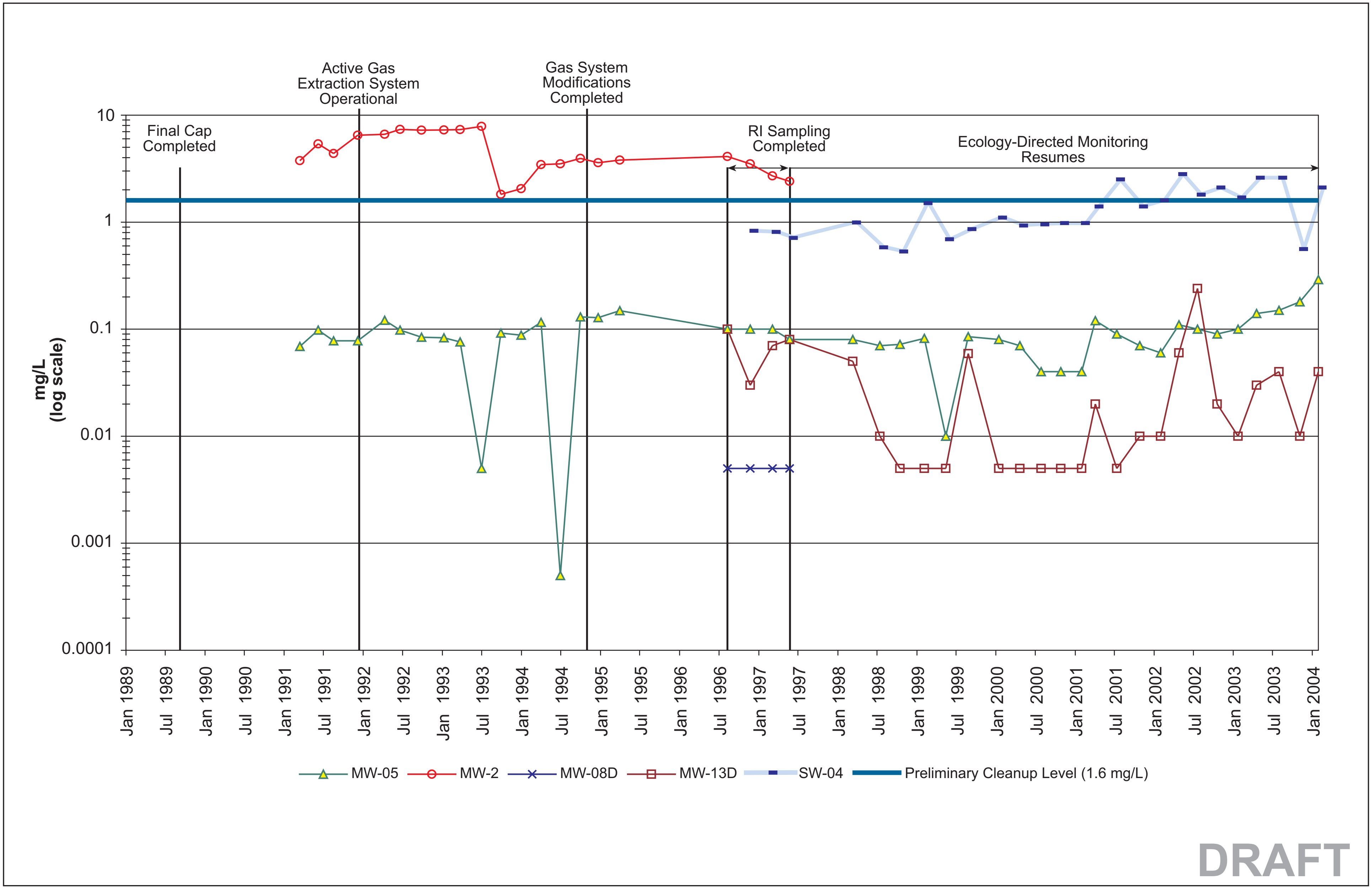


Figure 9-15b
Time-Series Plot of Nitrate in Groundwater and Surface Water for the MW-02 to SW-04 Flow Path
Hansville Landfill RI/FS

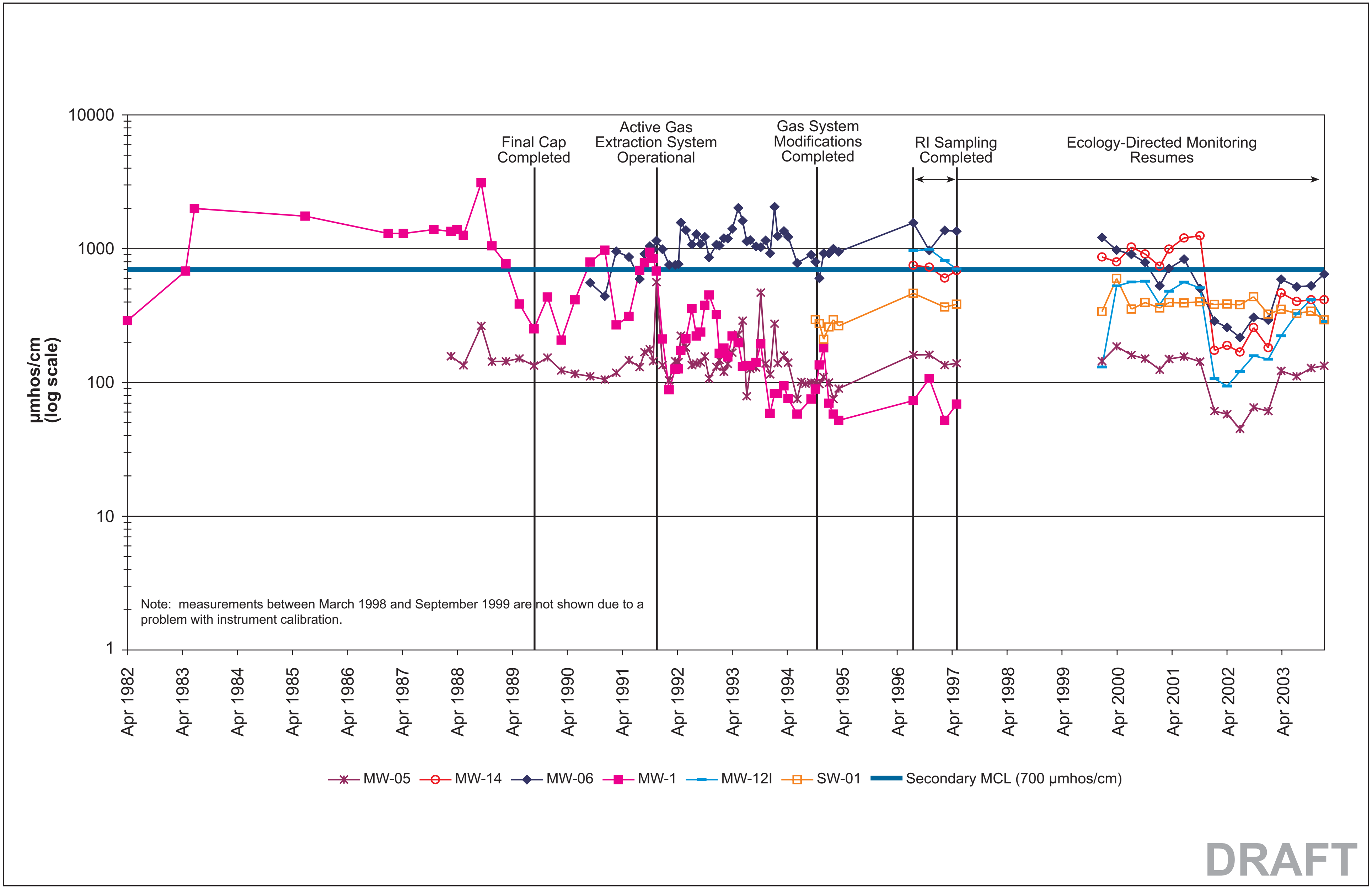


Figure 9-16a
Time-Series Plot of Specific Conductance in Groundwater and Surface Water for the MW-14 to SW-01 Flow Path
Hansville Landfill RI/FS

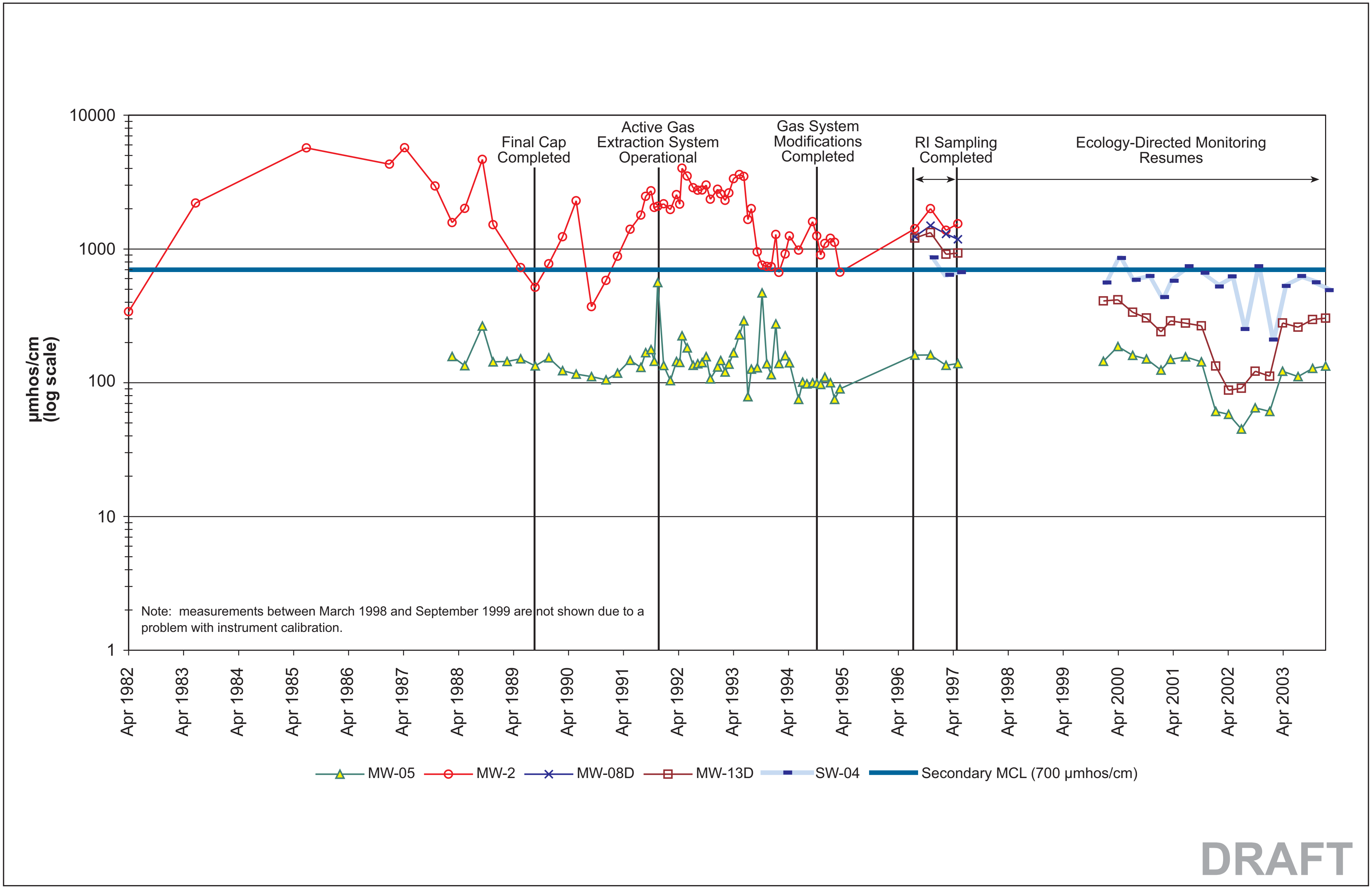
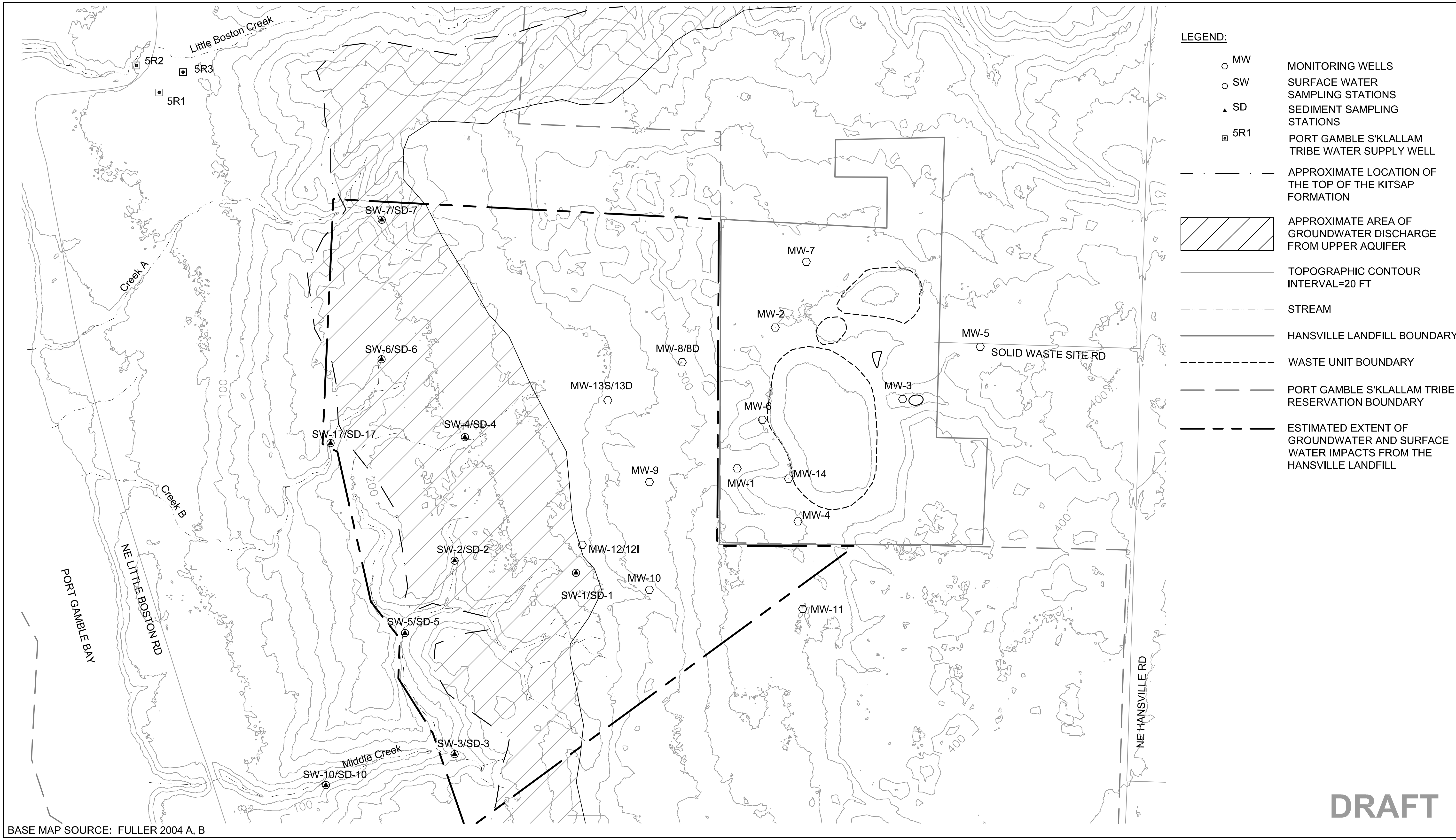


Figure 9-16b
Time-Series Plot of Specific Conductance in Groundwater and Surface Water for the MW-02 to SW-04 Flow Path
Hansville Landfill RI/FS



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N

0 600 SCALE IN FEET

VERTICAL DATUM: NAVD 83

Figure 9-17
Estimated Extent of Groundwater and Surface Water Impacts from the Hansville Landfill
Hansville Landfill RI/FS

10. FINDINGS AND CONCLUSIONS

1. During the time that the Landfill operated as a solid waste disposal site, waste deposited in the Landfill disposal areas consisted of municipal refuse, demolition debris, and pumpings from septic tanks.

2. The Landfill was closed in 1989 and an engineered system that met or exceeded landfill closure regulations was completed in 1990. This system included a geomembrane cover, surface water drainage controls, and a passive gas control system that was subsequently upgraded to an active landfill gas extraction and flaring system.

3. Field investigations of soil, groundwater, and surface water conditions on and adjacent to the Landfill Property confirm the following physical system:

   - The Site occupies an area that is underlain by a fine- to medium-grained sand unit with depths to groundwater ranging from about 50 to 100 ft below ground surface (approximately 45 to 55 ft beneath the lowest depth of waste). This shallow zone of groundwater is referred to as the upper aquifer. The upper aquifer is 80- to 120-ft thick beneath the Landfill Property.

   - The upper aquifer is bounded at its base by a thick clay unit known as the Kitsap Formation, which extends over the entire region and is approximately 150 ft thick beneath the Site. The Kitsap Formation effectively isolates the upper aquifer from an underlying sand and gravel unit (Salmon Springs Drift) that is a regional water supply aquifer in north Kitsap County.

   - Groundwater in the upper aquifer flows to the west and southwest from the Landfill and discharges to creeks that originate along the hillside west of the Landfill. These streams generally flow westward into Port Gamble Bay, a marine inlet of Hood Canal.

   - Surface water runoff from the Landfill does not come into contact with any waste on the Site. Most runoff from the Property is routed to the siltation basin located on the western property boundary. Because surface runoff from the Landfill (including discharge from the siltation basin) infiltrates into the sandy soils, there is no direct overland flow connection between the Landfill and the streams west of the Landfill.

4. Sampling of landfill gas, groundwater, surface water, and sediment indicates that impacts attributable to the Landfill are limited to a trapezoidal area that extends from the Landfill to the west and southwest onto Tribal property. This area is bounded by the eastern boundary of the waste disposal areas on the Property; the northern and southern extent of observed impacts to groundwater downgradient of the Landfill; the headwaters of Middle Creek, Creek A, and Creek B; and the area where the upper aquifer terminates at the outcrop of the underlying Kitsap Formation.

5. The nature and extent of chemicals attributed to impacts from the disposal areas of the Landfill have been characterized by the RI.

6. Chemicals detected in groundwater, surface water, and freshwater sediment during the Hansville Landfill RI were subjected to a screening process in order to establish preliminary cleanup levels, identify exceedances of these levels, and select chemicals for further evaluation in the Feasibility Study (FS). The “preliminary” terminology is used at this screening stage to acknowledge that “final” cleanup

levels will be established in the FS report. It will be these cleanup levels that will be used to the select an appropriate remedial alternative for the Site.

The results of the RI assessment of Landfill impacts are summarized as follows:

- Air

  On-site and off-site exposure pathways are effectively eliminated by the active landfill gas extraction and flaring system. The landfill gas is combusted and destroyed within the landfill gas flares. Continued operation of this system (until landfill gas is depleted) will keep this exposure pathway incomplete.

  Although vinyl chloride is present in gas generated within the solid waste disposal area, this gas is effectively being extracted and destroyed in the active landfill gas extraction and flaring system (installed in 1991 and upgraded in 2003). The active landfill gas and flaring system has also been effective in removing gas that previously migrated into the surrounding soils, as confirmed by gas pressure and gas sampling data from multi-depth perimeter gas probes. Landfill gas was not found to be migrating beyond the Property boundary.

- Groundwater

  Arsenic, bis(2-ethylhexyl)phthalate, copper, lead, manganese, nickel, nitrate, silver, vinyl chloride, and zinc exceeded screening criteria and will be evaluated further in the FS. Vinyl chloride and manganese in the upper aquifer were found at highest concentrations adjacent to the waste disposal areas at the Landfill. Concentrations of these chemicals decrease downgradient, to the west and southwest, and beyond the Property boundary, where groundwater from the upper aquifer discharges to surface water. Although the highest detected concentrations of arsenic occur in the monitoring wells immediately adjacent to all three disposal areas, arsenic also occurs naturally in the upper aquifer.

- Surface Water

  Groundwater in the upper aquifer that is hydraulically downgradient of the waste disposal areas at the Landfill discharges to Middle Creek and its tributaries, Creek B, and possibly to Creek A, and is the source of base flow to those streams. Chemicals that exceeded screening criteria at the discharge to stream headwaters or at downstream sampling stations were arsenic, copper, vinyl chloride, and zinc. These chemicals will be carried forward to the FS.

- Sediment

  Surface water in the streams downgradient of the Landfill is in contact with sediments in the stream beds. The following chemicals in sediment exceeded screening criteria and will be evaluated in the FS: antimony, arsenic, chromium, manganese, nickel, and silver.

7. Based on the analysis conducted in the RI, the following chemicals are recommended for further evaluation in the FS: antimony, arsenic, bis(2-ethylhexyl)phthalate, chromium, copper, lead, manganese, nickel, nitrate, silver, vinyl chloride, and zinc.

8. The highest measured concentrations of chemicals that will be evaluated in the FS occur immediately adjacent to the Landfill waste disposal areas, with decreasing concentrations detected outside the Property boundary. The concentrations of these chemicals in on-site and off-site monitoring wells have been stable or declining over time, as the previously implemented source control/remedial actions (landfill closure, engineered cap/cover system, and active landfill gas extraction and flaring system) continue to function as designed.

9. Impacts of these chemicals to the groundwater beneath the waste disposal area from residual leachate and landfill gas should continue to decrease over time, as the engineered cover system and active landfill gas extraction and flaring system continue to function as designed.

10. Results of this RI will be used in the FS to assess potential risks posed by these chemicals to human health and the environment, and to determine the benefit and cost of remedial actions in addition to those already implemented at the Landfill, which included capping, surface water drainage control, and landfill gas control measures.

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