DEPARTMENT OF THE ARMY
U.S. ARMY ENGINEER DISTRICT, SACRAMENTO
CORPS OF ENGINEERS
1325 J STREET
SACRAMENTO, CALIFORNIA 95814-2922

REPLY TO
ATTENTION OF

August 6, 2007

Ms. Theresa McGarry
Department of Toxic Substances Control
8800 Cal Center Drive
Sacramento, CA 95826-3200

Dear Ms. McGarry:
Please find enclosed the *Draft Final, Five-Year Review Report for Former Hamilton Army Airfield Landfill 26, Novato, California* for your review and comment. The purpose of this five-year review of Landfill 26 on Hamilton Army Airfield is to make sure that cleanup activities associated with landfill soil/refuse, groundwater and soil-gas continue to protect human health and the environment. The review generally consists of studying information about the site, conducting a site inspection and interviewing personnel who are familiar with the site history and cleanup.

As part of the review, site issues are identified and follow-up actions are recommended to address the issues. A protectiveness statement explains whether the cleanup continues to be effective and what other measures may still be needed at the site.

If possible, we would like you to provide your comments or concurrence on this document to us by September 7, 2007. If you have any questions, please contact me at (916) 557-6965.

Raymond E. Zimny
Project Manager

See Distribution List

DRAFT FINAL
FIVE-YEAR REVIEW REPORT

FOR
FORMER HAMILTON ARMY AIRFIELD LANDFILL 26
NOVATO, CALIFORNIA

July 2007

Prepared for
Contract No. GS-10F-0132K
Delivery Order W9 1238-06-F-0135
United States Army Corps of Engineers
1325 J Street, CESPK-CT-B
Sacramento, CA 95814-2922

Approved by: **Date:**

_____ _____

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List of Acronyms

ARAR	applicable or relevant and appropriate requirements
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
CAO	Corrective Action Order
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	constituents of concern
COPC	constituent of potential concern
CSM	conceptual site model
ESD	Explanation of Significant Differences
GMP	gas monitoring probes
GSA	General Service Administration
HAAF	Hamilton Army Airfield
HDPE	high-density polyethylene
MWH	Montgomery Watson Harza
NPDES	National Pollutant Discharge Elimination System
O&M	operation and maintenance
OU	Operable Unit
PCB	polychlorinated biphenyl
RCRA	Resource Conservation and Recovery Act
RI/FS	remedial investigation/feasibility study
ROD	Record of Decision
SVOC	semivolatile organic compound
TPH	total petroleum hydrocarbons
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency

VLDPE	very low-density polyethylene
VOC	volatile organic compound
Water Board	California Regional Water Quality Control Board, San Francisco Bay Region
WCC	Woodward-Clyde Consultants
WDR	Waste Discharge Requirement

Five-year Review Summary Form
SITE IDENTIFICATION
Site name : Landfill 26, Former Hamilton Army Airfield
EPA ID: CA0000556308
Region: 9 **State:** CA **City/County:** Novato/ Marin
SITE STATUS
NPL status: o Final o Deleted ☒ Other (specify) Non NPL Status
Remediation status (choose all that apply): ☒ Operating ☒ Complete
Multiple OUs? ☒ YES o NO **Construction completion date:** N/A Landfill Soil/Refuse OU and Groundwater OU
Has site been put into reuse? o YES ☒ NO
REVIEW STATUS
Reviewing agency: o EPA o State o Tribe ☒ Other Federal Agency: United States Army
Author name: Terri Herson, with senior review by Caroline Ziegler
Author title: Project Manager **Author affiliation:** CH2M HILL Inc.
Review period: January 2, 2007 – May 24, 2007
Date(s) of site inspection: February 27, 2007
Type of review: ☒ Statutory o Policy o Post-SARA o Pre-SARA o NPL-Removal only oNon-NPL Remedial Action Site o NPL State/Tribe-lead o Regional Discretion

Review number: ☒1 (first) o 2 (second) o 3 (third) o Other (specify)

Triggering action:

o Actual RA Onsite Construction at OU

o Actual RA

o Previous Five-year Review Report

☒ Construction Completion

o Other (specify)

Triggering action date: _Landfill Cap Construction Complete, 1995

Due date (five years after triggering action date): ___ 2000 (This five-year review is overdue)

Issues and Recommendations

Issue
The groundwater extraction and treatment system that was installed has not been operated since startup testing. This decision not to treat groundwater was not addressed in the site decision documents.

Recommendation
The site decision documents will be updated to reflect the current groundwater remedy. Also the USACE has prepared a technical memorandum for decommissioning of the water treatment plant and planning considerations for future reuse.

Issue
While an interim remedy exists at Landfill 26, a final remedy to address methane in soil-gas has not been established.

Recommendation
The USACE submitted a Feasibility Study for soil-gas in May 2007 (anticipated to become Final in late 2007). This will establish the final remedy for methane in soil-gas, as continued used of the current passive venting system with a perimeter trench and institutional controls.

Issue
Site security issues including vandalism and trespassing are occurring and require additional controls.

Recommendation
Because potential vandalism is resulting in damage to the cap (ruts) as well as to the monitoring wells/probes, it is recommended that site security be improved. Fencing and signs should be assessed and, where necessary, reinforced to allow for only authorized personnel entry. Driving routes within the landfill area should be well established with posted signs, if necessary, to prevent inadvertent damage during maintenance and monitoring activities.

Issue
The previous decision documents require updating to address the current remedy for methane in

soil-gas, groundwater and institutional controls.

Recommendation
The ARARs and decision documents will be updated. A ROD Amendment will be issued to incorporate the current selected remedy for methane in soil-gas, groundwater and institutional controls.

Issue
Coordination between the landfill and wetlands restoration project must ensure that measures are taken to continue adequate surface water drainage at the landfill.

Recommendation
It is recommended that the landfill and wetlands project team continue to collaborate and manage modifications to the drainage facilities to ensure proper surface water drainage and flood control.

Protectiveness Statement

The remedial actions at the Landfill 26 site are currently protective of human health and the environment. In general, potential sources of exposure that could result in unacceptable risks are being controlled.

The current remedial activities for groundwater are protective, with the monitoring network program serving as a means for providing advance notice if results indicate the need for a triggering action due to potential contaminant migration. Currently preferential groundwater pathways for contaminant movement downgradient of the landfill are not evident, and groundwater movement in this area is limited.

The remedial activities for soil/refuse including a RCRA-type cap are protective and maintained through a quarterly inspection program.

The interim remedy currently in place for soil-gas is protective of human health and the environment. The passive venting system with a perimeter trench is effective at preventing soil-gas from migrating to the nearby residential development. To ensure long term protectiveness, USACE conducted a thorough evaluation of the soil-gas data and in May 2007 completed the Draft Final Feasibility Study (FS) for soil-gas. The current interim remedy has been identified by the USACE as the preferred remedial alternative. In addition, institutional controls will prevent damage and limit access to the landfill cap for long term protectiveness.

Executive Summary

A five-year review of the former Hamilton Army Airfield Landfill 26 in Novato, California was completed in July 2007. This five-year review is required by statute and was conducted because hazardous substances, pollutants, or constituents remain at the site at concentrations above levels that would allow for unrestricted use and unlimited exposure. The triggering action for this review was construction completion of the landfill cap in 1995 which makes this five-year review overdue. During the interim period, USACE has continued working with the California Regional Water Quality Control Board, San Francisco Bay Region (Water Board) to update Waste Discharge Requirements and provisions for bringing Landfill 26 to post-closure status, including the preparation of this five-year review report.

Landfill 26 is located at Hamilton Army Airfield, a former military installation in the City of Novato, Marin County, California, approximately 22 miles north of San Francisco. The landfill began receiving refuse in the early 1940s. It was expanded throughout the 1960s and 1970s. Household, commercial, industrial, and construction wastes are believed to have been deposited in the landfill (USACE, 1993).

Investigative studies were conducted during 1985-1987 and culminated in July 1988 with the completion of the Landfill 26 remediation feasibility study. As a result of the feasibility study, the Record of Decision (ROD) for the remedy at Landfill 26 was signed in August 1989. The ROD included two Operable Units (OUs):

- Landfill/Soil Refuse OU: The objectives, as stated in the ROD, included fixation and immobilization (though a solidification process) of the contaminated soil/refuse exceeding levels appropriate for Class II landfills. An Explanation of Significant Differences (ESD) was signed in 1992 to propose changes to the preferred remedy and eliminate statements in the ROD. Specifically, the ESD determined that solidification should be eliminated as a remedy, and an upgraded cap should be constructed to address the soil/refuse. In 1994 and 1995, in response to the ROD and the ESD, Landfill 26 was covered by a Resource Recovery Conservation Act (RCRA)-type cap that has been maintained through a quarterly inspection program.
- Groundwater OU: Groundwater flow and leachate discharges from Landfill 26 were considered potential mechanisms for contaminants to migrate offsite. The 1989 ROD provided for a groundwater extraction and treatment system to treat contaminated groundwater. The 1992 ESD approved modified groundwater treatment processes to more effectively treat constituents in groundwater. The groundwater extraction and treatment system was built according to the ROD and ESD from 1992 to 1993; however, the system has not been operated. Based on years of groundwater monitoring, the data show that contaminants have not significantly impacted groundwater outside of the Landfill 26 boundary and do not pose a threat to human health or the environment. It was further concluded that extraction and treatment are not currently necessary to protect human health and the environment (WCC, 1997). Groundwater monitoring continues and the results are carefully reviewed for early indication of potential changes that might lead to offsite contaminant migration.

Landfill gas migration was not anticipated during the original remedy selection based upon studies conducted during the 1980's which showed only low levels of soil-gas contaminants. However, methane in soil-gas became an issue based on investigations concluding in 1999 which showed methane levels ranging from 5 to 50 percent. Additional remedial action at the site has been conducted based upon guidance suggested in Water Board Orders issued in December 2001. Specifically, Tentative Cleanup and Abatement Order No. 01-139 and Time Schedule Order No. 01-140 required the investigation and remediation of landfill soil-gas. These orders established a schedule for the development and implementation of corrective action plans for addressing landfill gas (particularly methane), post-closure maintenance activities, and improved groundwater and soil-gas monitoring. As a result, a passive venting system was constructed in 2002 and completed in January 2003 as an interim remedy. The vent trench is designed to allow landfill gas to passively flow through the gravel fill, into the horizontally perforated collection pipe, and to the surface where it naturally vents to the atmosphere through a series of vertical risers. Soil-gas monitoring continues to be performed.

Based on a review of documents and data, additional remediation activities will be conducted at the site to ensure long-term protectiveness. A feasibility study for soil-gas is currently underway. The feasibility study includes Comprehensive Environmental Response, Compensation, and Liability Act criteria evaluation of remedial technologies and alternatives to mitigate landfill refuse-related contaminants in soil-gas that resulted from past material disposal and handling and waste disposal practices at Landfill 26. Recommended follow-up action includes finalizing the soil-gas feasibility study and implementing the preferred alternative. The Draft Final Feasibility Study was submitted for agency review in May 2007 and is anticipated to be finalized by late 2007.

Also, an additional monitoring well northeast of the landfill has recently been installed in early 2007 to increase downgradient data capture and to monitor stable contaminant concentrations. Based upon review of the groundwater data and the regulatory history, this groundwater monitoring well provides a preferred location for monitoring downgradient migration.

USACE is currently evaluating the status of the groundwater treatment plant. Follow-up actions include completion and approval of the technical memorandum that will propose future land use and decommissioning considerations.

In addition, as part of this five-year review, technical memoranda have been prepared to document USACE's follow-up actions: updated risk assessment for the groundwater OU, proposed ARARs, development of performance-based groundwater monitoring to track changes in contaminant concentrations and the potential for their migration, and proposed institutional controls.

Currently, all implemented remedies are found to be functioning as intended by the decision documents, and are protective of human health and the environment. The findings of this review and the Draft Final Risk Assessment Update (completed in April 2007) indicate that Landfill 26 contaminants do not currently pose a risk to human health or the environment. However, results of the regulatory review, ongoing evaluations and recommendations for increased monitoring support the need for a ROD Amendment for Landfill 26.

SECTION 1.0

Introduction

The United States Army Corps of Engineers (USACE) conducted a five-year review of the remedial actions implemented at the Former Hamilton Army Airfield (HAAF) Landfill 26 in Novato, California (Figure 1-1). This review was conducted from January to May 2007.

The five-year review process evaluates whether the remedy at the Landfill 26 remains protective of human health and the environment. The methods, findings, and conclusions of reviews are documented in five-year review reports. In addition, five-year review reports identify any deficiencies found during the review and provide recommendations for addressing these deficiencies.

USACE is preparing this five-year review report pursuant to Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). CERCLA Section 121(c), as amended, states:

> If the President selects a remedial action that results in any hazardous substances, pollutants, or contaminants remaining at the site, the President shall review such remedial action no less often than each five-years after the initiation of such remedial action to assure that human health and the environment are being protected by the remedial action being implemented.

The United States Environmental Protection Agency (USEPA) interpreted this requirement further in the National Contingency Plan, 40 Code of Federal Regulations (CFR) Section 300.430(f)(4)(ii), which states:

> If a remedial action is selected that results in any hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such action no less often than every five years after the initiation of the selection remedial action.

Consequently, this report reviews all remedies implemented at the Landfill 26 site in Novato, California.

This is the first five-year review report for the site. The triggering action for the Landfill 26 five-year review report is the completion of the landfill cap construction which occurred in 1995. This five-year review, which should have been completed in 2000, is overdue. USACE is following the guidance provided in California Regional Water Quality Control Board, San Francisco Bay Region (Water Board) Order No. R2-2006-0064 which suggests that a five-year review should be conducted at the site and completed by December 2007. This report evaluates the remedial objectives as stated in the CERCLA decision documents including a 1989 Record of Decision (ROD), and 1992 Explanation of Significant Differences (ESD) for the Landfill/Soil Refuse and Groundwater Operable Units. Also USACE is considering the guiding principals stated in the Water Board Waste Discharge Requirement (WDR) #92-029 (and subsequent updates). The interim remedial action currently in place to address a soil-

gas and methane migration issue discovered subsequent to the CERCLA decision documents is also discussed in this report. Figure 1-2 provides a map of the study areas and the Landfill 26 vicinity.

This report is organized into sections that describe the history and setting of the Landfill 26, remedial action decisions and implementation, and an evaluation of remedial actions. These sections are:

- Section 2.0 provides a site chronology.
- Section 3.0 provides setting, the history of contamination, and initial response at the site.
- Section 4.0 discusses the remedial action implemented at the site, current status of the remedy, and treatment system operation and maintenance (O&M) activities and cost.
- Section 5.0 discusses activities performed during the five-year review process.
- Section 6.0 provides technical assessment of the remedial action implemented.
- Section 7.0 identifies issues.
- Section 8.0 provides recommendations and follow-up actions.
- Section 9.0 provides the protectiveness statement.
- Section 10.0 discusses the next five-year review.
- Section 11.0 provides list of works cited during the preparation of this document.

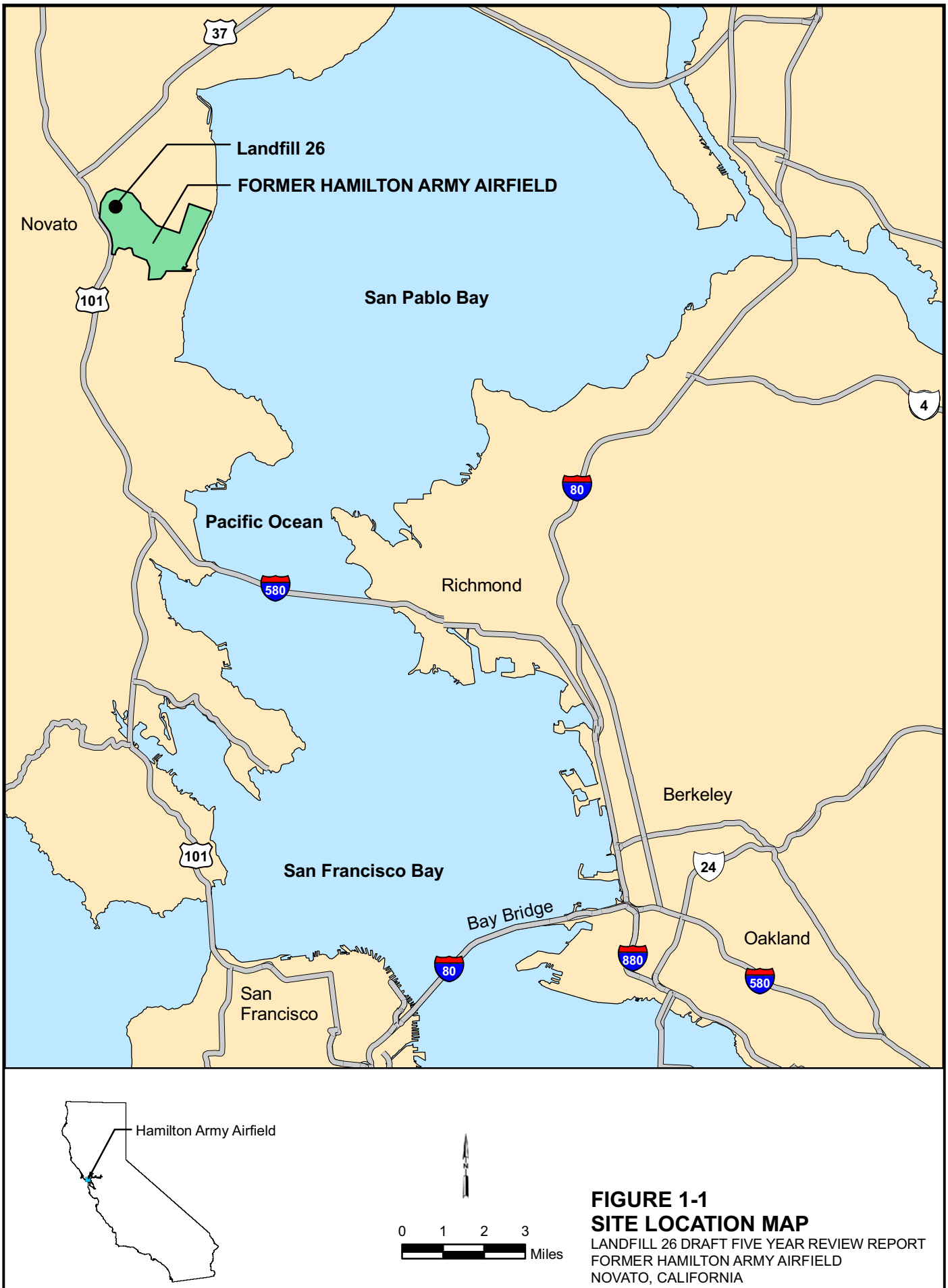
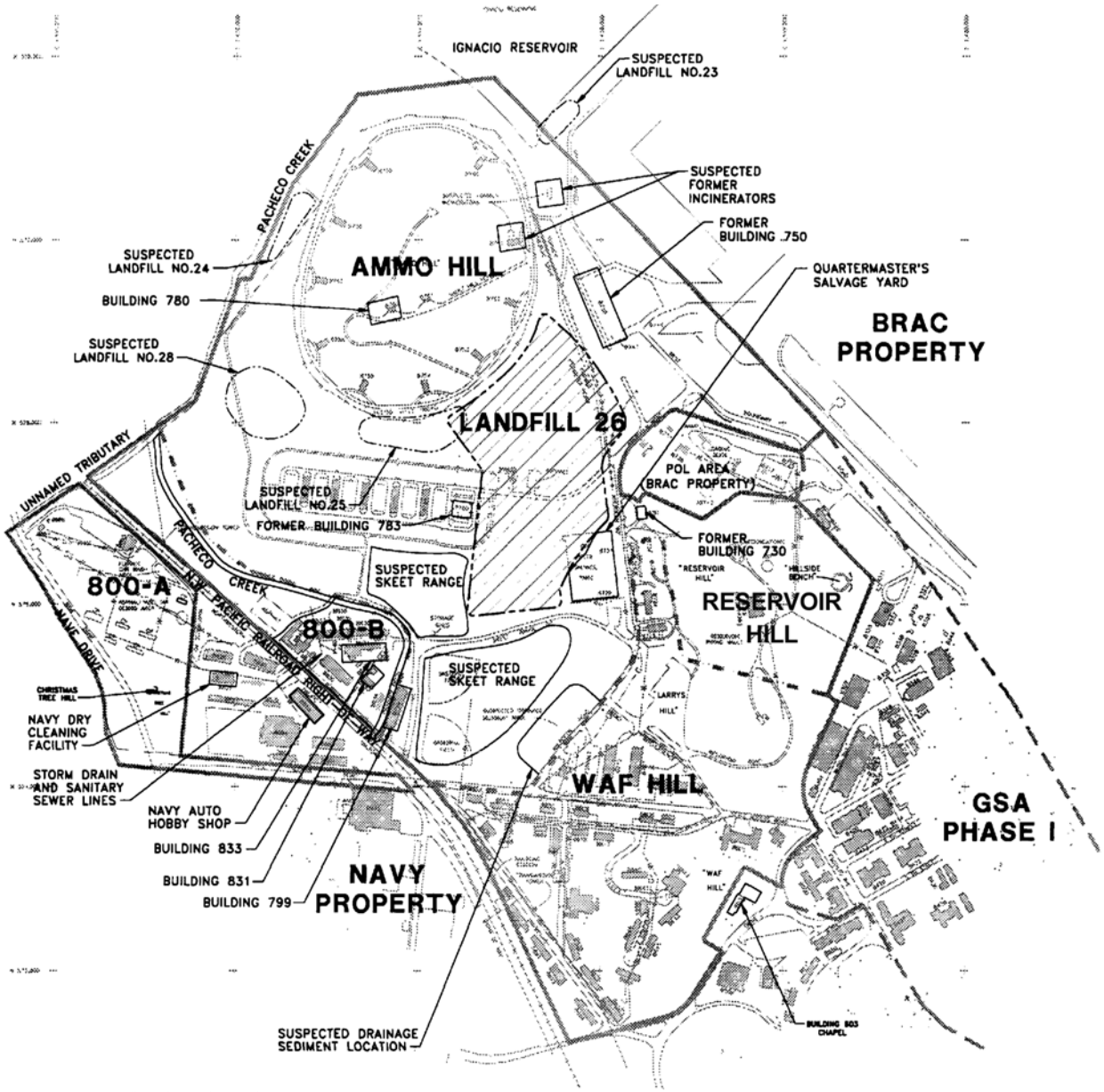


FIGURE 1-1
SITE LOCATION MAP
LANDFILL 26 DRAFT FIVE YEAR REVIEW REPORT
FORMER HAMILTON ARMY AIRFIELD
NOVATO, CALIFORNIA

CH2MHILL

SAC \\GLACIER\SACGIS\HAMILTON\MXD\MODEL_UPDATE\SITE_LOCATION.MXD 4/18/2006 13:59:32
ES032006019SAC_HAAF_Landfill_26 HAAF_0033_site_location_map.ai 05-12-06 tdaus



SCALE (FEET)

600 0 600

GENERAL SERVICES ADMINISTRATION (GSA) PHASE II SALE AREA BOUNDARY LINE

GSA PHASE II PARCEL BOUNDARY LINE

GSA PHASE I BOUNDARY LINE

APPROXIMATE LOCATION OF LANDFILL 26

NOTE: This figure depicts areas investigated for the GSA in the 1990s.

FIGURE 1-2
STUDY AREAS IN 1990s NEAR LF26
LANDFILL 26 DRAFT FIVE YEAR REVIEW REPORT
FORMER HAMILTON ARMY AIRFIELD, NOVATO, CALIFORNIA

SOURCE: Site Investigation Report 800-B and Ammo Hill Parcels, GSA Phase II Sale Area (IT, 1998a)

CH2MHILL

ES032006019SAC_HAAF_Landfill_26 HAAF_0001_study_areas.ai 05-12-06 tdaus

SECTION 2.0

Site Chronology

Table 2-1 provides a chronology of events at the HAAF Landfill 26.

TABLE 2-1
Chronology of Events
Five-year Review Report for Landfill 26, Former Hamilton Army Airfield, Novato, California

Date	Description
Early 1930s	Army acquired Hamilton Airfield property from Marin County.
1940s to early 1970s	Landfill 26 was used as refuse facility.
1974	Landfill 26 was listed as surplus property and deactivated.
1985	Woodward-Clyde Consultants (WCC) conducted a study of surface and subsurface hazardous material contamination of the General Service Administration (GSA) Phase I and II Sale Areas. Landfill 26 and surrounding areas were assessed for hazardous materials by Army. Levels of gross-alpha and beta radionuclides detected were believed to be related to the high total dissolved solids content of the water.
1986	Preliminary investigation was performed that included a methane study, groundwater and soil sampling, and topographic and geophysical surveys. Study concluded that Landfill 26 was nonmethanogenic, and the Refuse Zone was in a state of near-perennial saturation. Four primary horizons were characterized, and groundwater-level fluctuations were recorded and correlated with seasonal changes in precipitation. The investigation also identified an area of oily sludge and detections of several organic and inorganic constituents that warranted further investigation. The investigation also concluded that it is unlikely that any of the contaminants would present a significant threat to human health by inhalation or dermal contact. The assessment also concluded that groundwater contaminants did not present a significant threat to humans because groundwater from Landfill 26 was not being used—and would probably never be used—as drinking water.
1986	As part of the WCC 1986 investigation, a preliminary hazard assessment was conducted according to United States Environmental Protection Agency (USEPA) guidelines. The assessment concluded that it is unlikely that any of the contaminants would present a significant threat to human health by inhalation or dermal contact. The assessment also concluded that groundwater contaminants did not present a significant threat to humans because groundwater from Landfill 26 was not being used—and would probably never be used—as drinking water. However, since Landfill 26 and the surrounding suspected landfills were included in the parcel offered for sale by the GSA, it was reasonable to assume that the land and groundwater usage could change. Therefore, the USACE was required to complete a remedial investigation/feasibility study (RI/FS) and prepare a remedial plan to properly close Landfill 26.
1987	The remedial investigation was conducted and completed to estimate the volume and extent of contamination and to define potential treatment options in the feasibility study. The remedial investigation reported approximately 151,500 cubic yards of refuse in Landfill 26; however, because the soil and fill contamination exceeded Landfill 26's aerial boundary, the volume of contaminated material within Landfill 26 was estimated at approximately 233,000 cubic yards (based on preliminary cleanup criteria developed as

TABLE 2-1
Chronology of Events
Five-year Review Report for Landfill 26, Former Hamilton Army Airfield, Novato, California

Date	Description
	part of the feasibility study.
1988	A feasibility study was completed to evaluate the alternatives for remediation at Landfill 26. The feasibility study substantially complied with EPA guidance under the CERCLA. The feasibility study included both human health and environmental risk assessments, developed cleanup criteria for remediation of contaminated groundwater and soil/refuse, and presented detailed analysis and evaluation of various remedial alternatives. A preliminary assessment of the site remediation criteria revealed that compliance with applicable and relevant and appropriate requirements (ARARs) for the site would govern the selection of alternatives because the site contains solid waste, which must be managed in accordance with California regulations. The health risk assessment was considered to be a worst-case analysis and suggested that chronic exposures (via ingestion) of deposited airborne dust emitted from Landfill 26 may represent significant risk to people who were currently living and working at HAAF. USACE later re-evaluated the risks to human health under the existing land-use scenario, using a dispersion model that was more representative of the actual conditions at HAAF. This re-evaluation concluded that the risk associated with exposure to airborne dust would be insignificant under the existing land use scenario.
August 11, 1989	A ROD for Landfill 26 was signed that included eight remedial alternatives. The ROD described the selected remedial alternative, based on the feasibility study conducted in 1988. Chemical fixation and Class II closure with a variance was selected as the proposed remedy. This ROD was subsequently modified by the 1992 ESD.
1990	Sirrine Environmental Consultants began a 1-year assessment of the groundwater, surface water, and surface sediment quality in the vicinity of Landfill 26. The objective was to evaluate the effect of Landfill 26 on water and sediment quality in the vicinity. Sirrine concluded that the presence of Landfill 26 had an impact on groundwater and possibly surface water and sediments. Impacts on surface water and sediments could not be fully assessed with the limited data for groundwater sources to surface water that were not associated with Landfill 26. Due to the presence of contaminants, particularly petroleum hydrocarbons, in background groundwater monitoring wells and in hydraulically upgradient surface water and sediments, Sirrine concluded that it was not possible to determine the portions of the impacts to groundwater and surface water that could be solely attributed to Landfill 26.
1991	Additional soil and groundwater investigation was conducted to more accurately characterize the site and clarify ambiguities in the selected remedy. The additional studies suggested that contamination within Landfill 26 was restricted to a number of small “hot spots.” USACE noted that accurately locating these areas for solidification could be eliminated and that an upgraded Resource Conservation and Recovery Act (RCRA)-type cap placed on Landfill 26 would substantially diminish the possibility of exposure to the waste in Landfill 26. The modified remedy would provide a more effective cap on Landfill 26 than extraction and treatment of groundwater.
1992	ESD was signed. The ESD proposed capping the landfill and groundwater extraction/treatment.

TABLE 2-1
Chronology of Events
Five-year Review Report for Landfill 26, Former Hamilton Army Airfield, Novato, California

Date	Description
1992	The Water Board issued WDR #92-029 to implement the revised remedial alternative, which included closure of the landfill, construction of a low-permeable cap, and hydraulic containment, as described in the ROD and ESD. The Order also required further investigation of groundwater surrounding the landfill, ongoing monitoring of groundwater quality, measures to prevent landfill flooding and cap washout, and implementation of a wetland mitigation plan. Order 92-029 was rescinded by Order 96-113.
1992-1993	Following the ESD, installation of the groundwater remedy commenced. The groundwater extraction system / hydraulic containment system was constructed. A total of 14 groundwater extraction wells were installed to provide hydraulic containment.
1993	Quarterly groundwater monitoring program was initiated. USACE Sacramento District contracted WCC to conduct seven rounds of quarterly sampling beginning in December 1993.
1994 -1995	The landfill refuse/soil remedy was installed. During construction of the landfill RCRA-type cap, 18 groundwater wells were abandoned, the casings of 10 wells were extended, and two damaged wells were repaired.
1995	The landfill cover system and groundwater extraction and treatment systems were completed to meet the requirements of the ROD, ESD, and WDR #92-029. Twenty-three gas monitoring probes (GMPs) were installed at approximate 200-foot intervals around landfill.
1994 to 1996	USACE collected and analyzed landfill gas monthly, beginning in August 1994. The landfill gas samples were analyzed in the field for oxygen, nitrogen, carbon dioxide, methane, methylene chloride, and benzene using a portable gas chromatograph. Landfill gas was collected and analyzed monthly from August 1994 through September 1995. GMP-3 and GMP-5 were destroyed in May 1995 during construction around the Landfill 26 perimeter and were reinstalled in July 1995. Landfill gas was collected and analyzed one time in 1996.
1995	USACE Sacramento District proposed reductions in the groundwater monitoring program based on target analyte trends established from the initial 10 quarters of monitoring.
1995	The Water Board issued WDR #95-188 requiring a National Pollutant Discharge Elimination System (NPDES) permit for the discharge of treated groundwater to the local storm sewer system.
1996	The Water Board approved the proposed changes to the groundwater monitoring program: the reduction of monitoring frequency to annually (from quarterly) and elimination of halogenated volatile organic compounds (VOCs) by EPA Method 8010 and pesticides/polychlorinated biphenyls (PCBs) by EPA Method 8080 from the target analyte list.
1996	Water Board and Department of Toxic Substances Control determined the need for a Summary Technical Report to facilitate its evaluation of USACE Sacramento District's proposal to forego groundwater extraction/treatment and reduce the scope of groundwater monitoring.
1996	The Water Board issued WDR #96-113 requiring continued groundwater monitoring and preparation of the closure plan and the Summary Technical Report. The technical report would re-evaluate the need for hydraulic containment, propose the final closed landfill design, and perform statistical tests to determine the source(s) of groundwater contamination detected outside Landfill 26.
1997	USACE Sacramento District investigated the GSA Phase II Sale Area around Landfill 26.

TABLE 2-1
Chronology of Events
Five-year Review Report for Landfill 26, Former Hamilton Army Airfield, Novato, California

Date	Description
	This investigation noted that the source of halogenated VOC contamination on the west side of Landfill 26 originates from source(s) outside of Landfill 26.
1997	The Summary Technical Report concluded that contaminants from Landfill 26 have not significantly impacted groundwater outside the Landfill 26 boundary based on a comprehensive evaluation of several years of post-RCRA-type cap installation groundwater monitoring data. It was further concluded that extraction and treatment is not currently necessary to protect human health and the environment.
1998	The *Construction Quality Assurance Report, Hamilton Army Airfield, Landfill 26, Final Cover System* was prepared. This report summarizes the construction, installation, and quality control activities employed during the construction of the Landfill 26 final cover system completed in 1995. This report documents that the Landfill 26 final cover system was consistent with the goals of the project plans and technical specifications.
1998	The *Groundwater Treatment System Decommissioning Study* was conducted. The purpose of this study was to decommission ("mothball") the existing Landfill 26 treatment plant and extraction well system. Data from ongoing groundwater monitoring suggested that contaminants in Landfill 26 have not significantly impacted groundwater outside of the Landfill 26 boundary. The study presents the scope of work and specific procedures required to decommission the groundwater treatment plant at Landfill 26.
1998	The *HAAF Landfill 26, Perimeter Grading and Drainage Modifications Alternatives* was prepared to evaluate three perimeter grading modifications options to improve drainage and access to the Landfill 26 top deck, and to repair erosion damage and a side slope seep. The original Landfill 26 design was based on a surface water drainage system that will be significantly altered by the proposed Base Realignment and Closure (BRAC) property development plan. Drainage adjustments were made to prevent flooding of Landfill 26 during a 100-year storm event.
1998	The *Construction Quality Assurance Report, Hamilton Army Airfield, Landfill 26, Grading and Drainage Adjustments* was prepared to summarize the construction, installation, and quality control activities employed during the construction of the Landfill 26 grading and drainage improvements.
1999	USACE Sacramento District prepared the *Boring Log for New Landfill 26 Monitoring Well*, which documents the installation of a downgradient groundwater monitoring well, MW-L26-1, to provide an additional downgradient monitoring point outside the edge of Landfill 26.
1999	The *Final Closure and Post-Closure Maintenance Plan* was completed. The plan includes a groundwater analytical program focused only on known landfill contaminants of concern with samples collected yearly. The plan includes a landfill gas monitoring program to analyze for methane and other landfill gases yearly.
1999	ITSI performed gas sampling during September and December. GMP-4 though GMP-13 were monitored during September; all GMPs that could be monitored were monitored during each of two sampling events in December.
2000	The Army completed a supplemental soil-gas program. The program consisted of nine events, which included sampling of temporary and permanent soil-gas probes. Methane was detected at levels from 5 percent to 50 percent by volume in areas between the eastern margin of the landfill and the southeastern edge of the buffer zone near GMP-17.
2000	USACE conducted an annual landfill monitoring event. 10 GMPs were sampled. Methane was detected at 1 percent by volume at GMP-5 and 21 percent by volume at GMP-9.

TABLE 2-1
Chronology of Events
Five-year Review Report for Landfill 26, Former Hamilton Army Airfield, Novato, California

Date	Description
2001	In January, ITSI completed the *Draft Landfill Gas Migration Study: An Evaluation of the Presence and Distribution of Landfill Gas Along the Eastern Margin of Landfill 26, Hamilton Army Airfield, Novato, California.* The purpose of the study was to evaluate the presence, distribution, and migration of landfill gas along the eastern margin of Landfill 26. Significant additional gas monitoring was conducted for this study.
2001	The Water Board issued Corrective Action Order (CAO) No. 01-139 and Time and Schedule Order (TSO) No. 01-140 requiring investigation and remediation of methane originating from Landfill 26.
2001	USACE conducted additional investigation of methane and VOCs in the landfill southern buffer area and at Hamilton Meadows. Chemical, geochemical, and geologic data were gathered from GMPs, monitoring wells, boreholes, and trenches. Soil-gas data from 2001 to 2003 is presented in the USACE Methane Investigation Report (2004), which found that many contaminated sections beyond the landfill boundary could be attributed to outside sources.
2002-2003	The vent trench for migration control was installed in the landfill buffer zone. The first phase of the gravel filled trench (GMP-07 to GMP-11) was completed in February. The remainder of the trench was finished in August, with the geomembrane installation completed in January 2003.
2003	Shea Homes conducted additional investigations in the southern area of the landfill (near Lot 30). Additional geologic information was obtained from boreholes and trenching and included soil sampling and testing for methane-producing bacteria.
2003	Montgomery Watson Harza (MWH) conducted groundwater and soil-gas monitoring from October to November to determine the effectiveness of the landfill cap in preventing the movement of target analytes. The highest frequency of organic analyte detections was reported for wells screened in the Refuse Zone. The highest concentrations of organic analytes were detected in wells/piezometers screened in the Cross-Gradient West and Upgradient Zone materials and located southwest of the landfill boundary.
2004	MWH conducted soil-gas monitoring event in April. Trends of the April 2004 event were consistent with previous monitoring at Landfill 26. The highest frequency of organic analyte detections was reported in wells screened in the Refuse Zone within the landfill boundary. In October, a semiannual monitoring program was started.
2005	USACE submitted a Landfill 26 Soil-gas and Groundwater Level Field Monitoring Work Plan in June. An addendum to this work plan was submitted by USACE in August.
2005	USACE submitted a *Final Corrective Action Investigation Work Plan* in November 2005 in response to the CAO No. 01-139 and Time and Schedule Order No. 01-140.
2006	Water Board Order R2-2006-0064 issued which rescinded Orders 96-113, 01-139, 01-140.
2006	USACE prepared an updated conceptual site model (CSM) for Landfill 26. This submittal provided an update to the CSM that was presented in the *Corrective Action Investigation Work Plan*. This document explains the overall site conditions and the contaminant source, fate, and transport potential.

SECTION 3.0

Site Background

Landfill 26 is located at the HAAF, a former military installation in the City of Novato, Marin County, California, approximately 22 miles north of San Francisco. HAAF is bordered by US Highway 101 on the west, private development to the north and south, and San Pablo Bay on the east (Figure 1-1). The HAAF is inactive as a military facility, and parts of the property have been transferred to private developers and the City of Novato. This section provides site background including the land and resource use, the physical setting, the history of contamination, and the initial response to cleanup the contamination.

3.1 Land and Resource Use

Currently, Landfill 26 itself covers approximately 26 acres. In addition, a 150- to 200-foot-wide buffer zone (22 acres in total area) was established around the perimeter of the landfill. USACE retains fee-title to the landfill and buffer zone. Landfill 26 is surrounded to the west and north by primarily undeveloped land; however, the Hamilton Meadows residential housing development directly borders Landfill 26 to the south and southeast. According to a 1995 City of Novato Community Development Department Land Use and Zoning map, all of the immediately adjacent area surrounding the landfill is designated as open space with the exception being in the southeast corner. The Hamilton Meadows is zoned for low density residential which is defined as 1.1 to 5.0 dwellings per acre.

Also located in the area surrounding Landfill 26 to the north/northeast is the wetlands restoration area. This is a former Base Realignment and Closure parcel where habitat restoration is occurring. A phased approach has been adopted to complete the design and construction of the Hamilton Wetlands Restoration Project in conjunction with the availability of the real estate parcels and dredge material. One of the issues associated with this restoration project that impacts Landfill 26 is that it will result in a loss of the current surface water drainage. The Army has committed to coordination between the landfill and wetlands project teams to make modification to the drainage system facilities for flood prevention. A lift station funded by the BRAC program and to be maintained by the City of Novato is projected to be installed along the northern landfill boundary by Spring 2008.

Another issue that relates to the wetlands restoration project has to do with the primary haul route for project construction along Todd Road. This route closely traverses a dense residential area (Hamilton Meadows) and has been a source of complaints from neighbors. The intense level of citizen involvement resulted in a cooperative planning process including Federal, State, and Local interests, with a basic conclusion that a relocated access road was in the best interest of all parties in order to minimize perceived disruption to the affected neighborhoods.

Landfill 26 is currently covered with a RCRA-type cap. The surface of the landfill is relatively flat and is covered with grass and low brush. An unpaved road runs around the perimeter of the landfill. Vehicle access to the cap area is controlled by locked gates.

Pedestrians have access to the Landfill 26 area and the area is currently used for recreational purposes (for example walking, bicycling, etc.). The only structure currently within the landfill area is the groundwater treatment plant building, which is within the buffer zone, just east of the landfill. As part of an interim remedy, a subsurface passive vent trench system was installed along the south and southeast perimeter of the landfill to control migration of vadose zone gases.

Future land use as a recreational area has been informally discussed by USACE with the City of Novato, the most likely property transfer recipient.

3.2 Physical Setting

The climate in the vicinity of the HAAF Landfill 26 is typical for much of the San Francisco Bay Area. Summers are hot and dry, winters are cool and rainy, and spring and fall are mild with periods of rain. The Marin County Civic Center weather station, approximately 7 miles south of the site, has provided climatological information for various studies and designs.

Rainfall data for the Marin County Civic Center indicate an average annual precipitation of approximately 35 inches. Typically, the rainy season is from November through March. The winter rains have a pronounced impact on surface water flow and also cause elevated groundwater conditions in some years.

Temperature data show normal lows and highs in January (coolest month) of 40.6°F and 56.9°F and in August (warmest month) of 54.2°F and 81.5°F. Temperatures of 100°F are common in late summer.

Much of the HAAF lies on fairly flat land (reclaimed mudflats), with elevations generally below sea level. However, some portions of the HAAF lie on steep, highly eroded hills (comprising of bedrock) such as Ammo Hill and Reservoir Hill. Immediately to the west of the HAAF, steep coastal range mountains rise to more that 1,500 feet mean sea level. The HAAF is bounded by a system of dikes and levees on the north and east sides. Currently, a perimeter ditch and system of drains and pumps keep the water table at a depth of at least 2 feet below ground surface (bgs). Landfill 26 is situated in a valley between Ammo Hill and Reservoir Hill (Figure 1-2). Landfill 26 surface elevations currently range from approximately 4 to 28 feet mean sea level.

3.2.1 Geology

The geology of the Landfill 26 area consists of fill materials within the refuse zone, alluvial/colluvial sediments, Bay Mud formation, and Franciscan bedrock. The Franciscan bedrock is continuous beneath Landfill 26 and outcrops at Ammo and Reservoir Hills. For detailed information on these formations, refer to the *Summary Technical Report* prepared by WCC in 1997.

The principal geologic units are described below:

- Fill Materials within the Refuse Zone: fill consists of construction debris, domestic refuse, and petroleum-contaminated soil from fuel spill cleanups. Refuse materials are in contact with various geologic materials at the base of the landfill. The RCRA-type cap

is composed of multiple fine-grained sediments and upper layers of low permeability clays, synthetic membranes and textiles, clayey sand (select fill), topsoil, and vegetative cover. This cap extends over the entire landfill.

- Alluvium/Colluvium: the younger alluvium comprises primarily sandy clay and clayey sand with discontinuous zones of cohesionless poorly-graded sand and gravel. The older oxidized alluvium deposits comprise oxidized clays, silts, silty sands, and clayey sands, which are not clearly distinguished from fine colluvium or highly-weathered bedrock.
- The Bay Mud Formation and reduced clay units (gray clays) contain fine-textured, laterally-extensive distinct units. These fine-textured units act as aquitard materials and semiconfining units in portions of Landfill 26.
- Bedrock: basement rock beneath Landfill 26 consists of Cretaceous sandstones of the Franciscan Complex.

The Landfill 26 area historically has been subject to both freshwater and marine environments as sea levels rose and fell during the Quaternary period. The resulting variation in depositional environments has resulted in complex stratigraphy consisting of reworked and overlapping sediments with trapped organic matter and saline porewater. These Quaternary depositional patterns have created conditions that significantly affect groundwater and soil-gas flow and chemistry. The following are examples of these conditions:

- Naturally-occurring organic material in fine sediments degrades anaerobically in the subsurface to produce methane.
- Groundwater chemistry appears to be influenced by porewater and inorganic compounds deposited in marine and brackish marsh environments. Complex sediment stratigraphy acts to attenuate contaminant migration because permeable materials are discontinuous and separated by silt and clay deposits with low bulk hydraulic conductivity.

3.2.2 Hydrogeology

The water flow system of the Landfill 26 region consists of three key interconnected components: groundwater, surface water, and atmospheric water. The atmosphere is a significant contributor to (through rainfall) and a sink for (through evaporation) groundwater in the vicinity of Landfill 26. Surface water flow is less significant at this site because the surface flow is predominantly channelized around Landfill 26 and the presence of the RCRA-type cap prohibits direct infiltration of precipitation into the landfill materials. Atmospheric water and surface water do not come into direct contact with Landfill 26 refuse.

Groundwater at Landfill 26 primarily flows through alluvium and fill sediments of modest yield and poor water quality (Sirrine, 1991; WCC, 1997). The overall flow direction at Landfill 26 is from south to north. Groundwater flow generally occurs through one connected zone in the southern half of Landfill 26, in upgradient areas, and in upland crossgradient areas. Permeable sediments are separated by Bay Mud and Gray Clay units

creating upper and lower groundwater zones in the northern half of Landfill 26 and downgradient areas. This shallow flow zone exists only under the RCRA-type cap at the northern end of Landfill 26. A majority of groundwater migrating downgradient of Landfill 26 is consumed through evapotranspiration in the area directly beyond the northern boundary of the landfill cap (WCC, 1997).

Groundwater chemistry changes dramatically toward the northern end of Landfill 26. As groundwater migrates northward, the chemistry transitions from low-salinity, brackish water that is chemically similar to precipitation to hyper-saline water that is chemically similar to sea water, but with increased total dissolved solids resulting from evaporation processes. This change is caused by the interaction of groundwater, with both fine sediments deposited under saline marsh environments and saline porewater trapped in the sediments at the time of deposition.

Groundwater at Landfill 26 is not suitable for domestic/municipal use based on the Water Board criteria for total dissolved solids, production rates, and minimum well seal depth requirements, nor does Landfill 26 appear to be recharging any nearby areas that might affect other beneficial uses (CH2M HILL, 2006).

The vadose zone sediments in the Landfill 26 area are dissected by impermeable landfill cover materials and the perimeter passive vent trench system. Shallow unsaturated soil materials in the area are highly variable and have been reworked by natural processes and during different phases of construction at the site. However, these materials generally become more fine-grained north of the landfill and become sandy south of the landfill. The thickest and most permeable portion of the vadose zone lies southeast of Landfill 26 in the Hamilton Meadows area. Following the interim remedy installation of a perimeter passive vent trench system to the south and southeast of the landfill, the vadose zone within Landfill 26 is no longer connected to the vadose zone beyond the trench system and in the Hamilton Meadows area.

3.3 History of Contamination

3.3.1 Facility History

Hamilton Airfield, as it was first known, was constructed by the Army Air Corps on land acquired from Marin County and private landowners in the early 1930s. The airfield served as a base for fighter, bomber, and transport aircraft in the 1930s and 1940s. The base also served an important role as a training facility for fighter and bomber pilots and as a staging area for Pacific operations during World War II. The facility was renamed Hamilton Air Force Base when the Army Air Corps was reformed into the United States Air Force.

Hamilton Air Force Base was used as a fighter installation until 1974, when the site was deemed surplus property by the United States Department of Defense. Over the next 10 years, portions of the base were transferred to the Navy, the GSA, the Coast Guard, the Army and the State of California. In 1984, many portions of the base were transferred to the Army and the base was renamed Hamilton Army Airfield. Several portions of the base were offered for sale to the private sector by the Army under the GSA. The airfield portion of

HAAF was included in the first group of sites to be targeted for closure under the Base Realignment and Closure Act of 1988.

The landfill began receiving refuse in the early 1940s. It was expanded throughout the 1960s and 1970s. Household, commercial, industrial, and construction wastes are believed to have been deposited in the landfill (USACE, 1993). Methods of disposal within Landfill 26 were not documented. The landfill has been inactive since 1974, when the base was listed as surplus property.

3.3.2 Sources of Contamination

At Landfill 26, the refuse consists primarily of construction debris, domestic refuse, and petroleum-contaminated soil from fuel spill cleanups. Wastes observed from borings and trenches include wood, bottles, paper and household trash, airplane parts, scrap metal, wire, concrete, steel and other construction debris, and oily sludge (WCC, 1987; WCC, 1997). It can be surmised from the activities conducted at the base, as well as from the contaminants found in the soil/refuse, that waste products (industrial/commercial) generated from aircraft maintenance and base operations were also placed within Landfill 26. Additionally, Army records indicate that petroleum-contaminated soils obtained from cleanup of multiple petroleum spills in the 1970s were disposed of at Landfill 26.

Estimates of the extent and volume of refuse vary considerably in a number of historical site documents. The actual refuse is thought to be approximately 15 acres in extent. Borings drilled within the landfill have indicated Refuse Zone thicknesses of 0 to 11 feet (WCC, 1997), and the refuse is saturated by groundwater in some areas. The total estimated volume of refuse is 151,500 cubic yards, and the volume of the oily sludge is estimated to be 20,000 cubic yards. Therefore, the total estimated volume of Landfill 26 is 171,000 cubic yards.

A summary of soil contamination in Landfill 26 is provided in Table 3-1. In addition, other sources include non-Landfill 26 sources (ie. spills or releases from historical activities and/or storage tanks sites in the vicinity of Landfill 26) and natural/ambient sources (Table 3-2). These sources of detected chemicals in soil, groundwater and soil-gas are described below.

- Landfill 26: Landfill 26 fill materials are the primary source of detected chemicals in the soil, groundwater, and soil-gas within the landfill boundary and buffer zone. The groundwater and soil-gas that have been impacted by the refuse have the potential to be sources of contamination beyond the Landfill 26 RCRA-type cap and buffer zone. (CH2M HILL, 2006).
- Non-Landfill 26 Sources: Several other sources of chemicals from historic uses in the area that are not related to the Landfill 26 refuse are also known. These other documented spills or releases from historic activities in the vicinity of the landfill and buffer zone consist of multiple uncontrolled spill sites, former aboveground and underground storage tank sites, and other uses that involved the routine use of chemicals that were released to the environment at about a dozen locations around the landfill. These other sources are well-documented and have impacted groundwater and soil-gas quality in the Landfill 26 area (CH2M HILL, 2006).

- Natural and Ambient Sources: Four types of natural and ambient sources of chemicals are known to have impacted groundwater and soil-gas quality. These sources generally involve natural chemical reactions occurring in native soils and groundwater. The natural sources of chemicals detected in media in the area surrounding and within the landfill include decomposition of naturally-occurring organic matter present in sediments, ion exchange of inorganic minerals in soil, and atmospheric VOCs. In addition, there are a number of anthropogenic sources (e.g., VOCs in ambient air) of chemicals to groundwater and the atmosphere near the landfill. These natural and ambient sources of chemicals are known to contribute to some observed levels of some chemicals (CH2M HILL, 2006).

TABLE 3-1
Summary of Soil Contamination within Landfill 26
Five-year Review Report for Landfill 26, Former Hamilton Army Airfield, Novato, California

Contaminant Class	Constituents		Detection Frequency (%)	Total Analyses	Detection Range
VOCs	1,1,1-TCA		13.5	52	29-93 μg/kg
	Chlorobenzene		23	52	20-700 μg/kg
	BTEX		2-21	87	26-960 μg/kg
SVOCs	Chrysene		3.7	190	330-11,000 μg/kg
	Naphthalene		13	190	370-33,000 μg/kg
	PAHs: Benzo(a)anthracene, Benzo(b)fluoranthene, Benzo(f)fluoranthene, Benzo(g,h,i)perylene, Fluoranthene, Phenathrene, Pyrene		2.1-4.7	190	330-21,000 μg/kg
PCBs	Aroclor 1254		17	149	0.16-4.8 mg/kg
Pesticides	DDD		83	149	0.016-160 mg/kg
	DDE		28	149	0.016-3.6 mg/kg
	DDT		19	149	0.016-190 mg/kg
Petroleum	TPH-diesel		40	349	3.6-1,500 mg/kg
Metals	Metal (Background Concentration [mg/kg])				
	Arsenic	(2.3-21)	96	500	0.8-921 mg/kg
	Barium	(83.6-318.5)	98	500	20-1,600 mg/kg
	Cadmium	(0.62-0.82)	54	500	0.02-5.8 mg/kg
	Copper	(15-32)	98	500	1.0-2,600 mg/kg
	Iron	(not established)	100	500	2,200-73,000 mg/kg
	Lead	(15-95.5)	98	500	0.8-34,000 mg/kg
	Zinc	(41.2-120)	98	500	5.0-3,100 mg/kg

TABLE 3-1
Summary of Soil Contamination within Landfill 26
Five-year Review Report for Landfill 26, Former Hamilton Army Airfield, Novato, California

Contaminant Class	Constituents	Detection Frequency (%)	Total Analyses	Detection Range

Notes:

Data summarized from the Summary Technical Report (WCC, 1997) Tables 5-1 and 5-2.

Organic compounds detected at low concentrations in less than 2 percent if analyses are not included.

Metals with 90 percent detections at concentration within background are not included.

Antimony, boron, molybdenum, and thallium are not included because of lower detection frequency.

BTEX = benzene, toluene, ethylbenzene, and xylenes.

mg/kg = micrograms per kilograms.

TCA = trichloroethane.

SVOC = semivolatile organic compound.

mg/kg = milligrams per kilogram.

TABLE 3-2
Summary of Potential Contamination Sources Outside Landfill 26
Five-year Review Report for Landfill 26, Former Hamilton Army Airfield, Novato, California

Location	Potential Constituents of Concern	Potentially Impacted Media			
		Surface and Shallow Subsurface Soils	Sediment	Soil Below 3 Feet Deep	Ground-water
Parcel 800B storm drains & sanitary sewers	TPH, TCE, PAHs, metals		X		
Building 833, electrical and maintenance shop	TPH, PCBs, SVOCs	X			X
Navy property dry cleaners and auto hobby shop	TPH, VOCs, MtBE				X
Suspected LF 23	Low concentrations of TPH			X	X
TCE Spill	VOCs			X	X
Building 750 former USTs	TPH, PAHs			X	
Building 783 former USTs	Low concentrations of TPH				X
Building 799 former ASTs	TPH, BTEX, PAHs	X			X
Building 799 service pit, grease trap, and storm drain	TPH, TCE, PAHs, barium, pesticide			X	X
Quartermaster's Salvage Yard	TPH, BTEX, pesticides, PCBs, PAHs, metals	X			
Suspected Skeet Range	Lead (in north area)	X			
Suspected Drainage Sediment Location	TPH, PAHs, pesticides, metals	X			

Notes:

AST = aboveground storage tank.

UST = underground storage tank.

TCE = trichloroethylene.

TPH = total petroleum hydrocarbons.

PAH = polynuclear aromatic hydrocarbons.

MTBE = methyl tert-butyl ether.

SVOC = semivolatile organic compound.

BTEX = benzene, toluene, ethylbenzene, and xylenes.

Bold Locations are locations which can be shown to impact results from the Landfill 26 monitoring.

3.3.2.1 Chemicals Detected in Landfill 26 Fill Material

In summary, pesticides, PCBs, some petroleum contaminants, and select semivolatile organic compounds (SVOCs) are present in the Landfill 26 fill materials (also termed Refuse Zone) and appear to originate from landfill wastes. It is not clear whether some VOCs are landfill contaminants. Additionally, several metals were detected at concentrations within the range of background concentrations for soil (IT, 1998; WCC, 1997).

3.3.2.2 Chemicals Detected in Groundwater

In general, groundwater contaminants at the site include chlorinated VOCs, SVOCs, petroleum-related compounds and associated VOCs, and metals. Chlorinated VOCs are detected at low concentrations in wells west of and beneath the landfill but not in wells screened within the Refuse Zone. These detections follow a flow path from outside Landfill 26, with no detections linked to the refuse. Detections of trichloroethylene and dichloroethylene in groundwater can be attributed to the solvent spill area south of Ammo Hill. Also, total petroleum hydrocarbons (TPH), associated VOCs (BTEX), and SVOCs (naphthalene and methyl naphthalene) are attributed to various known releases upgradient of the landfill and oily sludge and petroleum hydrocarbon-contaminated soil from petroleum spill sites deposited at Landfill 26.

Concentrations of most metals in groundwater in the Landfill 26 area appear to be consistent with natural geochemical conditions. The only inorganic constituent related to Landfill 26 is barium.

Detailed information on historic groundwater data evaluations is provided in the *Summary Technical Report* and *Appendix N of the Final Closure Plan* prepared by CH2M HILL in 1999. These evaluations considered groundwater monitoring data through 1997 and 1998, respectively, and relied upon statistical methods and chemical covariant plots to screen the data and identify the constituents of concern (COCs) attributable to landfill materials. These documents presented COCs and constituents of potential concern (COPCs) for Landfill 26 groundwater based on risk-based evaluations, as well as available data on detection frequency and location. The list of COCs and COPCs was updated as part of the 2005 *Corrective Action Investigation Work Plan* prepared by CH2M HILL and re-evaluated in 2006, as part of the CSM update. Concentrations and frequencies of detection used to select the initial COCs and COPCs were compared against actual groundwater monitoring analytical results from 2000 to 2005. Based on that review, the recommended COCs include:

- VOCs: chlorobenzene and 1,4-dichlorobenzene.
- SVOC: naphthalene.
- Petroleum: TPH-diesel.
- Metals: barium.

It was recommended that TPH-gasoline no longer be considered a COPC.

3.3.3 Soil-gas Contamination

Soil-gas contamination includes methane and VOCs. For the purposes of this report, VOCs are defined as non-methane volatile organic compounds. This distinction is consistent with the municipal landfill regulations in California Code of Regulations (CCR) Title 27, Division 2 (Solid Waste) that distinguishes methane from other "trace gases" (ie. VOCs). Methane

from Landfill 26 includes naturally-occurring methane. VOCs detected in soil-gas probes outside the landfill have not shown any correlation with soil-gas inside the landfill. The detections of VOCs are either typical of local ambient air conditions or due to VOC sources, including spills, not associated with the landfill.

3.4 Initial Response

Numerous investigations and remedial actions have been conducted at Landfill 26 and the surrounding areas. Sediment, soil, groundwater and soil-gas study activities at Landfill 26 began in 1985. In 1986, a preliminary hazard assessment was conducted according to USEPA guidelines. The assessment concluded it is not likely that any of the contaminants would present a significant threat to human health by inhalation or dermal contact. The assessment also concluded that groundwater contaminants did not present a significant threat to humans because groundwater from Landfill 26 was not being used, and would probably never be used, as drinking water. However, since Landfill 26 and the surrounding suspected landfills were included in the parcel offered for sale by the GSA, it was reasonable to assume that the land and groundwater usage could change. Therefore, the USACE was required to complete an RI/FS and prepare a remedial plan to properly close Landfill 26.

An RI/FS was conducted during 1987 and 1988. The feasibility study was completed in July 1988. The objectives of the RI/FS were to characterize physical conditions, characterize the nature and extent of contamination at the site, determine the extent to which this contamination may pose a threat to human health and the environment, and evaluate alternatives for remediation at Landfill 26.

3.5 Basis for Taking Action

In general, the following analytes were identified as soil and groundwater contaminants in the upper 5 feet of the landfill: VOCs, chlorinated VOCs, TPH, pesticides, and metals. Soil-gas contamination included methane and VOCs. As previously mentioned, geochemical evaluations indicated that only some of these chemicals in groundwater, soil, and soil-gas are representative of Refuse Zone contamination.

Three separate risk assessments were performed in the 1988 feasibility study by WCC, which included groundwater and soil contaminants in the upper 5 feet of the landfill:

- A public health risk assessment based on current land use at the HAAF and the surrounding areas.
- A public health risk assessment based on the possibility that a portion of the HAAF, including Landfill 26, would be sold for residential development.
- An assessment of impacts on aquatic organisms inhabiting water bodies that receive groundwater and surface water drainage from Landfill 26.

It was noted in the risk assessments that the aquifer was not being used as public drinking water; the failure of Landfill 26 groundwater to meet drinking water requirements was not due to anthropogenic impacts but rather natural properties of the aquifer (i.e., high total

dissolved solids, low production rate, etc.). The results of the risk assessment were presented in the 1989 ROD. Specifically, under the land use scenario, open area/restricted public visitation, Landfill 26 presented insignificant health risks to persons living and/or working at Hamilton for both toxic and carcinogenic effects. Assessment of the environmental impacts to aquatic organisms also indicated no threat to aquatic life.

In assessing the worst-case scenario for future health risks, based on a hypothetical future development, an additional risk assessment was conducted. Based on these findings, the 1989 ROD assumed that under direct exposure to soil/refuse and groundwater at the landfill (without remediation), the contaminants would pose unacceptable risks to public health. Section 4.0 describes the remedial action implemented at the site.

SECTION 4.0

Remedial Actions

To address contamination at Landfill 26 and potential risks to human health and the environment, several remedies were selected and have been implemented at the site. The site has not been placed on the National Priorities List (NPL) by the U.S. Environmental Protection Agency (EPA), however the remedial actions being implemented are following the CERCLA process.

4.1 Remedy Selection

Groundwater flow and leachate discharges from Landfill 26 are potential mechanisms for contaminants to migrate off-site. On August 11, 1989, a ROD for Landfill 26 was signed that included eight remedial alternatives. The ROD described the selected remedial alternative based on the feasibility study conducted in 1988. The ROD for Landfill 26 described two OUs for the landfill soil/refuse and the groundwater:

- Landfill Soil/Refuse OU – Immobilize contaminants in soil/refuse through a fixation process (solidification).
- Groundwater OU – Extract and treat contaminated groundwater.

The ROD states that the primary contaminants in the soil/refuse zone of Landfill 26 are petroleum hydrocarbons, semi-volatile organics, heavy metals, chlorinated pesticides, pesticide metabolites, and polychlorinated biphenyls (PCBs). A remedy for landfill gas emissions was not selected because during the 1980's it was determined that the rates of methane production were very low, therefore no methane control measures were included.

This ROD was subsequently supplemented and modified by the ESD in 1992. The 1992 ESD determined that solidification should be eliminated as a remedy and an upgraded cap should be constructed to address the soil/refuse. In addition, the 1992 ESD approved modified groundwater treatment processes to more effectively treat constituents in the groundwater.

The subsequent discovery of methane in soil-gas resulted in USACE conducting a thorough evaluation of the soil-gas data. Selection of an interim remedy to prevent offsite methane migration included construction of a passive venting system in 2002 which was completed in January 2003. In May 2007 a Draft Final Feasibility Study for soil-gas was submitted for agency review. The current interim remedy has been identified by the USACE as the preferred remedial alternative. The Feasibility Study is anticipated to be completed as final by late 2007.

4.2 Remedy Implementation

Existing remedies consist of a RCRA-type cap, a groundwater extraction system, and a perimeter passive vent trench (interim remedy). A detailed description of the remedies is provided in Sections 4.2.1 through 4.2.3. Section 4.2.4 includes a discussion on institutional controls which are necessary to ensure remedy implementation is not compromised. The regulatory history and actions at the site include:

- A RCRA-type landfill cap and groundwater extraction and treatment system were installed in response to the 1989 ROD, and 1992 ESD. Water Board Order No. 92-029 containing the WDRs for Landfill 26 which provided guidance to protect the waters of the State of California. During this time, the 150- to 200-foot buffer zone was established around Landfill 26, providing separation between the landfill and adjacent land.
- In 1996, Water Board Order No. 96-113 was issued; this Order required submittal of a closure plan and required that closure activities be performed per California Code of Regulations (CCR) Titles 14 and 23 (now Title 27) in effect at that time.
- A passive venting system was installed in 2002 and 2003, in response to Water Board Corrective Action Order No. 01-139 and Time Schedule Order No. 01-140, dated November 2001.

Water Board Order No. R2-2006-0064, issued on October 11, 2006, contains updated WDRs and outlines a regulatory framework for bringing Landfill 26 to post-closure status, including the preparation of a feasibility study for landfill refuse-related soil-gas contamination and this five-year review report. Water Board Order No. R2-2006-0064 also rescinds Order No. 96-113 (WDRs), Order No. 01-139 (CAO), and Order No. 01-140 (time schedule). USACE has generally followed the guidance provided in the various Water Board Orders as part of remedy implementation and to maintain compliance with State requirements for landfill closure.

4.2.1 RCRA-type Cap for Landfill Soil/Refuse OU

The RCRA-type cap was installed at Landfill 26 during 1994 and 1995, and the cap covers approximately 26 acres. The eight-layer cap includes (from bottom to top):

- A minimum 2- to 4.5-foot-thick foundation layer.
- A minimum 1- to 2-foot-thick compacted low-permeability clay layer.
- A geomembrane liner consisting of 40-mil very low-density polyethylene (VLDPE) and high-density polyethylene (HDPE) composite on the side slopes and VLDPE on the top deck. The composite membrane is VLDPE on the outer surfaces. Membrane material is smooth on minimum slopes (top deck) and textured on both sides on the 4:1 side slopes.
- A drainage layer (composite drainage net with subdrainage piping).
- A minimum 18-inch-thick protective layer (topsoil and vegetation).

The cap includes drainage features and erosion control devices to prevent deterioration of landfill and cap integrity. In addition, a 150- to 200-foot-wide buffer zone (22 acres in total area) was established around the perimeter of the cap. This provides separation between the

landfill and adjacent land. Access and intrusive activities are restricted within the buffer zone to protect the integrity of the cap and other landfill-related facilities. Figure 4-1 shows the approximate limits of the capped area and the buffer zone.

4.2.2 Extraction and Treatment System for Groundwater OU

A groundwater extraction and treatment system was installed at Landfill 26 in response to the 1989 Landfill 26 ROD, the 1992 Landfill 26 ESD, and Water Board Order No. 92-029. The extraction system was designed and installed to capture groundwater flowing northward within the landfill.

Constructed in 1992 and 1993, the groundwater extraction and treatment system consists of 14 extraction wells located within the landfill. The extraction wells are piped to an onsite groundwater treatment plant (Figure 4-2). The treatment plant along Aberdeen Road (east of the landfill) was designed to remove low levels of petroleum contamination, trace organics, and metals using an activated carbon filter system with preliminary aeration and skimmers. The extraction portion of the system was startup tested in April 1995.

In the 1997 *Summary Technical Report,* WCC concluded that contaminants from Landfill 26 have not significantly impacted groundwater outside the Landfill 26 boundary based on a comprehensive evaluation of several years of post-RCRA-type cap installation groundwater monitoring data. It was further concluded that extraction and treatment is not currently necessary to protect human health and the environment. Additional groundwater monitoring data collected since 1997 also demonstrate that contaminants in Landfill 26 have not significantly impacted groundwater outside of the Landfill 26 boundary (CH2M HILL, 2005). Therefore, with the concurrence of the regulatory agencies, the groundwater extraction and treatment system was never put into service.

USACE commissioned a groundwater treatment system decommissioning study in 1998. The purpose of this study was to establish appropriate parameters to decommission the existing Landfill 26 treatment plant and extraction well system. The study presented the scope of work and specific procedures required to decommission the groundwater treatment plant at Landfill 26. This five-year review will update the decommissioning study and establish recommendations for future land use (see Appendix A). Groundwater operation and maintenance activities including the current monitoring program are discussed in detail in Section 4.3 of this report.

4.2.3 Perimeter Passive Venting System

The interim remedy of a perimeter passive venting system was installed at Landfill 26 in response to 2001 Water Board Orders CAO No. 01-139 and Time Schedule Order No. 01-140. These orders established a schedule for the development and implementation of corrective action plans for addressing landfill gas (particularly methane), post-closure maintenance activities, and improved groundwater and soil-gas monitoring.

The perimeter passive venting system (including a venting trench and geomembrane trench liner) was installed within the landfill buffer zone on the east and southeast sides of the landfill in 2002 and 2003. The first phase of the venting trench was completed in February 2002. The remainder of the venting trench was finished in August 2002, and the geomembrane liner installation was completed by January 2003. Details of the design and

construction of the passive venting system are provided in the 2003 *Completion Report, Interim Landfill Gas Migration Control Trench* prepared by ITSI and are summarized below.

The existing passive venting system is located within the buffer zone along the southern and southeastern perimeter of Landfill 26, as shown on Figure 4-1. The venting trench extends from an area of high seasonal groundwater at the southwest corner of the landfill to an area of shallow bedrock along the northeastern side of the landfill, a distance of approximately 1,560 feet. Based on comprehensive landfill gas migration studies and remedial design studies (ITSI, 2001), the southern and southeastern portions of the perimeter of Landfill 26 are the only areas where the potential for methane migration exists.

The extent of the trench necessary to prevent landfill refuse-related methane migration was developed initially as part of the *Methane Remedial Measures Study* by CH2M HILL in 2002. Based on soil-gas data available at the time, as well as lithologic and hydrogeologic information, it was recommended that the trench be limited to the southern and southeastern portion of Landfill 26. The report further indicated that the trench could be divided into two distinct sections: one along the southern edge of the landfill between MW-089 and GMP-14 (approximately) and the other on the southeastern edge between GMP-10 and GMP-8 (approximately). These locations were selected based on the areas where methane had been detected outside the landfill limits that could possibly have been associated with migration of landfill refuse-related methane from Landfill 26. For final design and construction purposes, USACE took a more conservative approach to control methane migration and extended the trench to cover the entire landfill perimeter both within these two sections and between them.

The trench is designed to allow landfill gas to passively flow through the gravel fill in the trench, into the horizontally perforated collection pipe, then to the surface where it naturally vents to the atmosphere through a series of vertical risers. This natural flow occurs as the landfill gas migrates from an area of higher pressure to an area of lower pressure. This pressure gradient causes vadose zone gases to flow into the trench collection pipe and out the vertical vents.

The trench was divided into eight sections (Sections 1 through 8) to minimize the migration of groundwater along the trench. The 2- to 3-foot-wide trench was installed to a depth of approximately 3 feet below the lowest observed groundwater table elevation (Sections 5 through 8) or to bedrock (Sections 1 through 4). The depth of the trench ranges from approximately 2 feet bgs in Section 1, where shallow bedrock was encountered, to approximately 15.5 feet bgs in Sections 6 through 8. Concrete vertical barriers are located between each trench section. The barriers are wider and deeper than the adjacent trench and are designed to hydraulically isolate each trench section from the adjacent sections.

The trench is lined with a non-woven poly propylene geotextile (Contech C-60NW) to minimize the intrusion of fine-grained sediments. The trench sections are filled with a gravel pack consisting of 3/4–inch drain rock from the base of the trench to approximately 2 feet below grade. A 6-inch HDPE slotted conveyance pipe is installed within the drain rock to facilitate gas venting (this piping also allows for conversion of the passive venting trench to active collection trench in the future, if necessary). The conveyance pipe extends along the entire length of each trench segment, and a riser pipe (trench vent) is connected to each end. Each riser pipe extends to approximately 10 feet above ground surface.

An impermeable vertical barrier (i.e., a trench liner system) is installed in each of the trench segments on the outboard side (i.e., the side furthest from the landfill). The impermeable vertical barrier prevents migration of any soil-gas beyond the landfill boundary to outlying areas. The barrier is installed to a depth of approximately 1 foot above the bottom of the constructed trench. The impermeable barrier consists of interlocking, rigid HDPE panels (GSG GundWall®) driven in place following the initial construction of the trench.

4.2.4 Institutional Controls

Institutional controls are non-engineering methods by which access to contaminated environmental media is restricted. No specific institutional controls are addressed in the ROD or ESD.

Institutional controls can be comprehensive including land-use restrictions, well restrictions, fencing, and site access. For the Landfill 26, institutional controls would be applicable for within and beyond the landfill boundary. Proposed institutional controls for the use-related post-closure requirements and for property transfer (and post-property transfer) are described in Appendix B.

4.3 Operation and Maintenance (O&M)

This section documents routine O&M tasks. The maintenance of the landfill cap and the most recent WDR monitoring activities were evaluated as a part of this five-year review. No O&M activities are associated with the former groundwater extraction/treatment system.

The primary O&M activities include:

- Visual inspection of the cap with regard to the vegetative cover, settlement, stability, and erosion and drainage control and any need for maintenance.
- Visual inspection of the condition of the landfill gas vents and groundwater monitoring wells and any need for maintenance of these structures.
- Groundwater and soil-gas monitoring.

The Marin County Department of Environmental Health Services inspects the Landfill 26 site quarterly to assess the post-closure maintenance, including the above-mentioned landfill cover, settlement, drainage, erosion control, and security. Records from the Marin County Environmental Health Services indicate that the closed landfill is site appropriately maintained.

USACE maintains an active monitoring program to detect contaminant concentrations at locations within and around Landfill 26. The current monitoring program is described in Table 4-1 (and current monitoring locations are shown on Figure 4-1). The most recent events were generally in response to regulatory requirements, including WDRs 92-029 and 96-113 and the 1999 *Final Closure and Post-closure Maintenance Plan* prepared by CH2M HILL.

TABLE 4-1
Landfill 26 Current Monitoring Program
Five-year Review Report for Landfill 26, Former Hamilton Army Airfield, Novato, California

Medium	Monitoring Points	Objectives	Frequency
Landfill Gas[a]	TV-01 to TV-16	Monitor potential migration of landfill gas, concentrations of VOCs in soil-gas	Quarterly, except VOCs (annually)
	GMP-1 to GMP-38[b], and SGP-1 to SGP-20	Monitor potential migration of landfill gas, concentrations of VOCs in soil-gas	Quarterly, except VOCs (annually)
Groundwater[c]	MW-92-40, MW-92-43, MW-L26-1	Downgradient monitoring (northeast)	Annually
	MW-078, MW-82, MW-86	Landfill monitoring[d]	Annually
	MW-81D, MW-82D, MW86D	Landfill monitoring	Annually
	MW-89	Upgradient monitoring (southeast)	Annually
	PL-111A	Downgradient/cross-gradient monitoring (northeast)	Annually
	MW-POLA-119	Cross-gradient/upgradient monitoring (east)	Annually
	PZ-9	Cross-gradient monitoring (west)	Annually
	PZ-16	Cross-gradient monitoring (southwest)	Annually
	MW-92-38	Cross-gradient/upgradient monitoring (west)	Annually
Surface Water[c]	Visually-identified seep locations	Determine if contaminants are migrating from the landfill to surface soils	Annually

Notes:
[a] Target analytes for landfill gas monitoring: oxygen and methane quarterly; VOCs annually.
[b] Some probes were unable to be sampled due to high groundwater levels.
[c] Target analytes COCs for groundwater and surface water monitoring: chlorobenzene, 1,2-dichlorobenzene, 1,4-dichlorobenzene, naphthalene, diesel, arsenic, barium, copper, lead, and zinc.
[d] Monitoring-well screen located within Refuse Zone.

4.3.1 Soil-gas

The current soil-gas monitoring program consists of annual monitoring at the following locations:

- GMP-1 through GMP-38 (a few locations are susceptible to flooding and at times cannot be monitored)
- SGP-22 through SGP-41
- TV-1 through TV-16

Current GMP locations are shown in Figure 4-1. Target analytes include carbon dioxide, oxygen, nitrogen, and methane, in accordance with American Society for Testing and Materials D1946, and methylene chloride and benzene in accordance with USEPA Method TO-15. Soil-gas monitoring is conducted in accordance with CCR Title 27 requirements.

4.3.2 Groundwater

The Closure Plan includes post-closure monitoring to confirm the effectiveness of the cap and to provide data for early detection of target contaminant migration. The Closure Plan identified 15 wells across the site landfill area and included upgradient, source, and downgradient wells. The current sampling program requires these wells to be sampled annually in late summer, when methane concentrations in soil-gas tend to be highest. Target analytes include chlorobenzene, 1,2 dichlorobenzene, 1,4 dichlorobenzene, and naphthalene by USEPA Method 8260B; TPH as diesel by USEPA Method 8015B; arsenic, barium, lead, and zinc by USEPA Method 6010B; and copper by USEPA Method 721.

Groundwater elevations are calculated from depth-to-water levels, which are collected at each monitoring well, piezometer, and GMP included in the monitoring program. Groundwater levels are recorded each time a well is sampled.

As part of this five-year review, a memorandum has been prepared to document the proposed approach for development of a performance-based groundwater monitoring in order to track changes in concentrations of COCs and the potential for their migration within and outside of the Landfill 26 boundaries. The approach is described in Appendix C. Specifically, the two main components of the performance-based monitoring are: (1) continued confirmation of the groundwater flow direction and (2) identifying a change in contaminant levels through the use of statistical methods.

4.3.3 Surface Water

USACE has performed surface water sampling in recent years; however, surface water sampling is not required by the Water Board. The Closure Plan calls for annual visual inspections of the cover, with surface water sampling performed only if seeps are identified. One sample was collected from a seep in 1998, and one sample was collected from a drainage channel in 2001. These seeps were repaired, thereby preventing subsequent seeps. These two samples were analyzed for a wide range of compounds: unfiltered metals (by USEPA Methods 6010, 7470, 7041, and 7470), VOCs (by USEPA Methods 8010 and 8260B), SVOCs (by USEPA Method 8270), TPH-diesel (by USEPA Method 8015), TPH-gasoline (by USEPA Method 8015), pesticides (by USEPA Method 8081A), PCBs (by USEPA Method 8082), and anions and general chemistry parameters (by USEPA Methods 150.1, 160.1, 300.0, 310.1, 350.1 351.2, 351.3, 365.3 and 405.1). Two samples were collected from a drainage channel in 2003 and analyzed for a narrow suite of compounds. The 2003 samples were analyzed for unfiltered metals (arsenic by USEPA Method 7060, copper by USEPA Method 7211, lead by USEPA Method 7421, and barium and zinc by USEPA Method 6010B); chlorobenzene, 1,2-dichlorobenzene, 1,4-dichlorobenzene, and naphthalene (by USEPA Method 8260B); and TPH-diesel and TPH-gasoline (by USEPA Method 8015).

4.3.4 O&M Costs

USACE has provided annual costs for O&M of $150,000. This includes routine cap inspections and monitoring groundwater, soil-gas and surface water as described previously.

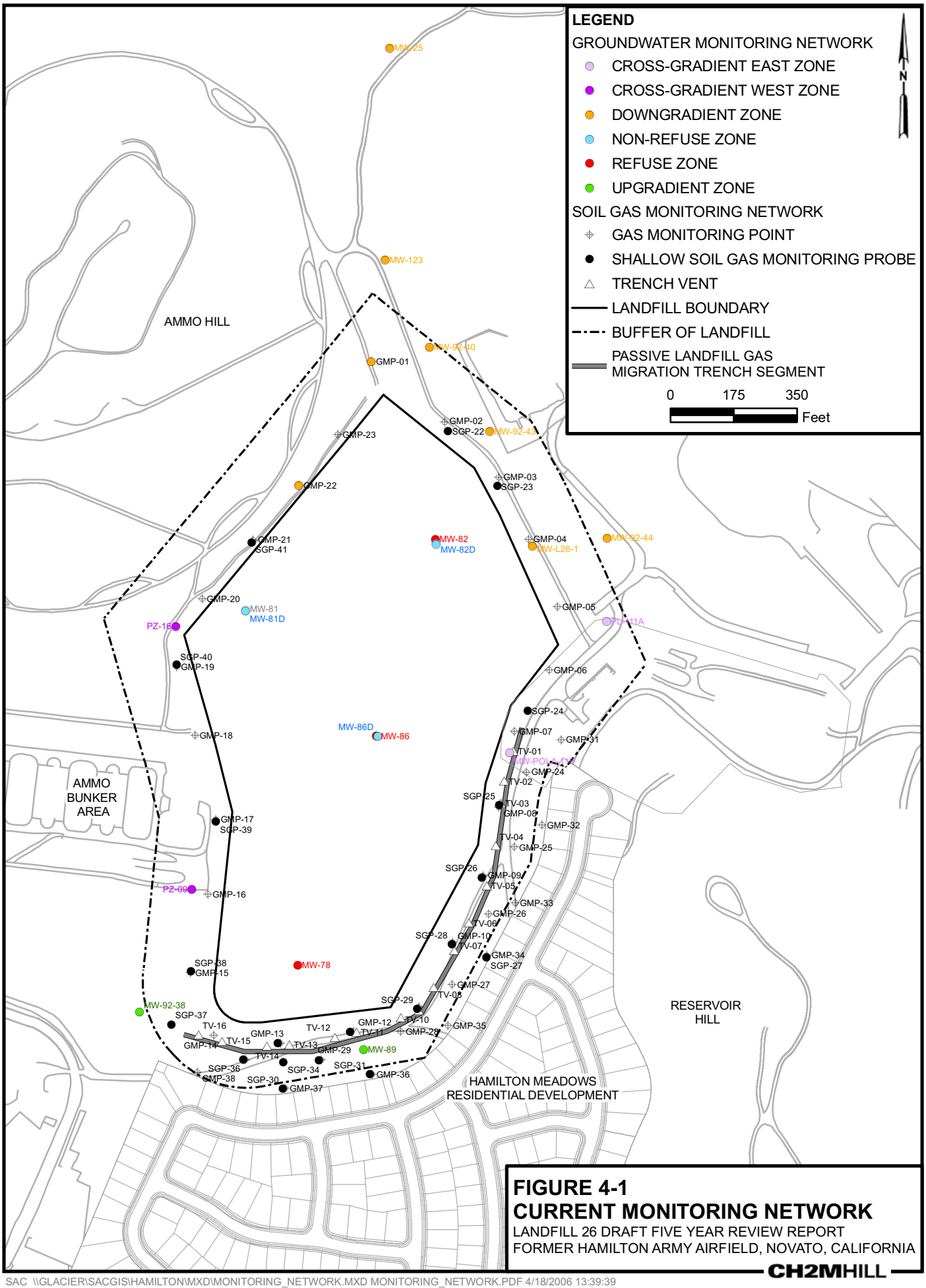


FIGURE 4-1
CURRENT MONITORING NETWORK
LANDFILL 26 DRAFT FIVE YEAR REVIEW REPORT
FORMER HAMILTON ARMY AIRFIELD, NOVATO, CALIFORNIA

CH2MHILL

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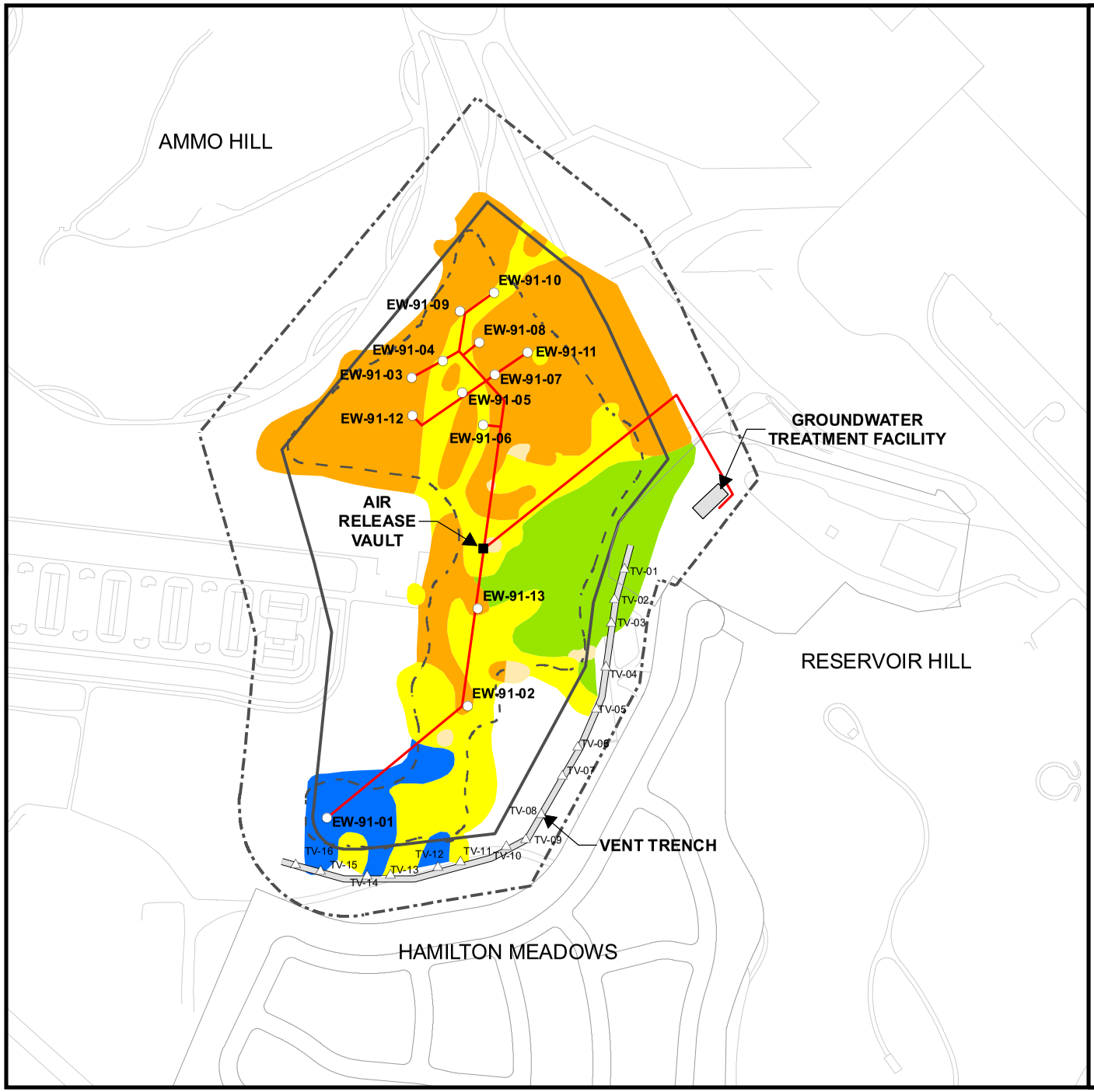
ES032006019SAC_HAAF_Landfill_26 HAAF_0034_current_monitoring_network.ai 05-12-06 tdaus



LEGEND

- GROUNDWATER EXTRACTION WELL
- EXTRACTION SYSTEM
- VENT TRENCH
- EXTENT OF REFUSE
- RCRA-TYPE CAP
- BUFFER OF ZONE

GEOLOGIC UNITS

- ALLUVIUM
- BAY MUD
- BEDROCK
- POORLY-GRADED SANDS
- GRAY CLAY

SOURCE: MODIFIED FROM *SUMMARY TECHNICAL REPORT FOR LANDFILL 26 AT HAMILTON ARMY AIRFIELD* (WCC, 1997)

N

0 200 400
FEET

FIGURE 4-2 FORMER GROUNDWATER EXTRACTION
LANDFILL 26 DRAFT FIVE YEAR REPORT
NOVATO, CALIFORNIA

CH2MHILL

ES112006010SAC_HAAF_LF26_FS Figure_1-4_Rev1.ai 12/07/06 afint

SECTION 5.0

Five-year Review Process

5.1 Administrative Components

The Hamilton Army Airfield Landfill 26 five-year review team was lead by Ray Zimny, USACE, Sacramento District Project Manager and included additional technical staff from USACE. CH2M HILL provided assistance in report preparation with expertise in regulatory review, risk assessment and five-year reviews. Additionally, Parker Design was responsible for community involvement. The review components included community involvement, a review of relevant documents (Appendix D), a regulatory review, a site inspection, interviews and report development and reviews. The review process began in December 2006.

5.2 Community Notification and Involvement

Following the release of the draft final document, the USACE issued a public notice in the local newspaper and sent a postcard announcement indicating that this review was available for public review. The location of the review document was provided as the Novato Library, 1720 Novato Blvd, and South Novato Library, 6 Hamilton Landing, both located in Novato, California. The report was also made available for review on the web at www.spk.usace.army.mil/projects/environmental/haaf/. The postcard invited the recipients to submit any comments to the USACE Project Manager, Ray Zimny.

At the August 2 Restoration Advisory Board (RAB) meeting, the public review schedule was provided to the RAB members. A public meeting was held on September 5, 2007 at the Margaret Todd Center in Novato which provided a five-year review information station allowing for the public to ask specific questions of personnel that had conducted the five-year review. A fact sheet describing the five year review process and findings was made available to the public.

5.3 Document Review

As a part of the five-year review process, CH2M HILL conducted a brief review of numerous documents related to site activities. The documents chosen for review ranged in publication date from 1987 to the present. Appendix D provides a list of the documents reviewed as part of this report.

5.4 Data Review

The following sections describe the periodic reporting and/or monitoring at the treatment facility for the Landfill 26, as required by the Water Board and Marin County Environmental Health Services.

5.4.1 Investigative and Monitoring History

Beginning in 1985 and continuing to the present, numerous investigations and monitoring activities have been conducted for Landfill 26. These investigations have included detailed topographic and geophysical surveys, soil borings, groundwater and landfill gas monitoring well installation, groundwater and surface water quality sampling and analysis, contaminant characterization, landfill gas sampling, trenching operations, water-level measurements, air quality sampling and analysis, sediment quality sampling and analysis, soil sampling and analysis, and stormwater drainage sampling and analysis. Over 36,000 groundwater and 43,000 soil-gas data points have been collected and evaluated during previous investigations. This includes over 25 rounds of groundwater monitoring and over 120 rounds of soil-gas monitoring.

5.4.1.1 Previous Investigations

Extensive data are available for Landfill 26 from a broad range of studies and investigations performed since 1985. A detailed chronology of these investigations can be found in the following documents:

- *Final Report, Investigation of Methane and Volatile Organic Compounds at Landfill 26 and Hamilton Meadows* prepared by USACE in 2004
- *Final Closure and Post-closure Maintenance Plan (Closure Plan) for Landfill 26* prepared by CH2M HILL in 1999

Table 5-1 summarizes previous and recent investigations at Landfill 26 and surrounding areas. A timeline illustrating the sequence of investigations is shown in Figure 5-1.

TABLE 5-1
Summary of Recent Investigations (1995 to 2005)
Five-year Review Report for Landfill 26, Former Hamilton Army Airfield, Novato, California

Date	Description	Objectives	Monitoring Points
Groundwater Activities			
Sep. 1993-Dec. 1995	Water Board WDRs Order No. 92-029: Quarterly Monitoring	Monitor up, down, and crossgradient wells. Monitor landfill refuse and non-refuse zones.	PL-103, PL-114, MW-030, MW-031, MW-92-41, MW-92-42, SAC 93-1D, MW-92-40, MW-92-43, MW-92-44, MW-123, MW-78, MW-81, MW-82, MW-86, MW-87, MW-88, MW-81D, MW-82D, MW86D, MW-88D, MW-92-38, MW-92-39, MW-89
1996-1998	Water Board WDRs Order No. 96-113: Annual Monitoring	Monitor up, down, and crossgradient wells. Monitor landfill refuse and non-refuse zones.	PL-114, MW-92-41, MW-92-42, MW-92-40, MW-92-43, MW-92-44, MW-81, MW-82, MW-86, MW-87, MW-88, MW-81D, MW-82D, MW86D, MW-88D, MW-92-38, MW-92-39, MW-89
1999-Present	Final Closure and Post-closure Maintenance Plan	Monitor up, down, and crossgradient wells. Monitor landfill refuse and non-refuse zones.	MW-92-40, MW-92-43, MW-L26-1, MW-078, MW-82, MW-86, MW-81D, MW-82D, MW86D, MW-89, PL-111A, MW-POLA-119, PZ-9,

TABLE 5-1
Summary of Recent Investigations (1995 to 2005)
Five-year Review Report for Landfill 26, Former Hamilton Army Airfield, Novato, California

Date	Description	Objectives	Monitoring Points
			PZ-16, MW-92-38
Jul. 2001-Dec. 2001	Shallow Soil-gas Investigation	Evaluate subsurface and groundwater conditions within the buffer zone and residential area with regard to the presence and distribution of methane	Phase I—various (see Table 2-1)
Surface Water Activities			
1996-1998	Water Board WDRs Order No. 96-113: Annual Monitoring	Determine if contaminants are migrating from the landfill to surface water	Visually identified seep locations
1999-Present	Final Closure and Post-closure Maintenance Plan	Determine if contaminants are migrating from the landfill to surface water	Visually identified seep locations
Landfill Gas Activities			
Sep. 1994-Jun. 1996	Post Cover System Construction: Monthly Monitoring	Monitor potential migration of landfill gas	GMP-1 to GMP-23
Sep. and Dec. 1999	Pre-Final Closure and Post-closure Maintenance Plan	Monitor potential migration of landfill gas	GMP-1 to GMP-23; GMP-5 and GMP-9 exceeded 5 percent methane by volume
1999-Present	Final Closure and Post-closure Maintenance Plan: Annual Monitoring	Monitor potential migration of landfill gas	GMP-5 to GMP-15
Jul.-Dec. 2000	Landfill Gas Migration Study	Assess presence and distribution of landfill gas and/or methane over time	GMP-5 to GMP-14
Jun. 2001-Present	Monthly Landfill Gas Monitoring Program	Monitor potential migration of landfill gas	GMPs, Shea probes, wells, trench vents
Soil-gas Activities			
Jun. 2001-Present	Monthly Landfill Gas Monitoring Program	Determine concentrations of VOCs in soil-gas for select monitoring events and samples	Five locations, typically from locations with elevated methane
Jul. 2001-Dec. 2001	Shallow Soil-gas Investigation	Assess presence and distribution of landfill gases and/or methane in the buffer zone and adjacent residential area; Identify types and extent of VOCs in soil-gas in the buffer zone and adjacent residential area; Identify preferential	Phase I—various (see Table 2-1)

TABLE 5-1
Summary of Recent Investigations (1995 to 2005)
Five-year Review Report for Landfill 26, Former Hamilton Army Airfield, Novato, California

Date	Description	Objectives	Monitoring Points
		pathways for soil-gas migration, if any, from the landfill to the residential area	
Jul. 2001-Dec. 2001	Shallow Soil-gas Investigation	Determine concentrations of VOCs in soil-gas in the residential area	Phase II—SA-SG1 through 21 (shallow soil-gas probes); SA-SG3D, 4D, and 8D (deep soil-gas probes)
Aug. 2003	Shallow Soil-gas Investigation	Determine concentrations of VOCs in soil-gas near Shea Homes Lot 30	Additional boreholes, trenching, and soil-gas samples near Lot 30

5.4.1.2 Previous Construction and Earthmoving Activities

As previously described, in 1992 and 1993, a groundwater treatment and extraction system was installed to meet the requirements of the ESD. Also as described previously, a RCRA-type final cover system was constructed between 1994 and 1995, including drainage and erosion control appurtenances. Grading and drainage improvements were completed in 1998. This work included seep repairs and is documented in the 1998 *Construction Quality Assurance (CQA) Report, Hamilton Army Airfield, Landfill 26, Grading and Drainage Adjustments* (Grading and Drainage Adjustments Report) by CH2M HILL. The cover system is undergoing post-closure monitoring and maintenance in accordance with the *Final Closure and Post-closure Maintenance Plan*.

The chosen remediation alternative for containing methane within the landfill and buffer zone was an interim landfill gas migration control trench. Construction is documented in the 2003 *Completion Report, Interim Landfill Gas Migration Control Trench, Landfill 26* by ITSI. Evaluation of data indicates the trench operates effectively (USACE, 2004).

5.4.2 Data Assessment

Based on a review of the relevant documents and monitoring data, the analytical data are of good quality and are sufficient for evaluating groundwater contamination from Landfill 26. In September 2006, USACE prepared a CSM update to assess the overall site conditions and contaminant fate-and-transport potential. The CSM update concluded that the groundwater monitoring network is adequate to monitor for potential migration, although it was recommended that a downgradient well be installed to achieve greater areal coverage. This well (MW-LF26-2) was recently installed in the vicinity (approximately 200 feet northeast) of MW-92-43. Survey coordinates for this new well are 576683.57 North, 1418357 East (see Figure 1 in Appendix C).

Based on detailed geologic, hydrogeologic and monitoring data, the CSM update also confirmed:

- Preferential groundwater flow pathways for contaminant movement downgradient are not evident, and groundwater movement in this area is limited.
- TPH and associated VOCs (BTEX and SVOCs) (naphthalene and methyl naphthalene) are attributed to various known releases upgradient of the landfill and oily sludge and petroleum hydrocarbon-contaminated soil deposited at Landfill 26. Data indicate that petroleum-related contaminants present within Landfill 26 groundwater do not have a significant effect on downgradient groundwater.
- The dissolved metals data for the 2003 to 2005 sampling events show that no significant metals contamination is observed in groundwater at Landfill 26. Concentrations of several metals correlate with natural groundwater quality zones rather than with contamination present at the site. Based on these data, barium is the only metal that appears to be linked to Landfill 26 fill materials. Therefore, the USACE has recommended that all inorganic constituents (arsenic, copper, lead, and zinc) be dropped from the list of COCs, with the exception of barium, because of the infrequency of detection and low concentration ranges.
- The great majority of VOC soil-gas detections are just above the laboratory detection limits and represent either typical ambient conditions or "noise" associated with analytical technique, sample contamination, or laboratory error. These detections are also far below the default concentrations used in the Bay Area Air Quality Management District modeling performed for the human health risk assessment (CH2M HILL, 2002), resulting in acceptable human health risk levels for VOC emissions from the vent risers.
- VOCs in soil-gas are not found to be migrating beyond the landfill in soil-gas. The existing monitoring network is adequate to detect VOCs in soil-gas that could migrate beyond the landfill.
- Methane, including naturally-occurring and potential landfill refuse-related methane, that may have accumulated under the RCRA-type cap does not appear to moving beyond the landfill and or vent trench anywhere along the perimeter. The vent trench is effectively blocking movement of soil-gas from Landfill 26.
- Along the southern boundary, methane detections have continued south of the vent trench, but multiple lines of evidence (including Carbon 14 dating, carbon isotope analysis, geochemical data showing upgradient reducing conditions, presence of high-concentration dissolved methane in groundwater, and lack of pressure gradients) show that the methane in the hot spots, located throughout Hamilton Meadows, is due to naturally-occurring organic sediments found there and are unrelated to landfill refuse.

5.4.3 Regulatory Review

A review of ARARs was conducted for the selected remedy at Landfill 26, as included in Appendix E. The review was conducted to determine if changes to standards have occurred since the ROD was issued in 1989 that might affect current protectiveness of the selected remedy.

The specific documents that were reviewed for any changes, additions, or deletions include the ROD (1989) and the ESD (1992).

Action-specific, chemical-specific, and location-specific ARARs established in the decision documents are summarized in Appendix E Tables E-1 through E-3. No changes were made to the existing ARARs, other that to re-direct references to California Administrative Code (CAC) to the applicable California Code of Regulations (CCR) requirements.

The tables also include a list of proposed changes to ARARs that would potentially be established if the ARARs were being developed at this time. These proposed ARARs, if necessary, would be memorialized in a ROD amendment.

5.5 Site Inspection

Caroline Ziegler and Terri Herson, representatives from CH2M HILL, took part in a site inspection on February 27, 2007. The inspection was accomplished by walking the site and observing, photographing, and documenting site information (see Appendices F and G). The purpose of the site inspection was to assess the protectiveness of the remedy at Landfill 26. Also, the inactive groundwater extraction and treatment system was included as part of this inspection.

The landfill site is accessible by foot. The main gate on Hamilton Road was not locked at the time of the inspection. Weather conditions during the inspection were overcast with scattered showers with temperatures around 55°F.

Landfill 26 is re-vegetated, and no signs of erosion were evident. The riprap located along the northern portion of the landfill was in good condition. In general, no sections of the cap appear to be exposed, and the integrity of the landfill cap appears to have been maintained. An extra 150 to 200 feet of property (the designated buffer zone) surrounds the landfill cap, providing an additional factor of safety. There is no leachate control system at this site. However, the existing monitoring system of groundwater wells and soil-gas points are used to regularly evaluate and control potential migration. The monitoring system appeared to be in good condition, and there were no indications of damage or disturbance to the wells/gas points. Landfill gas vents provide an additional gas control measure. These vents, which were installed in the trench along the south and southeast perimeters, were in good condition.

No uses of groundwater in the area were observed. No surface water was observed on the landfill cover. There was ponded water in the drainage ditch at the landfill's northern edge (located in a low-lying area). Previous site visits performed by the Marin County Environmental Health Services have indicated that ponded water was present in this ditch between the toe of the landfill and SPG-22, 23.

It appeared that seasonal marshlands were present to the far north of Landfill 26. Conversion of the land north of Landfill 26 to wetlands is part of the ongoing wetlands restoration project.

Inspection of the groundwater treatment plant was also conducted. The intended use of the plant was to provide a preventative measure of hydraulic containment and to treat extracted groundwater from wells located both downgradient and within Landfill 26. Although part of the selected remedy, this extraction and treatment system has remained inactive since the completion of construction in 1995. The treatment plant was securely locked. Outdoor

fencing was present along the perimeter of the plant; the main gate at the plant driveway was protected with a padlock. Entry to the plant was provided to CH2M HILL by Tom Purbaugh of Cerrudo Services, General Contractor (formerly involved in the plant construction). The major treatment components inside the plant building included an inactive oil/water separator, water filter, and empty neutralization, carbon and water storage tanks. The laboratory and chemical storage areas were also inspected. These areas have been emptied of chemicals and lab equipment to the maximum extent possible. Lime powder, titration trays, small scales, and a minimal volume of pH buffer/solution were present. The extraction system and treatment system are inactive, and no untreated or treated water was present. Also, electrical controls and instrumentation were not in use.

A Final Closure and Post-closure Maintenance Plan has been generated for this site, although the plan was not present at the site during the inspection. The facility has updated WDRs from the Water Board. Monitoring activities, as specified in this Order, are being conducted.

5.6 Interviews

Interviews were conducted with various parties connected to the site as follows:

Name	Title/Position	Organization	Interview Date
Karole Ward	Formerly Used Defense Sites (FUDS) Program Manager	USACE, Sacramento District	06/21/2007
Theresa McGarry	Hazard Substances Scientist/Project Manager	Department of Toxic Substances Control	07/06/2007
Brian Thompson	Engineering Geologist	Regional Water Quality Control Board	07/16/2007
Mark Janofsky	Senior Environmental Health Specialist	Marin County Environmental Health Services	06/18/2007
Matthew McCarron	Community Co-Chair	Restoration Advisory Board	06/15/2007

The general consensus of all the interviewees is that overall the Hamilton Landfill 26 project is well run. The exception was Brian Thompson who started working on the project in March 2006 and is still formulating his impression. The major concern seems to be related to access issues that could, in turn, be compromising both the landfill cap and some of the monitoring wells. All of the interviewees noted that they were aware of trespassing by unauthorized vehicles and that some were causing ruts in the landfill cap. Some suggested better signs and fencing in order to secure the area for authorized personnel only. Even authorized vehicles seem to cause some concern due to noise and disturbance by truck traffic along Todd Road (used by the Army and some of its contractors for other restoration sites at the former HAAF). Both Mark Janofsky and Matthew McCarron felt that the homes along the southeast landfill boundary were allowed to be built too close to the landfill and that soil-gas monitoring should continue. Mr. Janofsky also feels that it is important to

continue to evaluate possible methane issues along the north and west landfill boundary. Mr. Thompson felt that due to findings of recent inspections which showed erosion around the landfill perimeter, likely caused by burrowing animals, more rip-rap may need to be placed in these areas. He felt that it was important that the landfill cap be maintained and that adequate drainage be ensured. All agreed that there have been no changes to ARARs or land use/zoning.

The interview documentation form and interview records appear in Appendix H of this report.

SECTION 6.0

Technical Assessment

This section evaluates the functioning of the remedy as intended, the current status of assumptions, and new information affecting the remedy.

6.1 Question A: Is the Remedy Functioning as Intended by the Decision Documents?

Landfill Soil/Refuse Remedy: The review of documents, ARARs, risk assumptions, and the results of site inspection indicates that the remedy is functioning as intended by the ROD, as modified by the ESD; however, cautionary actions may be required:

- The RCRA-type cap component of the remedy pertains to appropriate closure of the landfill. Although portions of the landfill refuse are perennially saturated by groundwater, the primary purpose of the cap is to minimize the infiltration of rainwater into the underlying waste mass, thereby reducing the potential for waste contaminants and degradation byproducts to percolate into the groundwater. To enhance the Landfill 26 final cover system's performance in surface water removal, other components, including a drainage control system and erosion control measures (gradual slopes), were included in the closure and should be followed accordingly. Further, security measures do not appear to be currently adequate in deterring unauthorized personnel from entering the landfill area.

Groundwater Remedy: The review of documents, ARARs, risk assumptions, and the results of site inspection indicates that the remedy is not functioning as intended by the ROD, as modified by the ESD:

- The original remedy included a groundwater extraction and treatment component (listed in Section 4.0). Based on a comprehensive evaluation of several years of groundwater monitoring data, it was concluded that contaminants from Landfill 26 were not significantly impacting groundwater outside the Landfill 26 boundary. It was determined that extraction and treatment was not currently necessary to protect human health and the environment. The groundwater treatment plant was tested but was never placed into operation. Included in Appendix A of this five-year review is an evaluation of the groundwater treatment plant decommissioning process.

- Groundwater monitoring continues, however, and has indicated that groundwater concentrations are stable and not significantly impacting groundwater quality downgradient. Further, it is concluded that this monitoring program is protective of human health and the environment. Recently, additional fieldwork was completed to fill a data gap; the installation of one groundwater monitoring well was completed in May 2007, northeast of the landfill, to confirm downgradient groundwater quality. A proposed performance based approach to the groundwater program as a check for

potential offsite contaminant migration has been included as part of this five-year review (Appendix C). Preparation of a ROD Amendment is recommended.

Soil-Gas Remedy: The review of documents, ARARs, risk assumptions, and the results of site inspection indicates that this remedy (currently an interim remedy) was never recorded in a decision document and therefore is not functioning as intended. Findings, however, indicate that this interim remedy is protective of human health and the environment. In order for this remedy to become final, USACE has prepared a Feasibility Study and intends to prepare a ROD Amendment to incorporate this interim remedy as a final preferred remedy for the landfill soil-gas issue.

6.2 Question B: Are the Assumptions Used at the Time of Remedy Selection Still Valid?

This section assesses the exposure assumptions, toxicity data, cleanup levels, and remedial action objectives used at the time of remedy selection.

Changes in Site Conditions

- Since the ROD and ESD were prepared, investigative studies of the site have revealed that operating the existing pump-and-treat system would result in localized groundwater elevation depression and could have significant adverse impacts to soil-gas migration (CH2M HILL, 2006). The adverse impact cause by dewatering the refuse zone and creating a decline in groundwater elevation includes potentially undermining barriers to soil-gas contaminant transport in some areas of the buffer zone. These potential impacts to the vadose zone would challenge the accuracy of the protectiveness of the remedy. However, as mentioned above, since startup testing was conducted in 1995, the groundwater and extraction treatment system was not placed in operation.

- The greatest uncertainty with changes in site conditions for the Landfill 26 site is methane. Before the RCRA-type cap was designed, several methane studies and sampling events were conducted, and it was concluded that the landfill was non-methanogenic based on evaluations of the nature and extent of buried wastes (USACE, 1993; WCC, 1997). Because of this determination, the RCRA-type cap was not equipped with any form of gas collection system or passive gas vents. In 1994, as part of the landfill closure, 23 gas monitoring probes (GMP-1 through GMP-23) were installed at intervals of approximately 200 feet within the landfill buffer zone around the perimeter of the final cap. While initial monitoring results indicated that methane concentrations in soil-gas were generally well below the regulatory limit of 5 percent by volume (lower explosive limit for methane), in June 1996 (at probe GMP-5) and in September 1999 (at GMP-5 and GMP-9), methane was detected above 5 percent in soil-gas samples from two probes (GMP-5 and GMP-9) (ITSI, 1999). These findings resulted in:

  – Installation of additional monitoring probes. The gas monitoring program was augmented to encompass the landfill, the landfill buffer zone, and the proximate portions of the City of Novato's Hamilton Meadows development.

- A study conducted by USACE during 2000 that indicated that methane detections were sporadic and additional investigation was necessary.
- In November 2001, Water Board Order No. 01 -139 and Time and Schedule Order No. 01-140 that required investigation and remediation of methane originating from Landfill 26. Specific requirements set forth in the Order include preparation of a Corrective Action Investigation Work Plan; preparation of a Corrective Action Investigation and Corrective Action Report; preparation of a Landfill Corrective Action Remedial Design; installation and operation of the landfill corrective action system, and monitoring of groundwater, surface water, and soil-gas.
- Ultimately, additional remedial action was performed. A perimeter passive vent trench was installed in the landfill buffer zone in late 2002 and early 2003.

As mentioned, there have been a number of changes since the remedy was selected. As such, this 5- year review includes a list of proposed changes to ARARs that would potentially be established if the ARARs were being developed at this time (see Appendix E).

Changes in Exposure Pathways and Toxicity Values

Based on review of the 1988 risk assessment (basis of the ROD), it was determined that exposure assumptions and toxicity data have changed since that assessment was completed. An updated risk assessment was prepared using current exposure assumptions, toxicity data, and groundwater sampling results from 2003 to 2006. A technical memorandum related to risk assessment update and toxicology analysis is included in Appendix I. Although groundwater is not currently used and there are no plans to do so in the future, the risk assessment update concluded that potential risk exists under a hypothetical future residential exposure scenario. The risk assessment considered the primary contributor to the risk to be naphthalene. Naphthalene was only detected in 3 of 98 groundwater samples that make up the RA Update data set. Therefore, future risks may be overestimated using this data set containing samples from 2003 to 2006 assuming no reduction in chemical concentrations is occurring.

6.3 Question C: Has Any Other Information Come to Light that Could Call Into Question the Protectiveness of the Remedy?

The landfill gas sampling indicates that VOCs in soil-gas do not pose a potential risk to human health. However, there continues to be some concern that the refuse-related methane production could lead to potential explosive conditions if the buildup of methane concentrations reach or exceed the lower explosive limit. A Draft Final Feasibility Study was prepared to evaluate soil-gas remediation alternatives against CERCLA evaluation criteria and submitted for agency review in May 2007. It is anticipated to become final in late 2007. Based on preliminary findings of the draft feasibility study, the preferred alternative may be the existing passive venting system supplemented with additional components. The potential corrective action may include the existing passive vent trench augmented by vapor barriers, additional monitoring, and institutional controls.

Based on groundwater monitoring data, including chemical and hydraulic data, the migration of plume contaminants is controlled. The monitoring data show that contaminants have not significantly impacted groundwater outside of the Landfill 26 boundary and do not pose a threat to human health or the environment. The USACE recently installed one additional monitoring well to confirm conditions are stable downgradient (northeast) of the landfill. There is no other information that calls into question the protectiveness of the remedy.

SECTION 7.0

Issues

This section discusses each of the issues identified as part of this review.

1. Issue

The groundwater extraction and treatment system that was installed has not been operated since startup testing. This decision not to treat groundwater was not addressed in the site decision documents.

2. Issue

While an interim remedy exists at Landfill 26, a final remedy to address methane in soil-gas has not been established.

3. Issue

Site security issues including vandalism and trespassing are occurring and require additional controls.

4. Issue

The previous decision documents require updating to address the current remedy for methane in soil-gas, groundwater and institutional controls.

5. Issue

Coordination between the landfill and wetlands restoration project must ensure that measures are taken to continue adequate surface water drainage at the landfill.

SECTION 8.0

Recommendations and Follow-Up Actions

This section provides suggested recommendations for improvement of each of the identified issues.

1. Recommendation

The site decision documents will be updated to reflect the current groundwater remedy. Also the USACE has prepared a technical memorandum for decommissioning of the water treatment plant and planning considerations for future reuse.

2. Recommendation

The USACE submitted a Feasibility Study for soil-gas in May 2007 (anticipated to become Final in late 2007). This will establish the final remedy for methane in soil-gas, as continued used of the current passive venting system with a perimeter trench and institutional controls.

3. Recommendation

Because potential vandalism is resulting in damage to the cap (ruts) as well as to the monitoring wells/probes, it is recommended that site security be improved. Fencing and signs should be assessed and, where necessary, reinforced to allow for only authorized personnel entry. Driving routes within the landfill area should be well established with posted signs, if necessary, to prevent inadvertent damage during maintenance and monitoring activities.

4. Recommendation

The ARARs and decision documents will be updated. A ROD Amendment will be issued to incorporate the current selected remedy for methane in soil-gas, groundwater and institutional controls.

5. Recommendation

It is recommended that the landfill and wetlands project team continue to collaborate and manage modifications to the drainage facilities to ensure proper surface water drainage and flood control.

The issues, recommendations and follow-up actions are summarized in Table 8-1.

TABLE 8-1
Summary Table-Issues, Recommendations and Follow-up Actions
Five-year Review Report for Landfill 26, Former Hamilton Army Airfield, Novato, California

Issue	Recommendations and Follow-up Actions	Party Responsible	Oversight Agency	Milestone Date	Affects Protectiveness (Y/N)	
					Current	Future
1. Decision to not operate the groundwater extraction system not addressed or documented.	Finalize and approve technical memorandum to identify recommendations for future land use and decommissioning. Incorporate decisions relating to the groundwater treatment and extraction system into a ROD Amendment.	USACE	Department of the Army	June 2009	N	N
2. Final remedy to address soil-gas has not been established.	Finalize feasibility study to establish final remedy for methane in soil-gas.	USACE	Department of the Army	December 2007	Y	Y
3. Site security needs improvement.	Reinforcement of fencing and signs, as necessary. Establish driving routes in the landfill area.	USACE	Department of the Army	May 2008	N	Y
4. Decision documents need to be updated to reflect current site remediation activities for methane, groundwater, and institutional controls.	Prepare ROD Amendment and update ARARs.	USACE	Department of the Army	June 2009	N	Y
5. Landfill drainage could be impacted by activities conducted on the nearby wetlands restoration project, requiring coordination and cooperation between the project teams.	The landfill and wetlands restoration project teams should continue to collaborate and manage modification to drainage facilities to ensure proper surface water drainage and flood control.	USACE	Department of the Army	Ongoing	N	Y

SECTION 9.0

Protectiveness Statement

The remedial actions at the Landfill 26 site are currently protective of human health and the environment. In general, potential sources of exposure that could result in unacceptable risks are being controlled.

The current remedial activities for groundwater are protective, with the monitoring network program serving as a means for providing advance notice if results indicate the need for a triggering action due to potential contaminant migration. Currently preferential groundwater pathways for contaminant movement downgradient of the landfill are not evident, and groundwater movement in this area is limited.

The remedial activities for soil/refuse including a RCRA-type cap are protective and maintained through a quarterly inspection program.

The interim remedy currently in place for soil-gas is protective of human health and the environment. The passive venting system with a perimeter trench is effective at preventing soil-gas from migrating to the nearby residential development. To ensure long term protectiveness, USACE conducted a thorough evaluation of the soil-gas data and in May 2007 completed the Draft Final Feasibility Study (FS) for soil-gas. The current interim remedy has been identified by the USACE as the preferred remedial alternative. In addition, institutional controls will prevent damage and limit access to the landfill cap for long term protectiveness.

SECTION 10.0

Next Review

The next comprehensive five-year review will be completed on or before five years from the approval date of this report.

SECTION 11.0

References

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Appendix A
Groundwater Treatment Plant Decommissioning Process Evaluation

Hamilton Army Airfield Landfill 26 Groundwater Treatment Plant Decommissioning Process Evaluation

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DATE: June 13, 2007

PROJECT #: 350696.01.04

This memorandum has been prepared to document the evaluation of the current status of the groundwater treatment plant constructed as part of the remedial action for Landfill 26 (LF 26), and provide recommendations for the future use/demolition of the plant. The plant is located at the former Hamilton Army Airfield (HAAF) in Novato, California. The information presented in this memorandum is based on a recent site inspection (conducted February 27, 2007), discussions with the US Army Corps of Engineers (USACE) project team, and review of documents associated with this site.

1. Introduction and Regulatory Background

HAAF LF 26 is located within the former marshland and floodplain for Novato Creek along the margin of San Pablo Bay. LF 26 was used as a disposal area from the 1940s to the 1970s. No records were kept of the disposal practices at LF 26. However, based on evaluations from a number of field investigations, LF 26 received approximately 171,000 cubic yards of waste, including approximately 20,000 cubic yards of oily sludge. A groundwater extraction and treatment system and Resource Conservation and Recovery Act (RCRA)-type landfill cap were installed during the period from 1992-95. These remedial actions were conducted in response to the Regional Water Quality Control Board (RWQCB), Bay Area Region Waste Discharge Requirements (WDRs) Order No. 92-029, a Record of Decision (ROD) signed in August 1989, and a 1992 Explanation of Significant Differences (ESD).

In accordance with the ROD, the ESD and WDR 92-029, the purpose of the groundwater treatment system was to provide hydraulic containment of shallow groundwater beneath LF 26. The system includes 14 extraction wells and a treatment system capable of treating low levels of total petroleum hydrocarbons (TPH), volatile and semi-volatile organics, metals, and pesticides. In 1996, RWQCB issued WDR 96-113 requiring continued groundwater monitoring and preparation of a technical report that would, in part, re-evaluate the need for hydraulic containment and perform statistical tests to determine the source(s) of groundwater contamination detected outside LF 26 including volatile and semi-

volatile organics, petroleum hydrocarbons and metals. A Technical Summary Report was prepared by Woodward-Clyde Consultants in 1997. It concluded that hydraulic containment was not needed at that time and that contamination detected in wells outside LF 26 originates from sources other than and outside of the landfill, although some portion of the TPH originates from within LF26. Data from ongoing groundwater monitoring indicates that waste materials in LF 26 have not significantly impacted groundwater outside the landfill boundary (with the exception of TPH) and most recently confirmed in the Landfill 26 Conceptual Site Model Update prepared by CH2M HILL in 2006.

Based on the conclusion that hydraulic containment was not needed, in 1998, the USACE requested that CH2M HILL conduct a study that would present a scope of work and specific procedures required to decommission ("mothball") the existing LF 26 treatment plant and extraction well system. The groundwater extraction and treatment system is not currently in use. The reason is documented in the Regional Water Quality Control Board Order No. R2-2006-0064 which states that "groundwater impacts have not been noted so as to justify operation of the system".

2. Status and Inspection of Groundwater Treatment Plant

On February 27, 2007, the inactive groundwater extraction and treatment system was inspected by Terri Herson and Caroline Ziegler, of CH2M HILL, as part of a site visit that was conducted for preparation of a five-year review report. The treatment plant building is located on the east side of the landfill at the north end of the access road (Todd Road).

The groundwater treatment plant and associated extraction wells were intended to provide hydraulic containment and treat groundwater extracted from wells located down gradient and within LF 26. The system extracted and treated about 300,000 gallons of groundwater as part of a system prove-out in 1995.

The following is a summary of items noted during the site inspection:

- Outdoor fencing was present along the perimeter of the plant; the main gate at the plant driveway was protected with a padlock;
- The observed construction of the securely locked treatment plant building is prefabricated concrete walls on the exterior, cinderblock interior with a sealed concrete floor, approximate dimensions of 40 feet wide by 97 feet long;
- The roof is made of metal;
- No potentially hazardous building materials, such as asbestos containing materials (ACM) were observed;
- All utilities, such as electrical and water are currently disconnected;
- The building appears to be in good shape, although some broken windows and evidence of birds, lizards, rats, mice and insects were noted inside the building;
- All empty and clean pipelines, tanks, instrumentation and equipment were non-operational;

- The discharge effluent piping appears to still be connected to the storm drain system;
- The major treatment components inside the plant building include an oil/water separator, water filter, and empty neutralization, carbon and water storage tanks;
- The plant building includes laboratory and chemical storage areas. Some lime powder, titration trays, small scales and a minimal volume (less than 2 liters) of pH buffer/solution were observed;
- The lavatory was intact but not operational, with all plumbing still apparently hooked up to the septic system; and
- Most of the electronic and instrumental controls use analog technology.

Figure 1 provides the basic floor plan or layout of the existing equipment (process piping not shown). Photographs of the extraction and treatment system are available for review in the site inspection technical memorandum which is included as an appendix to the Five-Year Review report.

The extraction wells were not observed at the time of the February site visit. According to USACE, the extraction pumps are still in each of the extraction wells. The piping from the wells to the treatment system building is all underground.

3. Treatment Plant Decommissioning Process Evaluation

Several documents were reviewed as part of this Landfill 26 groundwater treatment plant decommissioning process evaluation:

- Groundwater Treatment Plant Decommissioning at Landfill 26, Hamilton Army Airfield (CH2M HILL, 1998)
- Final Closure and Postclosure Maintenance Plan, Hamilton Army Airfield Landfill 26 (CH2M HILL, 1999)
- Landfill 26 Conceptual Site Model Update, Hamilton Army Airfield, Novato, California (CH2M HILL, 2006)
- Order No. R2-2006-0064, Updated Waste Discharge Requirements and Rescission of: Waste Discharge Requirement Order No. 96-113; Cleanup and Abatement Order No. 01-139; and Time Schedule Order No. 01-140: United States Department of Defense, Department of Army, Landfill 26. Former Hamilton Army Airfield, Novato, Marin County (RWQCB-SFB, 2006)

These documents confirmed that impacts to groundwater are such that operation of the treatment system is not justified.

4. Comments and Recommendations for the Treatment Plant

CH2M HILL has the following comments and recommendations for the LF 26 Groundwater Treatment Plant.

- Groundwater extraction was problematic at this site due to low yields as a result of low permeability. Design extraction rates proved difficult to achieve during initial testing of the system in 1995.
- Operation of the extraction system and Groundwater Treatment Plant is not needed for the purpose it was designed (e.g. hydraulic containment of shallow groundwater beneath Landfill 26).
- Groundwater extraction and treatment is also not needed for remediation or hydraulic containment of other potential nearby sources of chemicals.
- A plan for dismantling of the Groundwater Treatment Plant should be prepared. This plan should include removal of all treatment system components and abandonment of the associated extraction wells and piping. Preference should be given to resale/reuse of the existing equipment elsewhere.
- If no potential reuses for the building are identified, then it is recommended that the building be removed.
- If viable potential reuse options are identified, than these options for the building should be evaluated with the local community and stakeholders. Consideration of future use of the building should consider:

Stakeholders – identification of the stakeholders and their connection to the site, e.g. site owner, current use, developer, local government, community members, etc.

Site Description – description of the physical features, location in relation to residential, commercial, industrial, recreational areas, etc.

Utilities – practicality of running electrical and water utilities to the building

Environmental Considerations – potential restrictions resulting from environmental contamination, groundwater use classification/determination

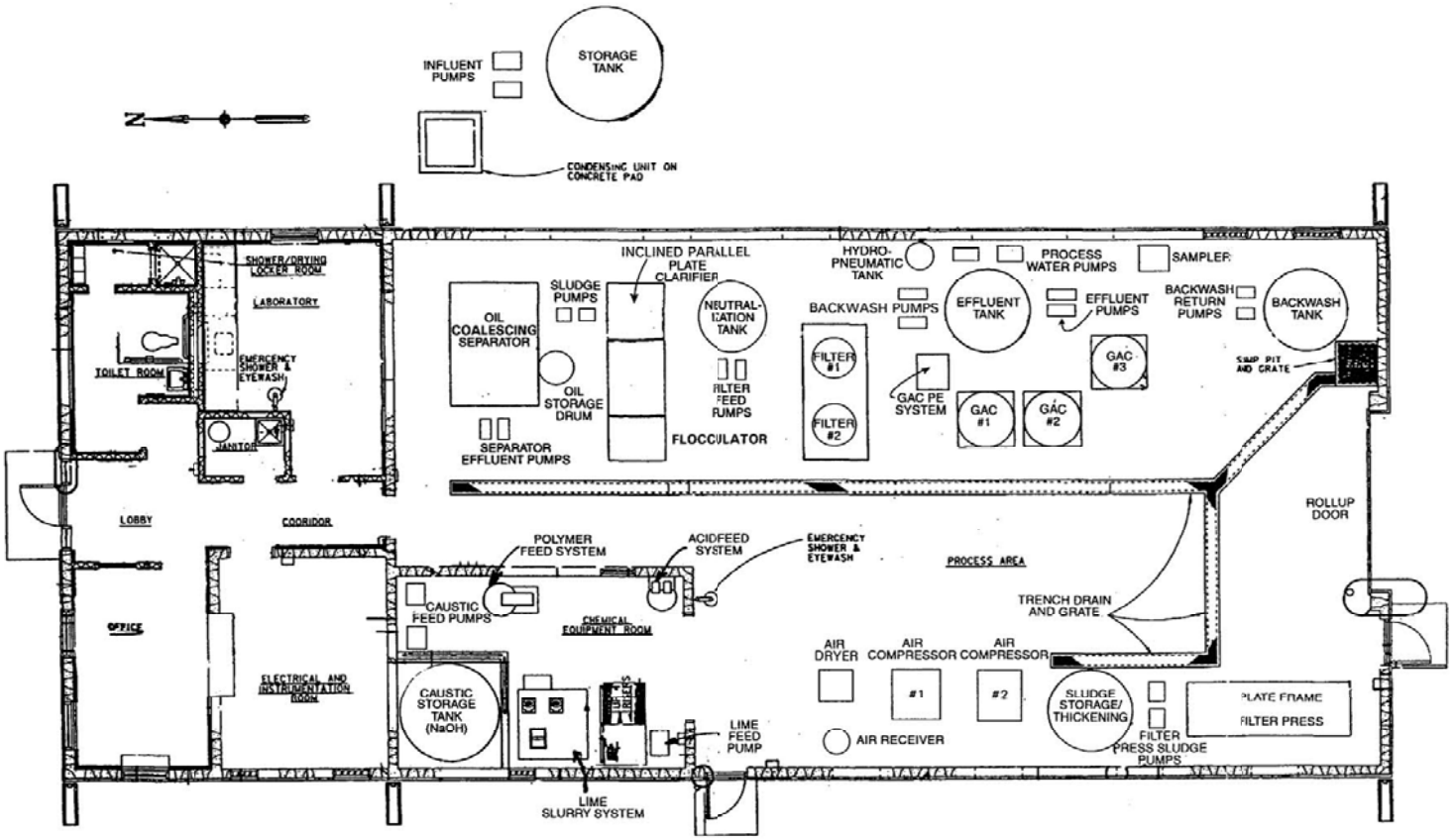
Site Ownership – entity that holds title to the site, who controls access, any property liens, owner preferences or plans including sale of the property

Land Use Considerations and Environmental Regulations – zoning, area master plans, federal, state and/or local environmental regulations impacting reuse, institutional controls such as easements or covenants already in place, historical or cultural resources

Community Input – future reuses that the community would support/oppose

Public Initiatives – infrastructure plans that may influence site uses, potential municipal/public uses, including park and recreational facility, funding availability for development

Most Likely Future Uses – summarization of information as the basis for concluding the most likely future use or uses



Notes:

1) Process piping not shown
2) See Appendix D, As-Built Drawings, for additional information
3) Locations of all treatment system components are approximate; field-verify all locations and components

Floor Plan

5/64" = 1 Foot

0 5'

Approx. Scale in Feet

Figure 1
Floor Plan
Groundwater Treatment Faciltiy
Hamilton Army Airfield
Novato, California

141421.A0.03 - Hamilton - Floor Plan GW Treat Facility - 3/5/98 - da - SFO

CH2MHILL

Appendix B
Institutional Controls Evaluation

Hamilton Army Airfield Landfill 26 Five-Year Review Institutional Controls Evaluation

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DATE: June 12, 2007

PROJECT #: 350696.01.01.01

Institutional controls are non-engineering methods by which access to contaminated environmental media is restricted and the integrity of the remedy is protected. This technical memorandum summarizes the results of an evaluation of institutional controls for Hamilton Army Airfield Landfill 26 (LF 26) located in Novato, Marin County, California.

A Record of Decision (ROD) was prepared for LF 26 in August 1989 and revised by a May 1991 Explanation of Significant Differences (ESD). The remedial actions taken as a result of the decision documents were construction of a RCRA-type landfill cap for the landfill soil/refuse operable unit from 1994 to 1995 and installation of a groundwater extraction and treatment system for the groundwater operable unit from 1992 to 1993. No institutional controls (ICs) were included as part of the selected remedies outlined in the ROD and ESD. At the time of LF 26 capping, however, a 150-foot to 200-foot "buffer zone" of property around the entire landfill perimeter was designated. The "buffer zone" was created in an effort to protect the low permeability cap and to allow access to the landfill and its groundwater extraction and treatment plant. As a result of soil gas investigations which have shown detections of methane and volatile organics at LF 26, additional remedial activities have been conducted. The most significant remedial activity is placement of a vent trench in the LF 26 "buffer zone". The vent trench was constructed in phases during 2002 and completed in January 2003.

The intent of institutional control is to limit or eliminate exposure pathways to receptors. Because HAAF has closed and areas immediately adjacent to LF 26 have been developed for residential use, land use restrictions will be essential to protect ongoing remedial activities, ensure the viability of the remedies, and protect human health and the environment. The following general types of institutional controls may be implemented:

- Governmental
- Proprietary
- Informational

The LF 26 area is currently owned by the Army; however, at some point in the future the property will likely be transferred to the City of Novato. In 1999, excess Army-owned property totaling approximately 260 acres and abutting the southern, western and northern edges of the "buffer zone" were sold to the City of Novato, who in turn, resold portions of the property to New Hamilton Partnership (NHP). Final land reuse plans for the landfill are not known at this time, although past discussions have included recreational and open space uses. Institutional controls will be necessary before, at, and following property transfer. The specific types of institutional controls to be implemented during each stage are discussed below.

Institutional Controls under Army Ownership

Prior to property transfer, the Army would implement institutional controls for LF 26. The primary mechanism for institutional controls will be the landfill postclosure maintenance requirements (a governmental control). The existing postclosure maintenance plan prepared in June 1999 will be updated to reflect any revised remedial activities that are implemented as a result of the five-year review findings.

State regulations for postclosure maintenance and land use are detailed in 27 CCR, Section 21190. These regulations call for a minimum of 30 years of postclosure monitoring, reporting, and site maintenance activities. Postclosure land uses are limited to those activities that will not affect the integrity or performance of the final cover system. This regulation sets forth the performance standards and the minimum substantive requirement for proper reuse of solid waste disposal sites to ensure protection of human health and the environment. Some of the site use-related postclosure requirements include the following:

- All proposed construction improvements and changes to end use on closed sites shall be submitted to the local enforcement agency (LEA) (that is, Marin County Department of Health Services), Regional Water Quality Control Board (RWQCB), and the California Integrated Waste Management Board (CIWMB) for review, comment, and approval regarding possible construction problems, hazards to health and safety, and concerns about the integrity of the landfill's final closure cover and environmental monitoring and control networks (for example, groundwater monitoring network, soil gas monitoring network, and drainage control system).
- Construction improvements on the site shall maintain the integrity of the final cover and liner(s), all components of the containment system(s), and the functions of the monitoring system(s).
- Construction of structural improvements on top of the landfill area during the postclosure period shall include the following components:
  - Automatic methane gas sensors designed to trigger an audible alarm when methane concentrations are detected shall be installed in all buildings.
  - Any utility connections shall be designed with flexible connections and utility collars and shall not be installed in or below the barrier layer of the final cover or any liner.
  - The LEA or CIWMB may require that an additional soil layer or building pad be placed on the final cover prior to construction to protect the integrity and function of the various layers of the final cover.

The postclosure requirements may also stipulate the need for all structures constructed on the land owner's property within 1,000 feet of the boundary of the disposal area to be designed and constructed to minimize the potential for methane migration into the structures in accordance with the following:

- A permeable layer of open-graded material of clean aggregate with a minimum thickness of 12 inches shall be between the geomembrane and the subgrade or slab.
- A geotextile filter layer shall be utilized to prevent the introduction of fines into the permeable layer.
- Perforated venting pipes shall be installed within the permeable layer and shall be designed to operate without clogging; automatic gas sensors that trigger an audible alarm when methane is detected shall be installed within the piping/permeable layer and inside the building.

Institutional Controls at Property Transfer

Pursuant to 27 CCR, Section 21200**,** the following actions must be taken if there is a property transfer during the postclosure maintenance period (minimum of 30 years):

1. Before the title to a disposal site is transferred to another person during closure or postclosure maintenance, the new owner shall be notified by the previous owner or his agent of the existence of these standards and of the conditions and agreements assigned to ensure compliance; and
2. The previous owner shall notify the LEA of the change in title within thirty (30) days and shall provide the name, firm, mailing address, and telephone number of the new owner.

Institutional Controls Following Property Transfer

The postclosure requirements will remain in effect after property transfer. However, because the Army will not fully control the property following transfer, the Army (or the State) may elect to impose further institutional controls on the property to ensure the safety of human health and the environment through the use of propriety controls. Proprietary controls are an aspect of private property law that can be used to restrict or affect the use of property. Common examples include covenants or easements restricting future land use or prohibiting activities that may compromise the remedy. Proprietary controls can be implemented as a possessory interest (for example, a landlord-tenant relationship) or as a non-possessory interest by which one party could control another's use of its own property. Deed covenants (beyond the 27 CCR requirements) are a non-possessory interest that the Army can implement on property transfer. The State can also implement land use covenant (SLUC) with the property owner (for example, the City of Novato after property transfer) to control land use. The state has authority to place land use restrictions under the Health and Safety Code Section 25355.5 for remediated sites (Toxic Substances Control Program Official Policy/Procedure No. 87-14) and under Title 22, Division 4.5, Chapter 39, Section 67391.1(e)(1). As an alternative, the California Department of Health Services and the property owner may enter into a mutual agreement regarding land use restrictions (Health and Safety Code Section 25222.1). By applying mutually reinforcing mechanisms

(that is, layering) (U.S. Department of Defense, 2001), the overall effectiveness of land use restrictions can be strengthened.

Advisories do not have any legal effect but can be used to provide notice to potential land users of residual contamination and the existence of the institutional control. Local public health agencies, the State, and/or the Army can implement the advisories through the existing community relations program.

Due to changes at the site since the remedy was selected, one of the five-year review recommendations is to prepare a ROD amendment and update ARARS. It is recommended that the ROD amendment incorporate institutional controls as part of the final remedy.

Appendix C
Performance-Based Groundwater Monitoring Approach

Hamilton Army Airfield Landfill 26, Performance-Based Groundwater Monitoring Approach

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DATE: June 12, 2007

PROJECT #: 350696.01.03

This memorandum has been prepared to document the proposed approach for development of a performance-based groundwater monitoring in order to track changes in concentrations of constituents of concern (COCs) and the potential for their migration within and outside of the Landfill 26 (LF 26) boundaries.

It is important to establish performance criteria as part of the groundwater evaluation monitoring required under Regional Water Quality Control Board (RWQCB) Order R2-2006-0064 (the Order) as the site moves toward postclosure maintenance and care. Generally, the Order, which is based in part on applicable state laws including the California Code of Regulations Title 27 (CCR Title 27), requires protection of groundwater and prohibits further degradation of groundwater quality and/or substantial worsening of existing groundwater impacts. Specifically, the Order requires continuation of evaluation monitoring where water quality impairment and/or determination of a statistically significant increase in indicator parameters or waste constituent concentrations has occurred based on detection monitoring per CCR Title 27 Sections 20380 through 20435.

1. Introduction

Hamilton Army Airfield (HAAF) LF 26 is located within former marshland and floodplain for Novato Creek along the margin of San Pablo Bay. LF 26 was used as a disposal area from the 1940s to the 1970s. It covers an area of approximately 30 acres. The refuse layer within LF 26 is approximately 5 to 8 feet in thickness and is mostly saturated with groundwater.

2. Status of Groundwater Monitoring Program

The Army has maintained an active monitoring program since 1993 to assess contaminant concentrations at locations within and surrounding LF 26. The current groundwater monitoring program includes annual monitoring of fifteen wells for target COCs including:

chlorobenzene, 1, 2-dichlorobenzene, 1, 4-dichlorobenzene, naphthalene, total petroleum hydrocarbons (TPH) - diesel, arsenic, barium, copper, lead, and zinc. These COCs were chosen due to their association with the refuse waste, their detection frequency and detection locations. The location of the wells, in the current monitoring program, are shown on Figure 1. MW-LF26-2 is a new well not currently in the monitoring program. It is discussed in more detail below.

3. Proposed Performance-Based Groundwater Monitoring Approach (Surveillance Monitoring)

To comply with the Order regarding further degradation of groundwater quality and/or substantial worsening of existing groundwater impacts, it is necessary to develop an approach that would fill a dual purpose. The approach should 1) include an indicator of change; and 2) provide triggers for further action if significant changes are observed.

The key elements of this surveillance monitoring approach are:

- Groundwater movement, especially down gradient of the landfill boundary; and
- Track changes in contaminant levels.

A change in groundwater movement directions or increase in contaminant levels would trigger further evaluation. Under CCR Title 27, corrective action could be needed due to potential negative impacts to human health and/or the environment. A possible example of corrective action, if significant increases in concentrations occurred, would be to re-evaluate the conceptual site model or the exposure pathway analysis for human and/or ecological receptors to determine if there is a potential risk to human health or the environment.

Data collection to confirm the groundwater flow direction will be an important aspect of the annual groundwater surveillance monitoring event. Historically, groundwater flow direction has been in a north to northeast direction. Therefore the monitoring wells located north and northeast of the landfill are down gradient of the landfill. The wells currently being monitored are: MW-25, MW-123, MW-92-40, MW-92-43, MW-L-26-1, and MW-92-44 (Figure 1, downgradient wells represented as orange). As long as a north to northeast groundwater flow direction is maintained, these wells will constitute the groundwater surveillance monitoring network.

A new downgradient well, MW-LF26-2, was installed in February 2007 (Figure 1). Per the USACE, the well is scheduled to be sampled on a quarterly basis for one year. Based on the analytical results obtained from the sampling events, this new downgradient well may be incorporated into the groundwater surveillance monitoring network.

As part of the proposed approach, changes in contaminant levels at the down gradient wells are to be statistically analyzed using combined Shewhart-CUSUM control charts (Gilbert, 1987; USEPA, 1989; Gibbons, 1994). These charts offer a graphical method to show when a concentration exceeds baseline concentrations levels due to a rising trend or an abrupt increase in concentration level. The method accommodates occasional non-detect results with proxy substitutions of one half the detection limit.

Typically the baseline sample set comprises the eight most recent samples from each well. The mean and standard deviation for the concentrations conditions are calculated for the baseline set. The Shewhart-CUSUM method assumes that the data are statistically independent and distributed normally. This allows the derivation of appropriate upper control limits for baseline concentrations to identify significant concentration shifts at individual wells.

Upper control limits are used to determine if an individual concentration at a down gradient well is "out of control" and needs investigating to determine if a release has occurred. It is assumed that the current sampling frequency (annual) and COC list provide independent and normally distributed concentration data.

Application of the Shewhart-CUSUM statistical analysis method to the groundwater monitoring data should be part of the annual reporting requirement. If concentrations remain in control for five years, then filing a request to the RWQCB either for the cessation of postclosure monitoring or a reduction in sampling frequency is recommended.

Site specific examples of how this methodology would be applied are attached to this memorandum (see Attachment A).

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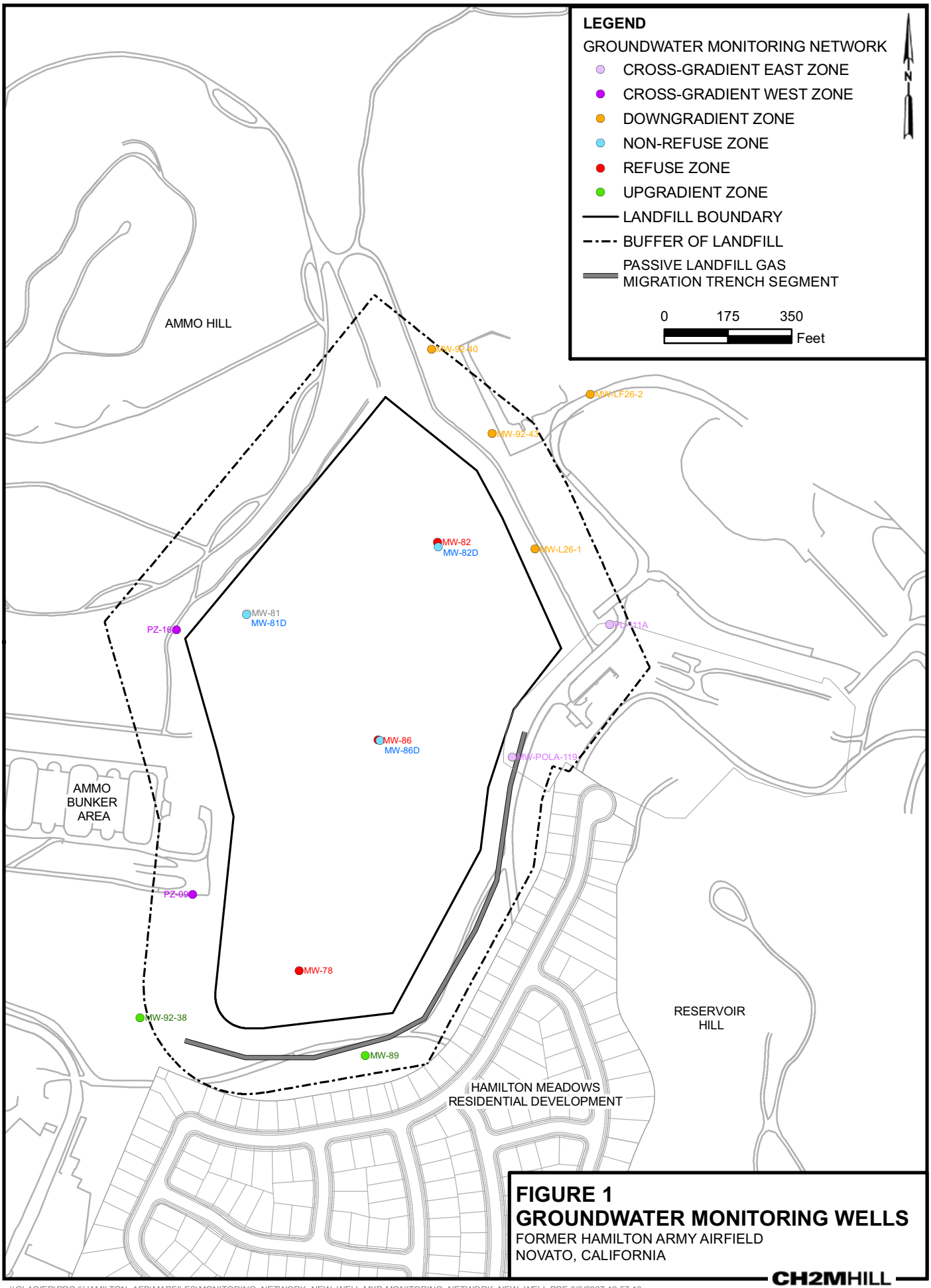


FIGURE 1
GROUNDWATER MONITORING WELLS
FORMER HAMILTON ARMY AIRFIELD
NOVATO, CALIFORNIA

CH2MHILL

\\GLACIER\PROJ\HAMILTON_AFB\MAPFILES\MONITORING_NETWORK_NEW_WELL.MXD MONITORING_NETWORK_NEW_WELL.PDF 6/6/2007 12:57:16

Attachment A
Site Specific Examples of Shewhart-CUSUM Control Charts

Shewhart-CUSUM Control Charts

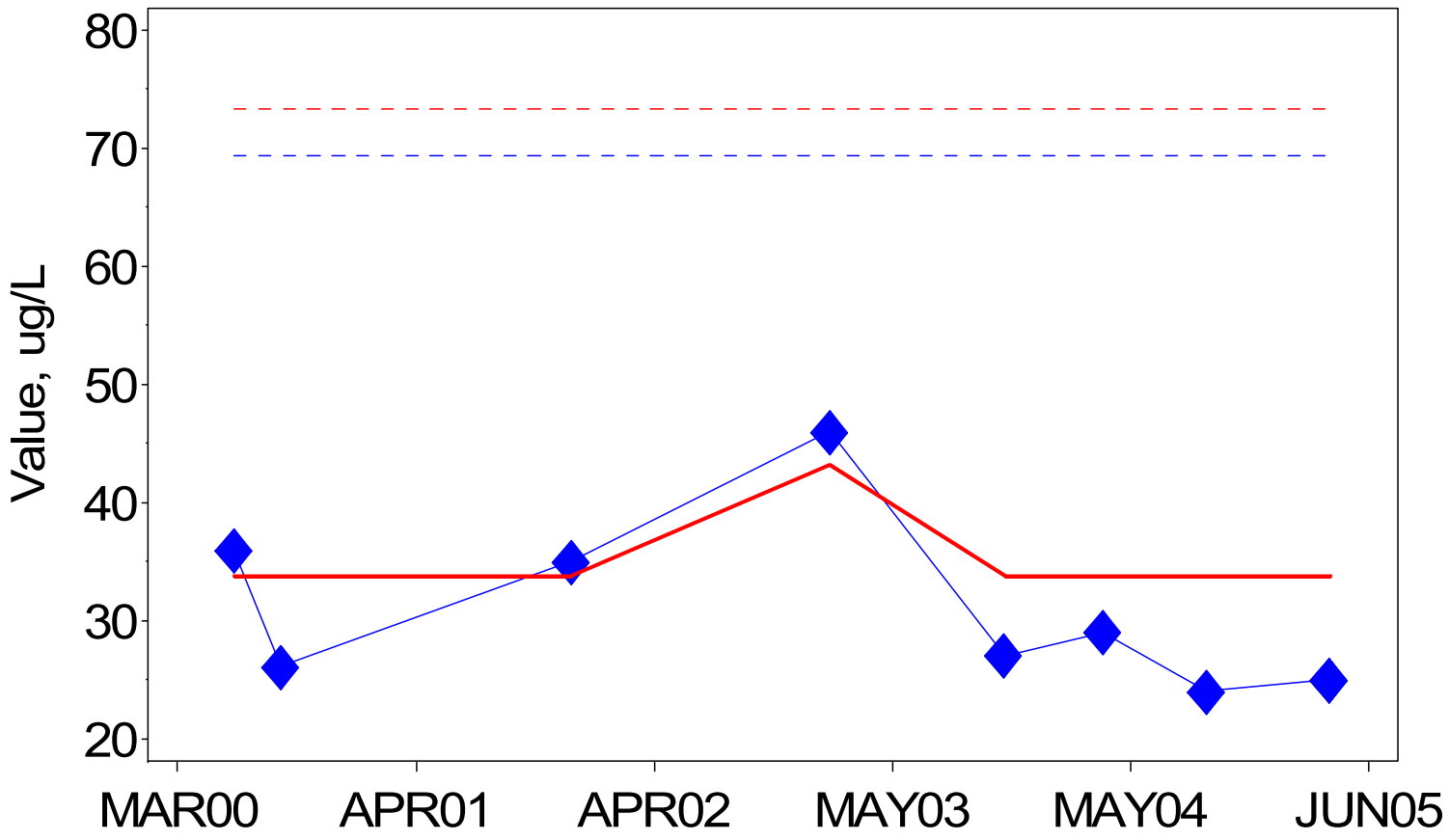
When several samples are taken from a population (such as groundwater concentrations from individual wells) over time, plotting the concentrations versus time aids in the understanding of temporal patterns in the data. When statistical limits, calculated with historical data, are added, the resulting plots are known as control charts. Control charts are widely used in industry to help determine when a process is becoming 'out of control'. Similarly, in groundwater applications, they can help determine when a single concentration or a group of concentrations are significantly different than the historical data.

Example control charts for Total Barium and TPH-Diesel from Well MW-L26-1, known as a downgradient well at LF 26, are presented as Figures 1 and 2, respectively. These data represent the eight most recent concentrations for these parameters. Two different control limits are plotted on these control charts. These are the Shewhart limits for individual concentrations and the cumulative sum (CUSUM) limits. The former rely simply on the variability within the individual baseline values to construct simple confidence limits about the data to which monitor data is directly compared. The latter are calculated taking into account pooled sums of recent events. This cumulative approach emphasizes trends in the data over time as opposed to single event snapshots of concentrations. The CUSUM plots offer an improved method for detecting small shifts in concentration patterns.

Descriptions of developing these limits for groundwater are provided in EPA guidance (EPA, 1989) and described in various technical sources (Gilbert, 1987; Gibbons, 1994) and serve as comparison thresholds for future monitoring concentrations. The individual concentrations are marked with diamonds and joined with a thin line. The Shewhart limits for comparison to these individual concentrations are derived as the mean plus 4.5 times the standard deviation of the monitoring well results or proxy substitutions of ½ the detection limit for non-detects (EPA, 1989).

As this guidance recommends, transformations of the data (e.g. log-transformations) are evaluated when the data do not appear normally distributed. The Total Barium concentrations did appear normally distributed per the Shapiro Wilk test for normality. This test, however, rejected the assumption that TPH-Diesel concentrations were normally distributed, and instead accepted an assumption of lognormality. For this reason, the data were log-transformed prior to calculating the limits.

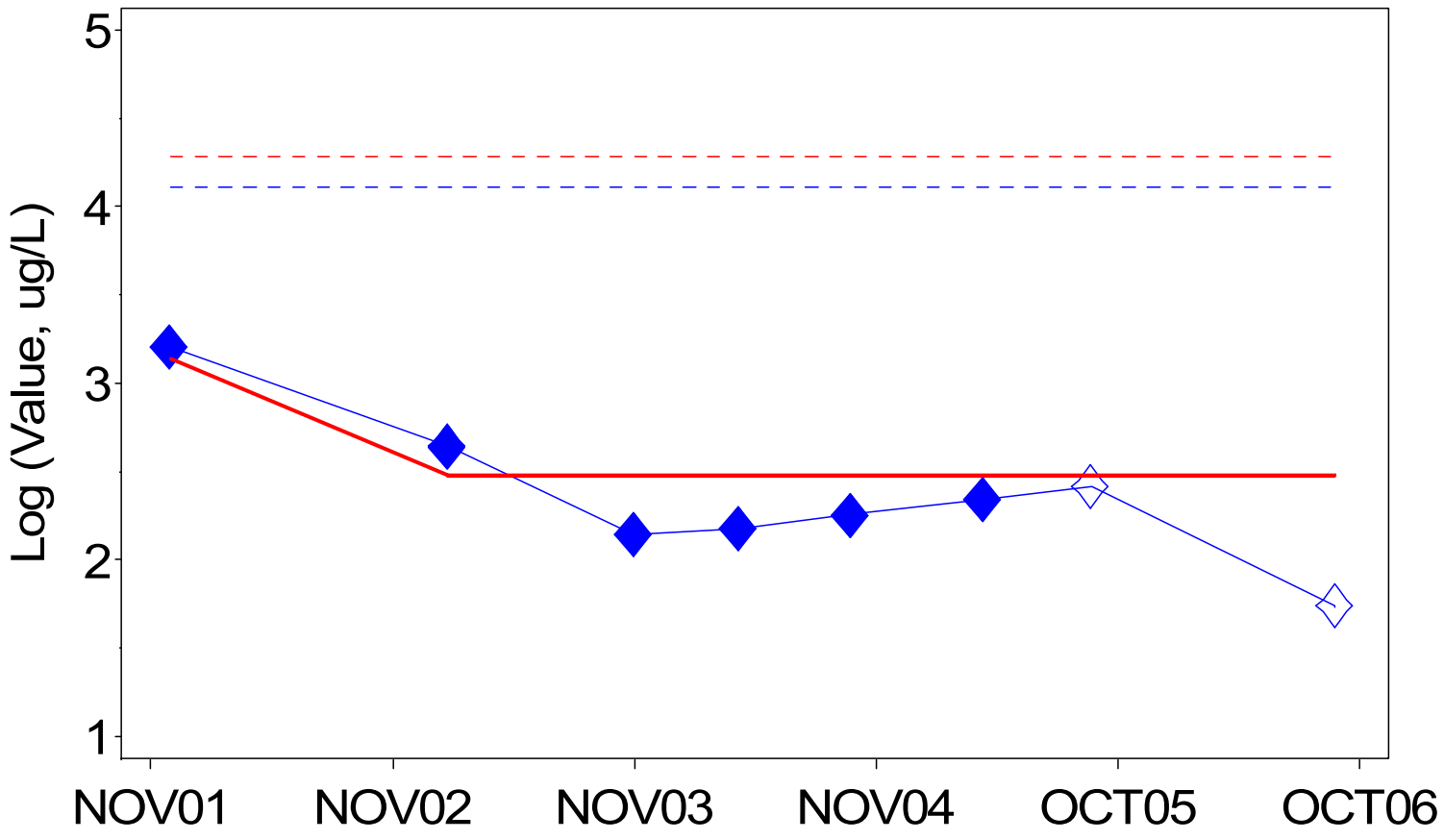
Figure 1: Shewhart-CUSUM Chart for Total Barium in Well MW-L26-1



Blue lines represent concentrations; Red lines represent CUSUM values

Limits are presented as dashed lines; Nondetect proxies (1/2 the detection limit) are presented as open symbols

Figure 2: Shewhart-CUSUM Chart for TPH-Diesel in Well MW-L26-1



Blue lines represent concentrations; Red lines represent CUSUM values

Limits are presented as dashed lines; Nondetect proxies (1/2 the detection limit) are presented as open symbols

Appendix D
Documents Reviewed

APPENDIX D

Documents Reviewed

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Appendix E
Regulatory Review, ARARs

APPENDIX E

Regulatory Review, ARARs

If a requirement is not legally applicable, the requirement is evaluated to determine whether it is relevant and appropriate. Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that, while not applicable, address problems or situations sufficiently similar to the circumstances of the proposed response action and are well suited to the conditions of the site. The criteria for determining relevance and appropriateness are listed in 40 Code of Federal Regulations (CFR) 300.400(g)(2).

Applicable. Applicable requirements are cleanup standards, criteria, or limitations promulgated under federal or state law that specifically address the situation at a CERCLA site. A requirement is applicable if the jurisdictional prerequisites of the environmental standard show a direct correspondence when objectively compared with the conditions at the site.

Relevant and appropriate. If a requirement is not legally applicable, the requirement is evaluated to determine whether it is relevant and appropriate. Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not applicable, address problems or situations sufficiently similar to the circumstances of the proposed response action and are well suited to the conditions of the site. The criteria for determining relevance and appropriateness are listed in 40 CFR 300.400(g) (2).

To be considered (TBC). TBC criteria are requirements that may not meet the definition of an ARAR, but still may be useful in determining whether to take action at a site or to what degree action is necessary. TBC criteria, as defined in 40 CFR 300.400(g) (3), are non-promulgated advisories or guidance issued by federal or state government that are not legally binding but may provide useful information or recommended procedures for remedial action. Although TBC criteria do not have the status of ARARs, they are considered together with ARARs to establish the required level of cleanup for protection of human health and the environment.

Pursuant to USEPA guidance, ARARs generally are classified into three categories: chemical-specific, location-specific, and action-specific requirements. These categories of ARARs are identified below:

- **Action-specific ARARs** are requirements that apply to specific actions that may be associated with site remediation. Action-specific ARARs often define acceptable handling, treatment, and disposal procedures for hazardous substances. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy. Examples of action-specific ARARs include requirements

applicable to landfill closure, wastewater discharge, hazardous waste disposal, and emissions of air pollutants.

- **Chemical-specific ARARs** include those laws and regulations that regulate the release to the environment of materials possessing certain chemical or physical characteristics or containing specified chemical compounds. These requirements generally set health- or risk-based concentration limits or discharge limits for specific hazardous substances.
- **Location-specific ARARs** are those requirements that relate to the geographical or physical location of the site, rather than the nature of the contaminants or the proposed site remedial actions. These requirements may limit the placement of remedial action, and may impose additional constraints on the cleanup action. For example, location-specific ARARs may refer to activities in the vicinity of wetlands, floodplains, endangered species habitat, and areas of historical or cultural significance.

Five-year Review of ARARs

The ARARs, presented in the following documents, were reviewed for any changes, additions, or deletions: The following are the decision documents for the site:

- ROD, issued August 11, 1989 by the Deputy for Environment, Safety and Occupational Health
- ESD, effective 1992, issued by the Deputy for Environment, Safety and Occupational Health

The 1989 ROD states that the primary contaminants in the soil/refuse zone of Landfill 26 are petroleum hydrocarbons, semi-volatile organics, heavy metals, chlorinated pesticides, pesticide metabolites, and polychlorinated biphenyls (PCBs).

Groundwater flow and leachate discharges from Landfill 26 are potential mechanisms for contaminants to migrate off-site. The 1989 ROD selected remedies for two operable units (OUs):

- Landfill Soil/Refuse OU – Immobilize contaminants in soil/refuse through a fixation process (solidification).
- Groundwater OU – Extract and treat contaminated groundwater.

The 1989 ROD did not select a remedy for landfill gas emissions.

The 1992 ESD determined that solidification should be eliminated as a remedy and an upgraded cap should be constructed to address the soil/refuse. In addition, the 1992 ESD approved modified groundwater treatment processes to more effectively treat constituents in the groundwater.

Review of Existing and Potential ARARs

The 1989 ROD established action–specific ARARs for soil/refuse remediation and groundwater remediation, but did not establish chemical-specific of location specific ARARs. There were no discussions of ARARs regarding landfill gas in the 1989 ROD. The 1992 ESD did not revise, add, or delete any ARARs.

The following three tables list the ARARs established in the above-referenced decision documents, summarize the requirement for each ARAR, cite the regulatory basis for each ARAR, state the evaluated status of each ARAR, and provide comments where applicable. Table E-1 contains chemical–specific ARARs, Table E-2 contains location–specific ARARs, and TableE-3 contains action-specific ARARs.

ARARs established in the 1989 ROD cited requirements by reference to the California Administrative Code (CAC). The CAC is no longer a valid reference. The CAC regulations were transferred into the California Code of Regulations (CCR) prior to the 1989 ROD.

Current versions of the CCR and the Code of Federal Regulations (CFR) were consulted (via the internet or in hardcopy) to review pertinent updates of laws, regulations, or guidance.

No changes were made to the existing ARARs, other that to re-direct references to CAC to the applicable CCR requirements.

Tables E-1 through E-3 contain the established ARARs, and list proposed ARARs. The proposed ARARs are those ARARs (in addition to existing ARARs) that would potentially be established if the ARARs were being developed at this time.

Although the requirements established in the 1986 Water Quality Control Plan for the San Francisco Bay Basin were considered applicable in the 1989 ROD, the Army now considers these requirements as To Be Considered (TBC).

TABLE E-1
Chemical-specific ARARs
Five-year Review Report for Landfill 26, Hamilton Army Air Field, Marin County, California

Chemical	Standard, Requirement, Criterion, or Limitation	Origin	ARAR Status	Description	Comment
--	--	1989 ROD	--	--	No chemical-specific ARARs were identified in the 1989 ROD or the 1992 ESD.
Landfill Gas	27 CCR 20919 through 20937 (Article 6, Gas Monitoring and Control at Active and Closed Disposal Sites)	Proposed ARAR	Applicable	Requires that methane gas generated by disposal sites not exceed 5% by volume in air at the property boundary or other approved monitoring point. Requires that concentrations of methane gas do not exceed 25% of the lower explosive limit (LEL) or 1.25% by volume in air within on-site structures. Requires a gas monitoring program and specifies requirements of the program. Requires a gas control system if methane concentrations exceed compliance levels.	Establishes chemical-specific standards for allowable concentrations of methane gas in air in the vicinity of Landfill 26. Also an action-specific ARAR for landfill gas controls.
Landfill Gas	California Health & Safety Code §25356.1.5(b)	Proposed ARAR	Relevant and Appropriate	Minimum standards for health and ecological risk assessments. Risk assessments that support remedy selection must not only meet National Contingency Plan requirements, but also must also include most current sound scientific methods, knowledge and practices of public health and environmental professionals	Any risk assessments performed in support of remedy selection for soil-gas would need to comply with these standards.

TABLE E-2
Location-specific ARARs
Five-year Review Report for Landfill 26, Hamilton Army Air Field, Marin County, California

Location	Standard, Requirement, Criterion, or Limitation	Origin	ARAR Status	Description	Comment
--	--	1989 ROD	--	--	No location-specific ARARs were identified in the 1989 ROD or the 1992 ESD.
Floodplain	22 CCR 66264.18(b)	Proposed ARAR	Relevant and Appropriate	A facility located in a 100-year floodplain or within the maximum high tide shall be designed, constructed, operated, and maintained to prevent washout of any hazardous waste by a 100-year flood or maximum high tide.	No RCRA hazardous waste facilities will be constructed in the 100-year floodplain at Hamilton. However, as part of this action, capping of disposal sites that pre-date RCRA regulations may occur. Therefore, this requirement may be relevant and appropriate to disposal sites located within or on the perimeter of the floodplain.
Migratory Bird Treaty Act	50 CFR 10 and 20	Proposed ARAR	To be considered	Prevents taking of migratory birds, their nests or eggs without special permits	Applies to construction and excavation activities that may disturb nesting migratory birds

TABLE E-3
Action-specific ARARs
Five-year Review Report for Landfill 26, Hamilton Army Air Field, Marin County, California

Action	Standard, Requirement, Criterion, or Limitation	Origin	ARAR Status	Description	Comment
Soil/Refuse Remediation	CCR Title 14 Division 7 Chapter 3 Article 4 [formerly California Administrative Code (CAC) Title 14, Chapter 2]	1989 ROD	Applicable	Definition of Solid Waste. Stated in the 1989 ROD "Requires that soil/refuse be managed as waste."	CAC is no longer a valid reference. The CAC regulations were transferred into the California Code of Regulations (CCR) prior to the 1989 ROD. The definition of "Solid Waste" is included in CCR Title 14 Division 7 Chapter 3 Article 4.
Soil/Refuse Remediation	CCR Title 22 Division 4.5 Chapter 11 (formerly CAC Title 22, Chapter 30)	1989 ROD	Applicable	Definition of Solid Waste. Stated in the 1989 ROD "Requires that soil/refuse be managed as waste."	CAC is no longer a valid reference. The definition of "Waste" is included in CCR Title 22 Division 4.5 Chapter 11.
Soil/Refuse Remediation	CCR Title 22 Division 4.5 Chapter 11 (CAC Title 22, Chapter 30)	1989 ROD	Applicable	Waste Classification. Stated in the 1989 ROD "Classifies soil/refuse for purposes of onsite or offsite disposal."	CAC is no longer a valid reference. This requirement is now covered in CCR Title 22 Division 4.5 Chapter 11.
Soil/Refuse Remediation	CCR Title 23 Division 3 Chapter 15 [formerly CAC Title 23, Chapter 3 (15)]	1989 ROD	Applicable	Waste Classification. Stated in the 1989 ROD "Classifies soil/refuse for purposes of onsite or offsite disposal."	CAC is no longer a valid reference. This requirement is now covered in CCR Title 23 Division 3 Chapter 15.
Soil/Refuse Remediation	CCR Title 22 Division 4.5 Chapter 11 (CAC Title 22, Chapter 30)	1989 ROD	Applicable	Generator Requirements. Stated in the 1989 ROD "Applies to offsite disposal of soil/refuse."	CAC is no longer a valid reference. This requirement is now covered in CCR Title 22 Division 4.5 Chapter 11.
Soil/Refuse Remediation	CCR Title 23 Division 3 Chapter 15 [formerly CAC Title 23, Chapter 3 (15)]	1989 ROD	Applicable	Landfill Classification. Stated in the 1989 ROD "Applicable for selection of offsite disposal facilities."	CAC is no longer a valid reference. This requirement is now covered in CCR Title 23 Division 3 Chapter 15.
Soil/Refuse Remediation	CCR Title 23 Division 3 Chapter 15 [formerly CAC Title 23, Chapter 3 (15)]	1989 ROD	Relevant and Appropriate	Landfill Closure and Post-Closure Requirements. Stated in the 1989 ROD "Relevant and appropriate for classification of landfill for determining closure standard."	CAC is no longer a valid reference. This requirement is now covered in CCR Title 23 Division 3 Chapter 15.

TABLE E-3
Action-specific ARARs
Five-year Review Report for Landfill 26, Hamilton Army Air Field, Marin County, California

Action	Standard, Requirement, Criterion, or Limitation	Origin	ARAR Status	Description	Comment
Soil/Refuse Remediation	CCR Title 22 Division 4.5 Chapter 14 and 15 (formerly CAC Title 22, Chapter 30)	1989 ROD	Relevant and Appropriate	Landfill Closure and Post-Closure Requirements. Stated in the 1989 ROD "Relevant and appropriate to onsite landfill closure activities."	CAC is no longer a valid reference. This requirement is now covered in CCR Title 22 Division 4.5 Chapter 14 and 15.
Soil/Refuse Remediation	CCR Title 27 Division 2 Subdivision 1 (formerly CAC Title 23, Chapter 30)	1989 ROD	Relevant and Appropriate	Technical Requirements for Treatment, Storage, Disposal (TSD) Units. Stated in the 1989 ROD "Not applicable because RCRA permitting not required. Relevant and appropriate for onsite waste management activities."	CAC is no longer a valid reference. This requirement is now covered in CCR Title 27 Division 2 Subdivision 1.
Soil/Refuse Remediation	CCR Title 27 Division 2 Subdivision 1 (formerly CAC Title 23, Chapter 30)	1989 ROD	Relevant and Appropriate	Variance Provisions. Nothing Stated in the 1989 ROD regarding variance provisions.	CAC is no longer a valid reference. This requirement is now covered in CCR Title 27 Division 2 Subdivision 1.
Groundwater Remediation	Water Quality Control Plan for the San Francisco Bay Basin as amended 1986	1989 ROD	Applicable	Objectives for Inland Surface Waters	Stated in the 1989 ROD "Applicable to all surface waters receiving groundwater discharge from the landfill, includes objectives for toxics." Now considered by the Army as To Be Considered (TBC).
Groundwater Remediation	Water Quality Control Plan for the San Francisco Bay Basin as amended 1986	1989 ROD	Applicable	Objectives for Groundwater	Stated in the 1989 ROD "Applicable to groundwater at the landfill." Now considered by the Army as To Be Considered (TBC).
Groundwater Remediation	Water Quality Control Plan for the San Francisco Bay Basin as amended 1986	1989 ROD	Applicable	Anti-degradation Policy	Stated in the 1989 ROD "Applicable to all waters affected by contaminants in the landfill." Now considered by the Army as To Be Considered (TBC).

TABLE E-3
Action-specific ARARs
Five-year Review Report for Landfill 26, Hamilton Army Air Field, Marin County, California

Action	Standard, Requirement, Criterion, or Limitation	Origin	ARAR Status	Description	Comment
Groundwater Remediation	Water Quality Control Plan for the San Francisco Bay Basin as amended 1986	1989 ROD	Applicable	Point Source Control Measures	Stated in the 1989 ROD "Applicable to treated groundwater discharged to surface. Requires minimum of secondary treatment for discharge to San Pablo Bay." Now considered by the Army as To Be Considered (TBC).
Groundwater Remediation	EPA Clean Water Act (CWA) Regulation; 40 Code of Federal Regulations (CFR) 122	1989 ROD	Applicable	National Pollution Discharge Elimination System (NPDES) Permit Regulations	Stated in the 1989 ROD "All treated groundwater discharged to surface water."
Groundwater Remediation	CWA Regulation; 40 CFR 403	1989 ROD	Applicable	Pretreatment Standard	Stated in the 1989 ROD "Discharge of recovered groundwater to the Novato Sanitary District (NSD)."
Groundwater Remediation	CWA Regulation; 40 CFR 133	1989 ROD	Relevant and Appropriate	Secondary Treatment Regulation	Stated in the 1989 ROD "Treated groundwater discharged to surface water."
Groundwater Remediation	EPA Drinking Water Regulations; 40 CFR 141 and 143	1989 ROD	Applicable	Primary Maximum Contaminant Levels (MCLs) and Secondary MCLs	Stated in the 1989 ROD "Ultimate goals for remediation of groundwater."
Groundwater Remediation	Local Waste Water Discharge	1989 ROD	Applicable	Novato Sanitary District (NSD) Regulations	Stated in the 1989 ROD "Discharge of recovered groundwater to NSD."
Groundwater Remediation	Local Waste Water Discharge	1989 ROD	Relevant and Appropriate	NSD Industrial Waste Ordinance (Proposed)	Stated in the 1989 ROD "Discharge of recovered groundwater to NSD."
Landfill Gas Control	27 CCR 20820 and 21137	Proposed ARAR	Applicable	Identifies requirements for municipal solid waste disposal facility operation including gas monitoring and control.	Applies to gas emissions from landfills.

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Action	Standard, Requirement, Criterion, or Limitation	Origin	ARAR Status	Description	Comment
Landfill Gas Control	27 CCR 20919 through 20937 (Article 6, Gas Monitoring and Control at Active and Closed Disposal Sites)	Proposed ARAR	Applicable	Requires that methane gas generated by disposal sites not exceed 5% by volume in air at the property boundary or other approved monitoring point. Requires that concentrations of methane gas do not exceed 25% of the lower explosive limit (LEL) or 1.25% by volume in air within on-site structures. Requires a gas monitoring program and specifies requirements of the program. Requires a gas control system if methane concentrations exceed compliance levels.	Applies to gas emissions from landfills.
Landfill Gas Control	27 CCR 21150	Proposed ARAR	Applicable	Drainage and Erosion Control: The drainage and erosion control system shall be designed and maintained to ensure integrity of post-closure land uses, roads, and structures; to prevent public contact with waste and leachate; to ensure integrity of gas monitoring and control systems; to prevent safety hazards; and to prevent exposure to waste.	Applies to gas emissions from landfills.
Landfill Gas Control	27 CCR 21160	Proposed ARAR	Applicable	Requires landfill gas and leachate control to be implemented and maintained during the closure and post-closure period. Leachate must be collected and controlled in a manner which prevents public contact.	Applies to gas emissions from landfills.

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Action	Standard, Requirement, Criterion, or Limitation	Origin	ARAR Status	Description	Comment
Landfill Gas Control	27 CCR 21180	Proposed ARAR	Applicable	Requires landfill final cover and environmental control systems to be maintained and monitored for no less than 30 years following closure	Applies to gas emissions from landfills.
Landfill Gas Control	27 CCR 21190	Proposed ARAR	Applicable	Post-closure construction activities may be restricted and must maintain integrity of final cover, drainage controls, landfill gas controls, and other systems. Buildings associated with post-closure land uses that are constructed within buffer zones must meet design requirements.	Applies to gas emissions from landfills.
Control of Air Emissions	BAAQMD Regulation 6, Particulate Matter and Visible Emissions	Proposed ARAR	Applicable	Limits visible emissions, particulate emissions by weight, and emissions from sulfuric acid plants and sulfur recovery units. Applicable to any remedial action activity which may discharge air contaminants as defined by the rule.	Regulation 6 last amended 12/19/1990. Construction of the selected remedy may generate visible air emissions.
Control of Air Emissions	BAAQMD Regulation 7, Odorous Substances	Proposed ARAR	Applicable	Limits odorous emissions per complaints received from persons on properties where the emissions did not occur, and the regulation places maximum concentration limits on certain organic emissions.	Regulation 7 last amended 3/17/1982. Will be applicable to soil-gas if gas produces odorous emissions and if complaints are received.

TABLE E-3
Action-specific ARARs
Five-year Review Report for Landfill 26, Hamilton Army Air Field, Marin County, California

Action	Standard, Requirement, Criterion, or Limitation	Origin	ARAR Status	Description	Comment
Control of Air Emissions	BAAQMD Regulation 8-34, Solid Waste Disposal Sites	Proposed ARAR	Applicable	Limits the emission of non-methane organic compounds and methane from the waste decomposition process at solid waste disposal sites. The use of materials that contain volatile organic compounds, such as contaminated soil or sludge, in land treatment or refuse cover operations is considered to be an aeration operation and is subject to Regulation 8, Rule 40.	Regulation 8-34 adopted 5/2/1984, last amended 6/15/2005.
Waste Characterization and Disposal	27 CCR 20200, 20210, 20220, and 20230 23 CCR 2520, 2521	Proposed ARAR	Applicable	Requires that wastes must be characterized to determine whether they are hazardous, designated, non-hazardous, or inert waste. Hazardous waste must be managed in accordance with the requirements of Title 22 CCR. Discharge of designated, non-hazardous, and inert waste shall be in accordance with 27 CCR 20210, 20220, or 20230.	Applies to wastes (including soil) that are excavated during construction of the remedy. Wastes must be characterized properly and disposed of at an appropriate waste management facility that is authorized to receive the type of waste.
Waste Characterization and Disposal	23 CCR 2550.7 through 2550.9 27 CCR 20435	Proposed ARAR	Relevant and Appropriate	Specifies requirements for design and installation of groundwater, surface water, and unsaturated zone monitoring systems for waste management units	Applies to soil-gas monitoring.
Excavation	22 CCR 66268.40	Proposed ARAR	Applicable	Movement of excavated materials characterized as hazardous to new location or placement in or on land will trigger Land Disposal Restrictions (LDRs).	Applicable if any excavated soil generated during implementation of the remedy is characterized as hazardous waste and is placed on land (e.g., accumulation of soil prior to disposal).

TABLE E-3
Action-specific ARARs
Five-year Review Report for Landfill 26, Hamilton Army Air Field, Marin County, California

Action	Standard, Requirement, Criterion, or Limitation	Origin	ARAR Status	Description	Comment
Disposal – Land Disposal Restrictions (LDRs)	22 CCR 66268.40 through 66268.43	Proposed ARAR	Applicable	Prohibition and Treatment Standards – Prohibits certain waste from land disposal unless waste meets one of three types of treatment standard requirements.	LDRs must be met for wastes excavated and then placed in an area outside of a corrective action management unit (CAMU), treatment unit, or staging pile. Also applicable to off site disposal.
Treatment Standards for Hazardous Debris	22 CCR 66268.45	Proposed ARAR	Applicable	Requires treatment of hazardous debris prior to land disposal to waste-specific treatment standards	Applicable to any debris identified as hazardous during excavation if debris will be placed for disposal in an area outside of a CAMU, treatment unit, or staging pile. Also applicable to off site disposal of debris.
Alternative LDRs Treatment Standards for Contaminated Soil	22 CCR 66268.7 and 66268.40 through 66268.44 and 66268.49	Proposed ARAR	Applicable	Prohibits hazardous waste from land disposal unless waste meets one of three types of treatment standard requirements. Establishes alternative standards for treatment of contaminated soil prior to land disposal.	LDRs must be met for hazardous wastes excavated and then placed in an area outside of a CAMU, treatment unit, or staging pile. Also applicable to off site disposal. If excavated soils are hazardous, then will have to meet these requirements.
Discharges of storm water from industrial areas.	40 CFR Parts 123 and 124 regarding NPDES, implemented by California Storm Water Permit for Construction Activities, State Water Resources Control Board Order 92-08-DWQ	Proposed ARARs	Relevant and Appropriate	Regulates pollutants in discharge of storm water associated with construction activity (clearing, grading, or excavation) involving the disturbance of 1 acre or more. Requirements to ensure storm water discharges do not contribute to a violation of surface water quality standards.	The CERCLA permit exemption applies to all discharges that are related to response actions and are “on-site”, as that term is defined in the NCP. Remedies should meet the substantive requirements of the NPDES Program.

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Action	Standard, Requirement, Criterion, or Limitation	Origin	ARAR Status	Description	Comment
National Oil and Hazardous Substances Pollution Contingency Plan – Procedures for planning and implementing off-site response actions	40 CFR 300.440	Proposed ARAR	Applicable	Off-site transfer of CERCLA remediation waste for disposal must be to an EPA-approved facility	This requirement applies to offsite disposal of wastes that could be generated during implementation of the remedy.

Appendix F
Five-year Review Site Inspection Checklist

Five-Year Review Site Inspection Checklist

I. SITE INFORMATION	
Site name: Hamilton Army Airfield Landfill 26	**Date of inspection:** 02/27/07
Location and Region: Novato, California	**EPA or Other ID:**
Agency, office, or company leading the five-year review: CH2M HILL Inc.	**Weather/temperature:** Mid 50s

Remedy Includes: (Check all that apply)

- ☒ Landfill cover/containment
- ☒ Access controls
- ☒ Institutional controls
- ☒ Groundwater pump and treatment (This is an inactive system)
- ☐ Surface water collection and treatment
- ☒ Other (explain) Interim remedy: vent trench and vertical barrier wall

Attachments: ~~Inspection team roster attached~~ Site map attached [in report]

II. INTERVIEWS (Check all that apply)

1. **O&M site manager** *[Not applicable]*

Name Title Date

Interviewed Phone No.
Problems, suggestions;

NOTE: All referenced attachments can be found in Five-Year Review Report.

2. **O&M staff** *[Not applicable]*

Name Title Date

Interviewed Phone No.
Problems, suggestions

3. **Local regulatory authorities and responsible agencies** (i.e., State and Tribal offices, emergency response office, police department, office of public health or environmental health, zoning office, recorder of deeds, or other city and county offices, etc.) Fill in all that apply.

Agency Department of Toxic Substances Control

Contact	Theresa McGarry	Hazard Substances Scientist	July 6, 2007	(916) 255-3664
	Name	Title	Date	Phone No.

Problems; suggestions

Agency San Francisco Bay Regional Water Quality Control Board

Contact	Brian Thompson	Engineering Geologist	July 16, 2007	(510) 622-2422
	Name	Title	Date	Phone No.

Problems; suggestions

4. **Other interviews** (optional)

III. ONSITE DOCUMENTS AND RECORDS VERIFIED (Check all that apply)

1. **O&M Documents**

O&M manual	Readily available	Up to date
As-built drawings	Readily available	Up to date
Maintenance logs	Readily available	Up to date

Remarks: Final Closure and Postclosure Maintenance Plan was available but not onsite.

2. **Site-Specific Health and Safety Plan** Readily available Up to date

Contingency plan/emergency response plan Readily available Up to date

Remarks *[Not applicable]*

3. **O&M and OSHA Training Records** Readily available Up to date ☒ N/A

Remarks *[Not applicable]*

4. **Permits and Service Agreements**

Air discharge permit	Readily available	Up to date	☒ N/A
Effluent discharge	Readily available	Up to date	☒ N/A
Waste disposal, POTW	Readily available	Up to date	☒ N/A
Other permits _____	Readily available	Up to date	☒ N/A

Remarks *[Not applicable]*

5.	**Gas Generation Records** Remarks	Readily available	Up to date	☒ N/A
6.	**Settlement Monument Records** Remarks	Readily available	Up to date	☒ N/A
7.	**Groundwater Monitoring Records** Remarks	Readily available	Up to date	☒ N/A
8.	**Leachate Extraction Records** Remarks	Readily available	Up to date	☒ N/A
9.	**Discharge Compliance Records** Air Water (effluent) Remarks	 Readily available Readily available	 Up to date Up to date	 ☒ N/A ☒ N/A
10.	**Daily Access/Security Logs** Remarks	Readily available	Up to date	☒ N/A

IV. O&M COSTS

1. **O&M Organization**

State in-house — Contractor for State
PRP in-house — Contractor for PRP
Other United States Army, Corps of Engineers

2. **O&M Cost Records**

Readily available ☒ Up to date
Funding mechanism/agreement in place Yes
Original O&M cost estimate NA Breakdown attached

Total annual cost by year for review period if available

Date	Date	Total cost
From 01/01/2006	To 12/31/2006	$150,000

Includes monitoring and reporting for annual groundwater/surface water and quarterly soil gas sampling.

3. **Unanticipated or Unusually High O&M Costs During Review Period**

Describe costs and reasons: *[Not applicable]*

V. ACCESS AND INSTITUTIONAL CONTROLS Applicable

A. Fencing

1. **Fencing** Location shown on site map Gates secured No

Remarks: There is a fence located at the southeast corner of the landfill. The padlock at the main gate was not in use. Unauthorized vehicles have access to the site through this unlocked entry point.

B. Other Access Restrictions

1. **Signs and other security measures** Location shown on site map N/A

Remarks: The signs do not clearly indicate that unauthorized personnel is not allowed. The site is accessible by foot.

C. Institutional Controls

1. **Implementation and enforcement**

Site conditions imply ICs not properly implemented Yes ☒ No N/A
Site conditions imply ICs not being fully enforced Yes ☒ No N/A

Type of monitoring (e.g., self-reporting, drive by) *[Not applicable]*
Frequency
Responsible party/agency _____

Contact

Name	Title	Date	Phone No.

Reporting is up-to-date Yes No N/A
Reports are verified by the lead agency Yes No N/A

Specific requirements in deed or decision documents have been met Yes No N/A
Violations have been reported Yes No N/A
Other problems or suggestions: Report attached

2. **Adequacy** ☒ ICs are adequate ICs are inadequate N/A

Remarks: Residential development in the vicinity seems to comply with the designated buffer zone.

D. General

1. **Vandalism/trespassing** Location shown on site map ☒ No vandalism evident

Remarks

2. **Land use changes onsite** ☒ N/A

Remarks

_____

3. **Land use changes offsite** ☒ N/A

Remarks

VI. GENERAL SITE CONDITIONS

A. Roads Applicable

1. **Roads** Location shown on site map Roads adequate N/A
Remarks: The main road is in good condition.

B. Other Site Conditions

Remarks

VII. LANDFILL COVERS Not Applicable

A. Landfill Surface

1. **Settlement** (Low spots) Location shown on site map ☒ Settlement not evident
Areal extent_____ Depth
Remarks

2. **Cracks** Location shown on site map ☒ Cracking not evident
Lengths _____ Widths_____Depth
Remarks

3. **Erosion** Location shown on site map ☒ Erosion not evident
Areal extent_____ Depth
Remarks

4. **Holes** Location shown on site map ☒ Holes not evident
Areal extent_____ Depth
Remarks

5. **Vegetative Cover** ☒ Grass ☒ Cover properly established ☒ No signs of stress
Trees/Shrubs (indicate size and locations on a diagram)
Remarks: The cover is re-vegetated and no signs of erosion were observed.

6. **Alternative Cover** (armored rock, concrete, etc.) ☒ N/A
Remarks

7. **Bulges** Location shown on site map ☒ Bulges not evident
Areal extent_____ Height
Remarks

8. **Wet Area/Water Damage** ☒ Wet areas/water damage not evident
Wet areas Location shown on site map Areal extent
Ponding Location shown on site map Areal extent
Seeps Location shown on site map Areal extent
Soft subgrade Location shown on site map Areal extent
Remarks

9. **Slope Instability** Slides Location shown on site map ☒ No evidence of slope instability
Areal extent
Remarks

B. Benches Applicable ☒ N/A
(Horizontally constructed mounds of earth placed across a steep landfill side slope to interrupt the slope in order to slow down the velocity of surface runoff and intercept and convey the runoff to a lined channel.)

1. **Flows Bypass Bench** Location shown on site map ☒ N/A or okay
Remarks

2. **Bench Breached** Location shown on site map ☒ N/A or okay
Remarks

3. Bench Overtopped Location shown on site map ☒ N/A or okay
Remarks

C. Letdown Channels Applicable ☒ N/A

(Channel lined with erosion control mats, riprap, grout bags, or gabions that descend down the steep side slope of the cover and will allow the runoff water collected by the benches to move off of the landfill cover without creating erosion gullies.)

1. **Settlement** Location shown on site map ☒ No evidence of settlement
Areal extent_____ Depth
Remarks

2. **Material Degradation** Location shown on site map ☒ No evidence of degradation
Material type_____ Areal extent
Remarks

3. **Erosion** Location shown on site map ☒ No evidence of erosion
Areal extent_____ Depth
Remarks_____

4. **Undercutting** Location shown on site map ☒ No evidence of undercutting
Areal extent_____ Depth
Remarks

5. **Obstruction** Type_____ ☒ No obstruction
Location shown on site map Areal extent
Size
Remarks

6. **Excessive Vegetative Growth** Type ☒ N/A
☒ No evidence of excessive growth
☒ Vegetation in channels does not obstruct flow
Location shown on site map Areal extent
Remarks

D. Cover Penetrations ☒ Applicable N/A

1. **Gas Vents** Active ☒ Passive
Properly secured/located ☒ Functioning Routinely sampled ☒ Good condition
Evidence of leakage at penetration
Remarks: Good condition noted.

2. **Gas Monitoring Probes**
☒ Properly secured/located ☒ Functioning Routinely sampled ☒ Good condition
Evidence of leakage at penetration
Remarks

3. **Monitoring Wells** (within surface area of landfill)
☒ Properly secured/located ☒ Functioning ☒Routinely sampled ☒ Good condition
Evidence of leakage at penetration
Remarks: Good condition noted.

4. **Leachate Extraction Wells**
Properly secured/located Functioning Routinely sampled Good condition
Evidence of leakage at penetration Needs O&M ☒ N/A
Remarks

5. **Settlement Monuments** Located Routinely surveyed ☒ N/A
Remarks

E. Gas Collection and Treatment Applicable ☒ N/A

1. **Gas Treatment Facilities**
Flaring Thermal destruction Collection for reuse
Good condition Needs O&M
Remarks

2. **Gas Collection Wells, Manifolds and Piping**
Good condition Needs O&M
Remarks

3. **Gas Treatment Facilities** (e.g., gas monitoring of adjacent homes or buildings)
Good condition Needs O&M N/A
Remarks

F. Cover Drainage Layer Applicable ☒ N/A

1. **Outlet Pipes Inspected** Functioning ☒ N/A
Remarks

2. **Outlet Rock Inspected** Functioning ☒ N/A
Remarks

G. Detention/Sedimentation Ponds Applicable ☒ N/A

1. **Siltation** Areal extent_____ Depth_____ ☒ N/A
Siltation not evident
Remarks

2. **Erosion** Areal extent_____ Depth ☒ N/A
Erosion not evident
Remarks

3. **Outlet Works** Functioning ☒ N/A
Remarks

4. **Dam** Functioning ☒ N/A
Remarks

H. Retaining Walls Applicable ☒ N/A

1. **Deformations** Location shown on site map Deformation not evident
Horizontal displacement_____ Vertical displacement
Rotational displacement_____
Remarks: ☒ N/A

2. Degradation Location shown on site map Degradation not evident
Remarks: ☒ N/A

I. Perimeter Ditches/Off-Site Discharge Applicable N/A

1. **Siltation** Location shown on site map ☒ Siltation not evident
Areal extent_____ Depth
Remarks:

2. **Vegetative Growth** Location shown on site map ☒ N/A
Vegetation does not impede flow
Areal extent_____ Type
Remarks:

3. **Erosion** Location shown on site map ☒ Erosion not evident
Areal extent_____ Depth
Remarks: Riprap along northern perimeter of the landfill is in good condition.

4. **Discharge Structure** Functioning N/A
Remarks: **A d**ischarge ditch is present north of Landfill 26. Ponded water was present at the time of the inspection.

VIII. VERTICAL BARRIER WALLS Applicable

1. **Settlement** ☒ Settlement not evident

Remarks: Concrete vertical barriers are located between each trench section of the passive vent trench system. The barriers are wider and deeper than the adjacent trench and are designed to hydraulically isolate each trench section from the adjacent sections. Also, an impermeable vertical barrier (i.e., a trench liner system) is installed in each of the trench segments on the outboard side (i.e., the side furthest from the landfill). The impermeable vertical barrier prevents migration of any soil gas beyond the landfill boundary to outlying areas. The barrier is installed to a depth of approximately 1 foot above the bottom of the constructed trench. The impermeable barrier consists of interlocking, rigid HDPE panels (GSG GundWall®) driven in place following the initial construction of the trench.

2. **Performance Monitoring** Type of monitoring soil gas monitoring
Frequency quarterly
Remarks: Facility site inspections are also performed on a regular basis.

IX. GROUNDWATER/SURFACE WATER REMEDIES Applicable

A. Groundwater Extraction Wells, Pumps, and Pipelines Applicable

1. **Pumps, Wellhead Plumbing, and Electrical**
Good condition All required wells located Needs O&M ☒ N/A
Remarks: Inactive pumps are downhole in existing wells.

2. **Extraction System Pipelines, Valves, Valve Boxes, and Other Appurtenances**
Good condition Needs O&M
Remarks: Extraction system pipelines are subsurface and inactive.

3. **Spare Parts and Equipment**
Readily available Good condition Requires upgrade Needs to be provided
Remarks: ☒ N/A

B. Surface Water Collection Structures, Pumps, and Pipelines ☒ Not Applicable

1. **Collection Structures, Pumps, and Electrical**
Good condition Needs O&M
Remarks

2. **Surface Water Collection System Pipelines, Valves, Valve Boxes, and Other Appurtenances**
Good condition Needs O&M
Remarks

3. **Spare Parts and Equipment**
Readily available Good condition Requires upgrade Needs to be provided
Remarks

C. Treatment System ☒ N/A Applicable

1. **Treatment Train** (Check components that apply)
Metals removal Oil/water separation Bioremediation
Air stripping Carbon adsorbers
Filters
Additive (e.g., chelation agent, flocculent)
Good condition Needs O&M
Sampling ports properly marked and functional
Sampling/maintenance log displayed and up to date
Equipment properly identified
Quantity of groundwater treated annually
Quantity of surface water treated annually
Remarks: The extraction and groundwater treatment system is inactive and is partially decommissioned. Tanks are empty. Equipment is not in use.

2. **Electrical Enclosures and Panels** (properly rated and functional)
☒ N/A Good condition Needs O&M
Remarks

3. **Tanks, Vaults, Storage Vessels**
☒ N/A
Remarks

4. **Discharge Structure and Appurtenances**
Good condition Needs O&M
Remarks
☒ N/A

5. **Treatment Building(s) – support building**
☒ N/A Good condition (especially roof and doorways) Needs repair
Chemicals and equipment properly stored
Remark: Building is secured, but not being used.

6. Monitoring Wells (pump and treatment remedy)
Properly secured/locked Functioning Routinely sampled Good condition
All required wells located Needs O&M N/A
Remarks: ☒ N/A

D. Monitored Natural Attenuation

1. **Monitoring Wells** (natural attenuation remedy)

Properly secured/locked Functioning Routinely sampled Good condition

All required wells located Needs O&M

Remarks ☒ N/A

_____

X. OTHER REMEDIES

If there are remedies applied at the site which are not covered above, attach an inspection sheet describing the physical nature and condition of any facility associated with the remedy. An example would be soil vapor extraction.

XI. OVERALL OBSERVATIONS

A. Implementation of the Remedy

Describe issues and observations relating to whether the remedy is effective and functioning as designed. Begin with a brief statement of what the remedy is to accomplish (i.e., to contain contaminant plume, minimize infiltration and gas emission, etc.).

Landfill 26 shows no signs of erosion or failure. No sections of the cap appeared to be exposed. The monitoring system (wells and gas points) appeared to be in good condition and functioning as intended. Monitoring allows for regular evaluation and control of potential migration.

B. Adequacy of O&M

Describe issues and observations related to the implementation and scope of O&M procedures. In particular, discuss their relationship to the current and long-term protectiveness of the remedy.

The Landfill 26 site has updated Waste Discharge Requirements from the Regional Water Quality Control Board. Monitoring activities as specified in this Order are being conducted. Groundwater extraction and treatment is not being performed. O&M procedures are therefore not applicable.

C.	Early Indicators of Potential Remedy Failure
	Describe issues and observations such as unexpected changes in the cost or scope of O&M or a high frequency of .unscheduled repairs, that suggest that the protectiveness of the remedy may be compromised in the future. N/A

D.	Opportunities for Optimization
	Describe possible opportunities for optimization in monitoring tasks or the operation of the remedy. N/A

Appendix G
Site Inspection Photographs

Photo of the Landfill 26 RCRA Type Cap and Cover.

Figure 1
Hamilton Army Airfield, Landfill 26
Novato, California

CH2MHILL

Photo of a gas vent and monitoring well, on the southeast side of Landfill 26.

Figure 2
Hamilton Army Airfield, Landfill 26
Novato, California

CH2MHILL

Photo of multiple gas vents and location of the passive vent trench (east and southeast perimeter of Landfill 26).

Figure 3
Hamilton Army Airfield, Landfill 26
Novato, California

CH2MHILL

Photo of the rip rap along northern side of Landfill 26.

Figure 4
Hamilton Army Airfield, Landfill 26
Novato, California

CH2MHILL

Photo of the Groundwater Treatment Plant.

Figure 5
Hamilton Army Airfield, Landfill 26
Novato, California

CH2MHILL

Photo of the mixed media filter inside the Groundwater Treatment Plant.

Figure 6
Hamilton Army Airfield, Landfill 26
Novato, California

CH2MHILL

Photo of the oil water separator inside the Groundwater Treatment Plant.

Figure 7
Hamilton Army Airfield, Landfill 26
Novato, California

CH2MHILL

Photo of the carbon tanks inside the Groundwater Treatment Plant.

Figure 8
Hamilton Army Airfield, Landfill 26
Novato, California

CH2MHILL

Photo of the chemical storage room inside the Groundwater Treatment Plant.

Figure 9
Hamilton Army Airfield, Landfill 26
Novato, California

Appendix H
Interview Forms

INTERVIEW DOCUMENTATION FORM

The following is a list of individual interviewed for this five-year review. See the attached contact record(s) for a detailed summary of the interviews.

Name	Title/Position	Organization	Date
Karole Ward	**FUDS Pgm Mgr**	**Corps of Engineers**	Jun 21, 07
Theresa McGarry	Hazard Substances Scientist / Project Manager	DTSC	Jul 6, 07
Brian Thompson	Engineering Geologist	Water Board	Jul 16, 07
Mark Janofsky	Sr. Envir Health Specialist.	Marin County Envir Health Services	Jun 18, 07
Matthew McCarron	Community Co-Chair	RAB	Jun 15, 07

INTERVIEW RECORD

Site Name: Hamilton Army Airfield, LF26	**EPA ID No.:** CA0000556308	
Subject: Five-Year Review	**Time:** 0900	**Date:** Jun 21, 07
Type: Telephone Visit Other **Location of Visit:** Sacramento District office	Incoming Outgoing	

Contact Made By:

Name: Brad Call	**Title:** Sr. Environmental. Engineer	**Organization:** USACE

Individual Contacted:

Name: Karole Ward	**Title:** FUDS Program Manager	**Organization:** USACE

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Summary Of Conversation

Ms. Karole Ward is the FUDS Program Manager and was recently the Project Manager for the landfill. She has been involved with the project for a little more than one year. Her overall sense is that the project is going well. Ms. Ward is aware that the community has several issues regarding the landfill. The community would like the landfill to be converted into a park and they are concerned with the noise and disturbance caused by truck traffic on Todd Road. Mr. Alan Burson, a local resident, expressed concerns regarding excessive weed growth. Ms. Ward is aware that unauthorized people are driving on the landfill and causing ruts. She is also aware of trespassing and damage to some of the landfill infrastructure like wells. It may be prudent to clearly lay out driving routes within the landfill boundary to show people where vehicles are allowed. Landfill 26 remains government owned property and so there have been no changes to the land use. The institutional controls include installation of "no trespassing" signs, the closure/post-closure maintenance plan, and the land use covenant established above the MTBE plume (a Navy responsibility). Overall she feels the remedies are performing well. There have been no changes in clean-up levels or ARARS since the interim soil gas remedy was put into service. On a program note she indicates that funding has been requested for this project. The exit strategy is to move the project once again into the closure/post closure mode and to continue with routine monitoring of groundwater and soil gas.

INTERVIEW RECORD

Site Name: Hamilton Army Airfield, LF26	**EPA ID No.:** CA0000556308	
Subject: Five-Year Review	**Time:**	**Date:** Jul 6, 07
Type: Telephone Visit Other **Location of Visit:**	Incoming Outgoing	

Contact Made By:

Name: Karole Ward	**Title:** Program Manager	**Organization:** USACE

Individual Contacted:

Name: Theresa McGarry	**Title:** Remedial Project Manager	**Organization:** DTSC

Telephone No: (916) 255-3664 **Fax No: NA** **E-Mail Address:** TMcgarry@dtsc.ca.gov	**Street Address:** 8800 Cal Center Drive **City, State, Zip:** Sacramento, CA 95826

Summary Of Conversation

Ms. Theresa McGarry of DTSC is a Hazardous Substance Scientist Project Manager and has worked on Landfill 26 since 2000. Her overall impression is that the site is well run. She does note that she would like more frequent coordination to ensure that all team members are informed regarding project activities and status. The discovery of methane gas along the southern fringe of Landfill 26 in 1999 had the effect of slowing home construction in the Shea development known as Hamilton Meadows. There is still public concern and she receives phone calls requesting information on the impacts of the landfill on homes in the area. Potential home buyers also phone her for information. Her regulatory concern is about the methane gas. Ms. McGarry indicates that she is still concerned even if the methane is a natural condition for this area. She notes that disclosures were included in home purchase documents. The issue of damage to the landfill top surface from vehicles is a concern. Ms. McGarry feels well informed about the site activities and progress, but see above. She notes that there have been some maintenance issues that have gone unattended for some time. There have been no changes in land use or zoning. She knows that there are Institutional Controls in place, such as property disclosures, and that the landfill is managed under Title 7. If title to the landfill is transferred she expects this to be done in accordance with Title 7. In her opinion the remedies seem to be working and she has little concern about methane migration from the landfill. She is not aware of any changes to clean-up standards or ARARs.

INTERVIEW RECORD

Site Name: Hamilton Army Airfield, LF26	**EPA ID No.:** CA0000556308	
Subject: Five-Year Review	**Time:**	**Date:** Jul 16, 07
Type: Telephone Visit Other **Location of Visit:**	Incoming Outgoing	

Contact Made By:

Name: Brad Call	**Title:** Sr. Environmental Engineer	**Organization:** USACE

Individual Contacted:

Name: Brian Thompson	**Title:** Engineering Geologist / Remedial Project Manager	**Organization:** San Francisco Regional Water Qual Control Board

Telephone No: (510) 622-2422 **Fax No:** NA **E-Mail Address:** brthompson@waterboards.ca.gov	**Street Address:** 1515 Clay Street, Suite 1400 **City, State, Zip:** Oakland, CA 94612

Summary Of Conversation

Mr. Brian Thompson is an Engineering Geologist/Remedial Project Manager with the San Francisco Regional Water Quality Control Board. He has been involved with the Hamilton Landfill 26 project since March 2006. Mr. Thompson is still formulating his overall impression of the project. He feels that there seems to be an effort to keep the project moving forward and there has been a reasonable collaboration between the regulatory agencies and the Corps of Engineers. Effects on the surrounding community include restricted access to some areas and public concerns regarding the use of Todd Road. All of these issues become linked in the minds of the public, whether they directly relate to management of the landfill project or not. Mr. Thompson is aware of damage to the top surface of the cap, but it is not clear if this is caused by vandalism or by consultants conducting the routine groundwater/soil gas monitoring. He feels that he has been kept well informed about site activities. Regarding suggestions to improve the site management, he notes that recent inspections have found erosion around the perimeter at certain locations and that burrowing animals are present. The erosion damage exposes the cap geotextiles, perhaps more rip-rap is necessary to prevent this. Another issue he noted is that the post and cable fence along the south edge of the cap has been cut. A short-term fix would involve splicing the cable back together, but perhaps the Corps should consider longer term solutions such as a more robust fence. In fact the Corps should consider long-term solutions for all issues at the landfill. Mr. Thompson is not aware of any changes in land use or zoning. He feels that the two remedies in place, the cap and the gas vent trench, are performing as intended. The cap must continue to be maintained and adequate drainage must be ensured. He is not aware of any changes to ARARs, but notes that chemical toxicity information is always subject to updates. He is also not aware of any new exposure routes or clean-up goals.

INTERVIEW RECORD

Site Name: Hamilton Army Airfield, LF26	**EPA ID No.:** CA0000556308	
Subject: Five-Year Review	**Time:** 1500	**Date:** Jun 18, 07
Type: Telephone Visit Other **Location of Visit:**	Incoming Outgoing	

Contact Made By:

Name: Brad Call	**Title:** Sr. Environmental Engineer	**Organization:** USACE

Individual Contacted:

Name: Mark Janofsky	**Title:** Sr. Envir Health Specialist	**Organization:** Marin County

Telephone No: (415) 499-6790 **Fax No:** NA **E-Mail Address:** NA	**Street Address:** 3501 Civic Center Dr., #236 **City, State, Zip:** San Rafael, CA 94903

Summary Of Conversation

Mr. Janofsky is a Senior Environmental Health Specialist with the Marin County Environmental Health Services office. He initially became involved with the Hamilton project in 1996, but became more involved in 2000 when the Landfill 26 methane issues first began. His impression of the project is that overall it is going well. His main concern is why Marin County was left out of the development of the first closure and post-closure maintenance plan for LF26. He is pleased with the performance of the Corps of Engineers and feels they did well in the face of the adverse public reaction to the landfill methane issue. Mr. Janofsky is not aware of any adverse effects the site operations are having on the local community. He is aware that incidents of trespass and vandalism have occurred. Unauthorized vehicles have driven on the landfill cap and caused ruts. People have damaged bollards surrounding monitoring wells/probes. In addition someone has cut the fence cable along the south side of the landfill. He feels pretty well informed about the site's activities and progress. Mr. Janofsky recommends that the Army should continue to evaluate possible methane issues along the north and west boundary of the landfill. One concern he has is in regards to the process by which Shea Homes was able to build so close to the landfill with no gas mitigation measures. Later Shea did add mitigation measures to the homes directly adjacent to the landfill. Mr. Janofsky feels that the remedies appear to be performing well but he cannot provide a blanket statement. There is a need for a methane investigation along the west and north side of the landfill. He is not aware of any changes in ARARs that would change the protectiveness of the remedy.

INTERVIEW RECORD

Site Name: Hamilton Army Airfield, LF26	**EPA ID No.:** CA0000556308	
Subject: Five-Year Review	**Time:** 0900	**Date:** Jun 15, 07
Type: Telephone Visit Other **Location of Visit:**	Incoming Outgoing	

Contact Made By:

Name: Brad Call	**Title:** Senior Env. Engineer	**Organization:** USACE

Individual Contacted:

Name: Matthew McCarron	**Title:** Community Co-Chair	**Organization:** RAB

Telephone No: (916) 341-6456 **Fax No:** NA **E-Mail Address:** Mmccarro@ciwmb.ca.gov	**Street Address:** 4 San Miguel Ct. **City, State, Zip:** Novato, CA 94945

Summary Of Conversation

Mr. McCarron is the Community Co-Chair of the Hamilton Restoration Advisory Board (RAB). He has been a member of the RAB since 1994 and aware of the project since 1992. His overall impression of the project is that it is managed quite well and that the regulatory agencies are providing good oversight. The Corps of Engineers is doing a good job in running the site. The site operations have not had much of an effect on the local community. He does feel that there has been some poor planning on the city's part and they should not have allowed Shea Homes to build homes so close to the landfill. The local community is concerned about vandalism at the landfill and the use of Todd Road for major truck traffic. Vandalism has caused damage to the cap and wells. He feels well informed about site activities and progress. In regard to recommendations he would like to see a better security effort and for the Army to block unauthorized access to the wells. Mr. McCarron did note that no member of the public has been exposed to contamination, but the investment in landfill infrastructure must be protected. The land use has obviously changed from a military base to residential / open space. He is concerned that the homes are too close to the landfill and he is also concerned regarding future development in the area. Mr. McCarron feels the remedies are performing well and he is pleased that the Water Board is closely watching the project. He is not aware of any changes in ARARs, they have remained relatively constant and unchanging. Mr. McCarron has a concern for long term groundwater and soil gas monitoring, he would like for this to continue.

Appendix I
Draft Final Risk Assessment Update

Appendix I

Draft Final Risk Assessment Update
Landfill 26
Former Hamilton Army Airfield
Novato, California

Prepared for

U.S. Army Corps of Engineers

April 2007

Prepared by

CH2MHILL

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Acronyms and Abbreviations

AL	action level
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylene
CalEPA	California Environmental Protection Agency
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm	centimeter
cm^2	square centimeters
cm^2-yr/kg-day	square centimeters-year per kilogram-day
cm/hour	centimeters per hour
COC	chemicals of concern
COPC	chemicals of potential concern
DTSC	Department of Toxic Substances Control
ELCR	excess lifetime cancer risk
USEPA	U.S. Environmental Protection Agency
Exposure Area	A portion of the property that is contacted on a daily basis by a resident, worker, or recreational user.
ESD	Explanation of significant differences
ESL	ecological screening level
HAAF	Hamilton Army Airfield
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HQ	hazard quotient
IRIS	Integrated Risk Information Systems
kg	Kilogram
L	Liter
L/m^3	Liters per cubic meter

m^3/day	cubic meters per day
MCL	Maximum Contaminant Level
MWH	Montgomery Watson Harza
mg/day	milligrams per day
mg/kg	milligrams per kilogram
mg/kg-day	milligrams of chemical per kilogram of body weight per day
mg/L	milligrams per liter
µg/m^3	micrograms per cubit meter
NCEA	EPA National Center for Environmental Assessment
NCP	National Contingency Plan
OEHHA	California EPA, Office of Environmental Health Hazard Assessment
PHG	Public health goal
PPRTVs	Provisional Peer Reviewed Toxicity Values
RA	risk assessment
RAO	remedial action objectives
RCRA	Resource Conservation and Recovery Act
REL	reference exposure level
RfD	reference dose
ROD1	Record of Decision
SFs	slope factors
TCE	trichloroethene
TDS	total dissolved solids
TPH	total petroleum hydrocarbons
USEPA	U.S. Environmental Protection Agency
WDR	Waste Discharge Requirements
WCC	Woodward Clyde Consultants

APPENDIX I

Risk Assessment Update, LF 26, Former Hamilton Army Airfield, Novato, California

Introduction

This appendix presents the methods and results of a risk assessment (RA) conducted for LF 26 (LF 26) at the Former Hamilton Army Airfield (HAAF). This RA is an update to the RA prepared for LF 26 in 1988 (Woodward Clyde 1988) and was prepared as part of the Comprehensive Five-Year Review for LF 26 following Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) guidelines.

A tiered approach was used for the RA update. For Tier I of the assessment, groundwater concentrations of LF 26-related chemicals were compared to the San Francisco Bay Regional Water Quality Control Board (RWQCB) environmental screening levels (ESLs) that are protective of human health (RWQCB 2005). The results of the Tier I comparison provides a summary of LF 26-related chemicals that are most likely to be associated with risks to future users of groundwater. Because there were detected concentrations of LF 26-related chemicals that exceeded the ESLs, a Tier II assessment was also conducted where cumulative potential cancer risks and noncancer hazards were calculated for the future residential scenarios.

1.1 Site Description

LF 26 is located at HAAF, a former military installation in the City of Novato, Marin County, California, approximately 22 miles north of San Francisco. HAAF is bordered by U.S. Highway 101 on the west, private development to the north and south, and San Pablo Bay on the east. HAAF is inactive as a military facility, and parts of the property have been transferred to private developers and the City of Novato.

LF 26 is located within former marshland and floodplain for Novato Creek along the margin of San Pablo Bay. LF 26 was used as a disposal area from the 1940s to the 1970s. There were no records kept of the disposal practices at LF 26. However, based on evaluations from a number of field investigations, LF 26 received approximately 171,000 cubic yards of waste, including approximately 20,000 cubic yards of oily sludge. A Resource Conservation Recovery Act-(RCRA) type landfill cap was installed in 1994-95, and constructed in response to the RWQCB, Bay Area Region Waste Discharge Requirements (WDRs) Order No. 92-029, a Record of Decision (ROD) signed in August 1989, and a 1992 Explanation of Significant Differences (ESD). During this time, the 150- to 200-foot buffer zone was established around LF 26, providing separation between the landfill and adjacent land.

1.2 Objectives of the Risk Assessment Update

As described in the U.S. Environmental Protection Agency's (USEPA) guidance for Comprehensive Five-Year Reviews (USEPA 2001a), a key purpose of the five-year review process for a site is to determine if the remedy is or upon completion will be protective of

human health. Protectiveness is generally defined in the National Contingency Plan (NCP) by the risk range and the Hazard Index (HI).

The following three questions are part of the technical assessment of the protectiveness of the remedy, as outlined in the USEPA five-year review guidance document:

- Question A – Is the remedy functioning as intended by the decision documents?
- Questions B - Are the exposure assumptions, toxicity data, cleanup levels, and remedial action objectives (RAOs) used at the time of remedy selection still valid?
- Question C – Has any other information come to light that could call into question the protectiveness of the remedy?

The second of the three questions, Question B, provided the framework for evaluating the risk assessment that was performed for the site in 1988 to determine if any updates were needed. Based on review of the 1988 risk assessment, it was determined that exposure assumptions and toxicity data have changed since that assessment was completed, so this updated risk assessment was prepared using current exposure assumptions, toxicity data, and groundwater sampling results from the 2003 to 2006 timeframe.

The objectives for this RA Update are to:

- Prepare an updated exposure pathway analysis that uses sampling and analytical data and other site information to depict the potentially complete exposure pathways for LF 26 including the relationships between potential chemical sources, migration pathways, and potentially exposed populations;
- Identify the chemicals of potential concern (COPCs) to be quantitatively evaluated in the RA Update;
- Estimate potential exposures to human populations from LF 26-related constituents in groundwater; and
- Discuss the degree of uncertainty associated with the assessment of health risks.

1.3 Organization of the Risk Assessment Update

The RA Update consists of the following five components:

1. **Tier I Assessment and Selection of Chemicals of Potential Concern for Tier II Assessment** – Summarizes data used in the RA Update, presents results of Tier I assessment, and identifies the chemicals that are carried through the Tier II risk quantification process.
2. **Exposure Assessment** – Identifies the pathways by which potential human exposures could occur; describes how they are evaluated; and evaluates the magnitude, frequency, and duration of these exposures.
3. **Toxicity Assessment** – Summarizes the toxicity of the selected chemicals and the relationship between magnitude of exposure and the occurrence of adverse health effects.

4. **Risk Characterization** – Integrates information from the exposure and toxicity assessments to characterize the risks to human health from potential exposure to chemicals in environmental media.
5. **Uncertainties Analysis** – Summarizes the basic assumptions used in the RA Update, as well as limitations of data and methodology.

Tables and figures are presented at the end of this appendix.

1.4 Human Health Risk Assessment Guidance

The methods to be used to conduct this RA Update are consistent with the following federal and state (i.e., California Environmental Protection Agency [CalEPA]; Department of Toxic Substances Control [DTSC]) guidance documents:

- *Risk Assessment Guidance for Superfund –Volume I: Human Health Evaluation Manual, Part A (Interim Final)* (USEPA 1989)
- *Exposure Factors Handbook Volume I General Factors* (USEPA 1997a)
- *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (USEPA 2002a)
- *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, (Part E, Supplemental Guidance for Dermal Risk Assessment) Final* (USEPA 2004b)
- *Recommended DTSC Default Exposure Factors for Use in Risk Assessment at California Military Facilities* (DTSC 2005)

2.0 Tier I Assessment and Selection of Chemicals of Potential Concern for Tier II Assessment

This section describes the data used in Tier I and Tier II of the RA Update, the results of the Tier I assessment, and the selection COPCs that are carried through the Tier II assessment phase. Based on the exposure pathway analysis presented in Section 3, groundwater is the only environmental medium that is addressed quantitatively in the RA Update. Therefore, summary statistics are only presented for groundwater and COPCs are selected for groundwater only.

2.1 Data Used in the Risk Assessment Update

Analytical data evaluated for this RA Update include those from groundwater wells located in or near the landfill boundaries that are part of the groundwater monitoring network (Figure 1). Analytical data included in the RA Update are from groundwater monitoring events that occurred between 2003 and 2006. This timeframe was selected to represent current potential exposure conditions.

Table 1 provides a list of the wells used in the RA Update and which groundwater monitoring events are associated with each well. Table 2 presents summary statistics for this 2003 to 2006 groundwater data set.

2.2 Landfill 26-Related Constituents

In September 2006, a report entitled *Landfill 26 Conceptual Site Model Update* (CH2M HILL 2006) was prepared to explain and document current overall site conditions at LF 26. The report contains information and evaluations pertaining to contaminant source(s), fate and transport potential for contaminants, and contaminant degradation and interaction potential.

As part of the conceptual model update, groundwater data were reviewed and the following organic analytes were identified as chemicals representative of refuse zone contamination (i.e., constituents of concern [COCs] for LF-26 groundwater):

- Total Petroleum Hydrocarbons (TPH) – diesel
- Naphthalene
- 1,4 – Dichlorobenzene
- Chlorobenzene

In addition to these organic COCs, barium was identified as the only inorganic analyte that can be attributed to LF 26 contamination based on the geochemical evaluations presented in the conceptual site model update. Therefore, barium is the only inorganic COC identified for LF 26. Details of the groundwater evaluations and selection of COCs are presented in Appendix B of the conceptual model update. Based on the findings reported in the conceptual model update, only the COCs for LF 26 (i.e., chemicals related to LF 26 refuse) were carried through the HHRA process.

2.3 Tier I Assessment

For the Tier I assessment, the maximum detected concentrations of LF 26-related chemicals in groundwater were compared to ESLs (RWQCB 2005). The ESLs are generally based on California drinking water criteria (e.g., maximum contaminant levels [MCLs], public health goals [PHGs], action levels [ALs]). If a California criterion is not available for a chemical, a risk-based goal assuming a residential drinking water scenario is calculated for the ESL using a target risk level of 1×10^{-6} for carcinogenic effects and a relative source contribution factor of 20 percent for noncarcinogenic effects.

Table 2 presents the comparison of detected concentrations of LF 26-related chemicals in groundwater to the ESLs. The following chemicals have maximum detected concentrations that exceed the ESLs: 1,4-dichlorobenzene and barium. In addition, the maximum detected concentration of total petroleum hydrocarbons (TPH) – diesel exceeds the ESL.

2.4 Criteria for Selection of COPCs for Tier II Assessment

All LF 26-related chemicals detected in the 2003 to 2006 groundwater data set were identified as COPCs for the Tier II assessment of the RA Update with the exception of petroleum hydrocarbon mixtures. Petroleum hydrocarbon mixtures (i.e., TPH) detected in samples were not considered COPCs because toxicity factors are not available from USEPA or CalEPA for these mixtures of constituents. Potential health risks associated with exposure

to petroleum hydrocarbons were evaluated using the detected concentrations of naphthalene, a petroleum-related component compound that has been assigned published toxicity values. The COPCs for the RA update are listed on Table 3.

3.0 Exposure Assessment

The exposure assessment component of the risk assessment update identifies the means by which individuals on or near the LF 26 area may contact chemicals in environmental media. The exposure assessment also identifies the populations that might be exposed; the routes by which these individuals might become exposed; and the magnitude, frequency, and duration of potential exposures.

The exposure assessment step of the risk assessment update includes the following:

- Summary of 1988 risk assessment exposure pathways
- Exposure pathways analyzed in this risk assessment update
- Exposure pathways not analyzed in this risk assessment update
- Calculation of chemical intake

Figure 2 presents the results of the exposure pathway analysis.

3.1 Summary of 1988 Risk Assessment Exposure Pathways

Three separate RAs were performed in the 1988 Feasibility Study (WCC 1998): 1) A public health RA based on current land use at HAAF and the surrounding areas; 2) A public health RA based on the possibility that a portion of HAAF, including LF 26, would be sold for residential development; and 3) An assessment of impacts on aquatic organisms inhabiting water bodies that receive groundwater and surface water drainage from LF 26.

Based on the current use at the time of completion of the RAs, the potential public exposure to chemical substances found in LF 26 was assumed to occur primarily through inhalation of volatile emissions and contaminated soil particles transported to areas where people work, reside, or otherwise frequent. It was also assumed that contaminated soil could settle on surfaces in occupied areas and become available for ingestion and absorption through the skin. The inhalation and oral exposure pathways were evaluated in the first public health RA for current use at that time. The dermal exposure route was not evaluated because no acceptable intake rates had been established for that exposure route at the time the RA was prepared.

For the future residential exposure scenario, the RA evaluated ingestion of soil and ingestion of groundwater exposure pathways for the hypothetical future residents. Dermal contact with contaminated soil through participation in outdoor activities, dermal contact with contaminated water through bathing and swimming, inhalation of volatile organic compounds (VOCs) through showering and other household uses of groundwater, and ingestion of “home-grown” fruits and vegetables raised in contaminated soil or water with contaminated groundwater were potential exposure pathways for the hypothetical future resident that were not evaluated due to the absence of data and lack of generally accepted techniques to estimate exposures and evaluate health risks.

For the third RA, surface water data were reviewed for potential impacts to aquatic organisms. Six rounds of surface water samples were collected from four stations in Pacheco Creek and analyzed for priority pollutants. Two of the stations were hydraulically upgradient of LF 26 and two stations were hydraulically downgradient of LF 26. These data were used to estimate the impact of the landfill on Pacheco Creek by comparing the occurrence and concentrations of chemicals obtained in upstream and downstream samples. The only analytes detected in those water samples were the metals cadmium, chromium, copper, lead, nickel, vanadium, and zinc. A statistical comparison was performed between the upstream and downstream concentrations. This statistical comparison of the metals data showed that leachate and storm runoff from LF 26 did not contribute to measurable increases in the chemical substances found in Pacheco Creek and probably have no impact on resident aquatic organisms. Because Pacheco Creek is the closest hydraulically downgradient body of surface water to LF 26, it was anticipated that the landfill should not have any significant impact on other bodies of water in the area.

Based on a review of the pathways in the 1988 RA report some of the pathways are still considered potentially complete, while others are not potentially complete because of activities that have occurred at LF 26 since 1988. The following sections describe the pathways that are and those that are not quantitatively evaluated in the RA Update for the five-year review report.

3.2 Exposure Pathways Analyzed in the Risk Assessment Update

Groundwater in the LF 26 region is not currently used for municipal or domestic drinking water, and there are no known plans to do so in the future. According to the California State Water Resources Control Board (Resolution 88-63) and the Water Quality Control Plan for the San Francisco Bay Region, groundwater at this site is not suitable for drinking water because of high total dissolved solids (TDS) and a low sustainable yield (WCC, 1997). Three requirements are necessary for groundwater to be considered appropriate as a source of drinking water:

- The TDS of the water should be below 500 mg/L (Recommended Secondary Maximum Contaminant Level [MCL]).
- Wells must yield 200 gallons per day at a minimum.
- Drinking water wells must be screened at depths such that annular seals of 50 feet or greater can be installed.

It is not possible to construct a well at LF 26 that meets the above requirements and produces water of sufficient quality and yield to meet drinking water regulations. The failure of LF 26 groundwater to meet drinking water requirements is not due to anthropogenic impacts but rather natural properties of the aquifer. These properties are as follows:

- The TDS of the groundwater at LF 26 ranges from 200 mg/L to greater than 40,000 mg/L, and is typically greater than 500 mg/L across a vast majority of the site (WCC 1997 and MWH 2005).

- Lower permeability silts occur throughout much of the area and monitoring well purge data indicate sustained yields of less than 200 gallons per day at many locations (MWH, 2005; CH2M HILL, 1999).
- Wells screened at depths greater than 50 feet below ground surface (bgs) will be located within dense unfractured bedrock with very low yield, which may be subject to intrusion by sea water (WCC, 1997; MWH, 2005).

Although groundwater is not currently used and there are no plans to do so in the future because of the reasons described above, the groundwater risk assessment from 1988 was updated using current analytical data and current toxicity data. Therefore, the exposure pathways that are quantitatively analyzed in the RA update are 1) ingestion of groundwater by the hypothetical future resident; 2) dermal contact with groundwater by the hypothetical future resident; and 3) inhalation of VOCs by the hypothetical future resident through household use of water (i.e., showering, dishwashing, etc.). Groundwater data collected from 2003 through 2006 are used in the RA update.

3.3 Exposure Pathways Not Analyzed in the Risk Assessment Update

Several exposure pathways are not quantitatively analyzed in the RA update because they are not considered potentially complete; these include 1) inhalation of volatile emissions and soil particles based on the current use of LF 26; 2) ingestion of contaminated soil based on the current use of LF 26; 3) dermal contact with contaminated soil based on the current use of LF 26; 4) ingestion of contaminated soil by the hypothetical future resident; 5) inhalation of VOCs volatilizing from soil gas to indoor air by the hypothetical future resident; 6) inhalation of VOCs volatilizing from groundwater to indoor air by the hypothetical future resident; and 7) evaluation of risk to aquatic life or other ecological receptors.

The first three exposure pathways not quantitatively analyzed in the RA Update were included in the 1988 RA based on the current use of LF 26 at that time. The fourth exposure pathway not quantitatively analyzed in the RA Update was included as a potential future exposure pathway. These exposure pathways are not analyzed in the RA Update because a RCRA-type landfill cap was installed and constructed in 1994-95 in response to the RWQCB, Bay Area Region WDRs Order No. 92-029; a ROD signed in August 1989; and a 1992 ESD. In general, the LF 26 cover system was constructed to a depth such that the impermeable membrane component is below the low groundwater elevation in most of the western and northern perimeters of LF 26. The RCRA-type cap was constructed with a 2- to 4.5-foot foundation composed of compacted clayey and silty sands and gravels. On top of the foundation is the hydraulic barrier, composed of 1 to 2 feet of low-permeability clays, and synthetic membranes and textiles. This is topped by 2 to 3 feet of clayey sand, a topsoil, and vegetative cover (CH2M HILL 1999). The RCRA-type cap extends over the entire landfill and into the groundwater around most of the landfill's perimeter. Therefore, the cap effectively cuts off any exposure of receptors to soil and resuspended particulates from the landfill surface. In addition, during this time, the 150- to 200-foot buffer zone (consisting of undeveloped land) was established around the landfill, providing separation between the landfill and adjacent land. Therefore, the exposure pathways for soil are considered incomplete and are not analyzed in the RA Update.

The fifth and sixth exposure pathways listed above are not quantitatively analyzed in the RA Update because they were evaluated in a separate RA completed in May 2002 (CH2M HILL 2002). In that RA it was determined that concentrations of VOCs detected in soil gas do not indicate the presence of current or future threats to human health for individuals in the residential area through the vapor intrusion to indoor air pathway.

The last exposure pathway that is not evaluated in the RA Update is the evaluation of risk to aquatic life or other ecological receptors. Although surface water sampling is not required by the RWQCB, samples were collected from the northerly landfill drainage channel by the U.S. Army Corps of Engineers and analyzed for the same chemicals of concern (COCs) sampled in the groundwater (CH2M HILL, 2006). Those data indicate there is no surface water contamination directly attributable to LF 26, so the risk to aquatic life is not evaluated in the RA Update. Assuming that the integrity of the landfill cap is maintained so that burrowing animals or other ecological receptors (plants and animals) cannot be exposed to LF 26-related chemicals within or near the landfill, exposure pathways for terrestrial plants and animals are incomplete. Therefore, there is no need for further ecological risk assessment for the site.

3.4 Calculation of Chemical Intake

Exposure that is normalized over time and body weight is termed "intake" (expressed as milligrams of chemical per kilogram body weight per day [mg/kg-day]).

3.4.1 Direct Contact Exposure Equations

This section describes the equations and exposure assumptions that were used to calculate direct contact exposures to contaminants in groundwater. The chemicals concentrations, or EPCs, that were used in the calculations are presented in Table 3.

Intake Equations for Ingestion of Groundwater.

The following equation was used to calculate the intake of carcinogenic and noncarcinogenic constituents associated with ingestion of groundwater under the hypothetical future residential exposure scenario:

$$Intake = \frac{C_w \cdot IRW \cdot EF \cdot ED}{AT \cdot BW} \quad (1)$$

where:

C_W = Chemical concentration in groundwater (mg/L)
IRW = Groundwater ingestion rate (L/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (days)

The exposure assumptions for estimating chemical intake from the ingestion of groundwater are presented in Table 4.

Intake Equations for Dermal Contact with Groundwater. Hypothetical future residents may be exposed through dermal absorption of constituents in groundwater during showering or bathing. The magnitude of potential exposure through this pathway is related to the concentration in water, surface area of exposed skin, the ability of the constituent to penetrate through the skin, and frequency and duration of exposure. The intake (or dose) from dermal contact with constituents in groundwater is based on the following equation (assuming one event per day):

$$Intake = \frac{DA_{event} \cdot SA \cdot EF \cdot ED}{AT \cdot BW} \tag{2}$$

where:

DA_{event} = Absorbed dose per event (mg/cm^2-event)
EF = Exposure frequency (days per year).
BW = Body weight (kg).
AT = Averaging time (days)
ED = Exposure duration (years)
SA = Skin surface area (cm^2)

The dermally absorbed dose per event (DA_{event}) for inorganic and organic parameters is estimated using the approach presented in *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual* (USEPA 2004b). The equation for estimating the DA_{event} for inorganic parameters is calculated using the following equation:

$$DA_{event}(inorganics) = K_p \cdot C_w \cdot t_{event} \tag{3}$$

The K_p for inorganics is provided in Exhibit 3-1 of USEPA 2004b and t_{event} (1 hour) is based on Exhibit 3-2 of the *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual* (USEPA 2004b).

The equation for estimating the DA_{event} for organic parameters is shown below (USEPA 2004b). The following procedure is used to estimate DA_{event} values for organics:

STEP 1. Estimate K_p (cm/hour):

$$Log\ K_p = -2.80 + 0.66 \log K_{ow} - 0.0056\ MW \tag{4}$$

Log K_{ow} and molecular weight (MW) values used in this equation are presented in Table B-2 in *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual* (USEPA 2004b).

STEP 2. Calculate B (dimensionless):

$$B = K_p \frac{\sqrt{MW}}{2.6} \tag{5}$$

STEP 3. Calculate the diffusion coefficient through skin, D_{sc} (cm^2/hour) from the following equation, assuming that 1_{sc} = 10 ∝m = 10^{-3} cm:

$$Log\frac{D_{sc}}{l_{sc}} = -2.80 \ - 0.0056MW \tag{6}$$

STEP 4. Calculate τ (hour) from the following equation, assuming that l_{sc} = 10 ∝m = 10^{-3} cm:

$$\tau = \frac{l_{sc}^2}{6D_{sc}} \tag{7}$$

STEP 5. Calculate the time needed to achieve steady-state t* (hour), based on the value of B:

$$If \ \ B \leq 0.6, \ then \ \ t^* = 2.4\tau \tag{8}$$

$$If \, B > 0.6, \, then \ t^* = 6\,(b - \sqrt{b^2 - c^2})\,\tau \tag{9}$$

where:

$$b = \frac{2}{\pi}(1+B)^2 - c$$

$$c = \frac{1 + 3B + 3B^2}{3\,(1+B)}$$

STEP 6. Calculate DA_{event} (mg/cm²-event):

$$If \, t_{event} \leq t^*, then: DA_{event} = 2K_p C_v \sqrt{\frac{6\tau t_{event}}{\pi}} \tag{10}$$

$$If \, t_{event} > t^*, then: DA_{event} = K_p C_v \left[\frac{t_{event}}{1+B} + 2\tau \left(\frac{1 + 3B + 3B^2}{(1+B)^2} \right) \right] \tag{11}$$

The K_p values used in the RA Update are presented in Table 5. The calculations and assumptions for DA_{event} are presented in Attachment 1.

Intake Equations for Inhalation of Vapors in Groundwater. The following equation was used to calculate the intake of carcinogenic and noncarcinogenic contaminants associated with inhalation of vapors from showering, bathing, or other household activities under the hypothetical residential exposure scenario:

$$Intake = \frac{C_w \cdot \ INH \ \cdot VF \cdot \ EF \cdot \ ED}{AT \cdot \ BW} \tag{12}$$

where:

C_w = Chemical concentration in water (mg/L)
INH = Inhalation rate (m³/day)
EF = Exposure frequency (days/year)

ED = Exposure duration (years)
BW = Body weight (kg)
VF = Volatilization factor (L/m^3)
AT = Averaging time (days)

The assumptions used to estimate exposure from inhalation of volatile constituents are presented in Table 4.

Volatile constituents considered for the inhalation pathway are operationally defined as those COPCs with a Henry's Law constant greater than 10^{-5} atm-m^3/mole and a molecular weigh less than 200 grams per mole (USEPA 2002b).

4.0 Toxicity Assessment

This toxicity assessment evaluates the relationship between the magnitude of exposure to a chemical from LF 26 and the likelihood of adverse health effects to potentially exposed populations. This assessment provides, where possible, a numerical estimate of the increased likelihood of adverse effects associated with chemical exposure (USEPA 1989). The toxicity assessment contains two steps: hazard characterization and dose-response evaluation. These two components are discussed in the following two subsections.

4.1 Hazard Characterization

Hazard characterization identifies the types of toxic effects a chemical can exert. For the toxicity assessment, chemicals can be divided into two broad groups based on their effects on human health: noncarcinogens, and carcinogens. This classification has been selected because health risks are calculated differently for noncarcinogenic and carcinogenic effects, and separate toxicity values have been developed for them.

Carcinogens are those chemicals suspected of causing cancer following exposure; noncarcinogenic effects cover a wide variety of systemic effects, such as liver toxicity or developmental effects. Some chemicals (such as arsenic) are capable of eliciting both carcinogenic and noncarcinogenic responses; therefore, these carcinogens are also evaluated for systemic (noncarcinogenic) effects.

4.2 Dose-response Evaluation

The magnitude of chemical toxicity depends on the dose to a receptor. Dose refers to exposure to a chemical concentration over a specified period of time. Human exposures are generally classified as acute (typically less than 2 weeks), subchronic (about 2 weeks to 7 years), or chronic (7 years to a lifetime). This RA Update specifically addresses chronic exposure. A dose-response curve describes the relationship between the degree of exposure (the dose) and the incidence of the adverse effects (the response) in the exposed population. USEPA uses this dose-response information to establish toxicity values for particular chemicals, as described in the following paragraphs.

4.3 Toxicity Values

The more conservative toxicity value from USEPA and the Cal EPA were used in the RA update, except for TCE, which is described below. Toxicity values (cancer slope factors and noncancer reference doses [also known as RfD]) used in this RA Update were obtained from the following sources:

- The Integrated Risk Information System (IRIS) database available through the USEPA National Center for Environmental Assessment (NCEA) in Cincinnati, Ohio. IRIS, prepared and maintained by USEPA, is an electronic database containing health risk and USEPA regulatory information on specific chemicals (USEPA 2007).
- The Health Effects Assessment Summary Tables (HEAST), provided by the USEPA Office of Solid Waste and Emergency Response (USEPA 1997b), is a compilation of toxicity values published in various health effects documents issued by USEPA.
- NCEA, formerly the Environmental Criteria and Assessment Office, as cited in USEPA Region 9 PRG Table (USEPA 2004a) at www.epa.gov/docs/region09/waste/sfund/prg/index.html. The USEPA Region 9 PRG able includes reference doses (RfDs) and slope factors (SFs) from NCEA that are not yet available on IRIS or that have been withdrawn from IRIS, pending further evaluation.
- California EPA, Cancer Potency List and Chronic Reference Exposure Levels; Office of Environmental Health Hazard Assessment (OEHHA) (Cal EPA 2005a and 2005b).

Toxicity values are not available for the dermal exposure route. Oral RfDs and SFs were used for the dermal exposure route. The toxicity values were updated from the toxicity values used in the 1988 RA for this RA Update.

4.3.1 Reference Doses for Noncarcinogenic Effects

The toxicity value describing the dose-response relationship for noncancer effects is the RfD value. For noncarcinogenic effects, the body's protective mechanisms must be overcome before an adverse effect is manifested. If exposure is high enough and these protective mechanisms (or thresholds) are exceeded, adverse health effects can occur. USEPA attempts to identify the upper bound of this tolerance range in the development of noncancer toxicity values. USEPA uses the apparent toxic threshold value, in conjunction with uncertainty factors based on the strength of the toxicological evidence, to derive an RfD. USEPA defines an RfD as follows:

> *In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfD is generally expressed in units of mg/kg-day* (USEPA 1989).

The RfDs for the detected chemicals for this RA Update are summarized in Table 6.

4.3.2 Slope Factors for Cancer Effects

The dose-response relationship for cancer effects is expressed as a cancer slope factor that converts estimated intake directly to excess lifetime cancer risk (ELCR). Slope factors are

presented in units of risk per level of exposure (or intake). The data used for estimating the dose-response relationship are taken from lifetime animal studies or human occupational or epidemiological studies where excess cancer risk has been associated with exposure to the chemical. However, because risk at low intake levels cannot be directly measured in animal or human epidemiological studies, a number of mathematical models and procedures have been developed to extrapolate from the high doses used in the studies to the low doses typically associated with environmental exposures. The model choice leads to uncertainty. USEPA assumes linearity at low doses and uses the linearized multistage procedure when uncertainty exists about the mechanism of action of a carcinogen and when information suggesting non-linearity is absent.

It is assumed, therefore, that if a cancer response occurs at the dose levels used in the study, then there is some probability that a response will occur at all lower exposure levels (that is, a dose-response relationship with no threshold is assumed). Moreover, the dose-response slope chosen is usually the UCL on the dose-response curve observed in the laboratory studies. As a result, uncertainty and conservatism are built into the USEPA risk extrapolation approach. USEPA has stated that cancer risks estimated by this method produce estimates that "provide a rough but plausible upper limit of risk." In other words, it is not likely that the true risk would be much more than the estimated risk, but "the true value of the risk is unknown and may be as low as zero" (USEPA 1996). The cancer slope factors used in this assessment are summarized in Table 6.

5.0 Risk Characterization

This section summarizes the approach used to develop the human health risk estimates for the RA Update and presents a quantitative risk characterization for groundwater. In this risk characterization step, quantification of risk is accomplished by combining the results of the exposure assessment (estimated chemical intakes) with the results of the dose-response assessment (toxicity values established in the toxicity assessment) to provide numerical estimates of potential health risks. The quantification approach differs for potential noncancer and cancer effects, as described in the following subsections.

USEPA has published a *Risk Characterization Handbook* (USEPA 2000), which provides a suitable basis for the presentation of risk results. USEPA recommends that information should be presented on the range of exposures derived from exposure scenarios. Individual exposure, dose, and risk can vary widely in a population.

Although this RA Update produces numerical estimates of risk, it should be recognized that these numbers might not predict actual health outcomes because they are based largely on hypothetical assumptions. Their purpose is to provide a frame of reference for risk management decision making. Any actual risks are likely to be lower than these estimates, and may even be zero. Interpretation of the risk estimates provided should consider the nature and weight of evidence supporting these estimates, as well as the magnitude of uncertainty surrounding them.

For the purposes of this evaluation, the risk results are discussed in the following context:

- For carcinogenic COPCs, ELCR values are compared to the risk-management range of 10^{-6} to 10^{-4}.

- For noncarcinogenic COPCs, an HI (the ratio of chemical intake to the RfD) greater than 1 indicates that there is some potential for adverse noncancer health effects associated with exposure to the COPCs.

5.1 Cancer Risk Estimation Method

The potential for cancer effects is evaluated by estimating ELCR. This risk is the incremental increase in the probability of developing cancer during one's lifetime in addition to the background probability of developing cancer (that is, if no exposure to chemicals released from LF 26 occurs). For example, a $2x10^{-6}$ ELCR means that, for every 1 million people exposed to the carcinogen throughout their lifetimes, the average incidence of cancer might increase by two cases of cancer. As previously mentioned, cancer slope factors developed by the USEPA represent upper-bound estimates, so any cancer risks generated in this assessment should be regarded as an upper bound on the potential cancer risks rather than precise representations of actual cancer risk. The true cancer risk is likely to be less than that predicted (USEPA 1989). ELCRs were estimated by using the following formula:

$$Risk = CDI \cdot SF \tag{13}$$

where:

Risk = ELCR (unitless probability)

CDI = Chronic daily intake averaged over a lifetime (mg/kg-day); referred to as Intake in Section 4.0

SF = Cancer slope factor $(mg/kg\text{-}day)^{-1}$

Although synergistic or antagonistic interactions might occur between cancer-causing chemicals and other chemicals, information is generally lacking in the toxicological literature to predict quantitatively the effects of these potential interactions. Therefore, cancer risks for individual chemicals are treated as additive (i.e., were summed) within an exposure route in this assessment. This is consistent with the USEPA guidelines on chemical mixtures (USEPA 1986). For estimating the cancer risks from exposure to multiple carcinogens from a single exposure route, the following equation is used:

$$Risk_T = \sum_1^N Risk_i \tag{14}$$

where:

$Risk_T$ = Total cancer risk from route of exposure
$Risk_i$ = Cancer risk for the ith chemical
N = Number of chemicals

5.2 Noncancer Risk Estimation Method

For noncancer effects, the likelihood that a receptor will develop an adverse effect is estimated by comparing the predicted level of exposure for a particular chemical with the highest level of exposure that is considered protective (that is, its RfD). The ratio of the chronic daily intake divided by RfD is termed the hazard quotient (HQ):

$$HQ = CDI / RfD \tag{14}$$

When the HQ for a chemical exceeds 1 (that is, exposure exceeds RfD), there is a concern for potential noncancer health effects. To assess the potential for noncancer effects posed by exposure to multiple chemicals, an HI approach was used according to USEPA guidance (USEPA 1989). This approach assumes that the noncancer hazard associated with exposure to more than one chemical is additive; therefore, synergistic or antagonistic interactions between chemicals are not quantitatively addressed. The HI may exceed 1 even if all the individual HQs are less than 1. In this case, the chemicals may be segregated by similar mechanisms of toxicity and toxicological effects. Separate HIs may then be derived based on mechanism and effect. The HI is calculated as follows:

$$HI = \sum_{1}^{N} CDI_i / RfD_i \tag{15}$$

where:

HI	=	Hazard index
CDI_i	=	Daily intake of the ith chemical (mg/kg-day)
RfD_i	=	Reference dose of the ith chemical (mg/kg-day)
N	=	Number of chemicals

5.3 Groundwater Risk Estimates

This section summarizes the risk estimates for the hypothetical future residential exposure scenario. The COPCs identified for groundwater are described in Section 2.4 and presented in Table 3. Risk estimates for the hypothetical future residential exposure scenarios are provided for the ingestion, dermal, and inhalation routes, as well as cumulative risks across all exposure routes. It is important to note that there are no wells currently used for drinking water or irrigation in the LF 26 area.

A summary of the risk estimates for each exposure scenario is provided in Table 7. The risk calculation data sheets used to develop the risk summary tables for each of the groundwater exposure scenarios described below are provided in Attachment 1.

5.3.1 Future Adult Resident

The potential cumulative ELCR for the hypothetical future adult resident exposed to groundwater is 5E-05 which is within the risk management range of 10^{-6} to 10^{-4}. The primary contributor to the total risk is naphthalene (77 percent). Thenaphthalene risk is predominantly from the inhalation exposure route. It is important to note that naphthalene was only detected in three of 98 groundwater samples that make up the RA Update data set. These three detections were in 2003 and naphthalene has not been detected in the monitoring wells used in the RA Update since 2003.

The noncarcinogenic HI for the hypothetical future adult resident is 1, indicating there are not likely to be adverse noncancer health effects to future adult residents from using the groundwater .

5.3.2 Future Child Resident

The potential cumulative ELCR for the hypothetical future child resident was not calculated because the ELCR is based on a lifetime of exposure and the exposure duration of the hypothetical future child resident is 6 years.

The noncarcinogenic HI for the hypothetical future child resident is 2 with naphthalene being the primary contributor (86 percent) to the HI. As noted above, naphthalene has not been detected in the monitoring wells used for the RA Update since 2003 and was only detected in 3 of 98 samples for the entire RA Update data set.

6.0 Uncertainty Analysis

Full characterization of health risks means that the numerical estimates of health risks must be accompanied by a discussion of the uncertainties inherent in the assumptions used in estimating these risks. Uncertainties in the risk estimation process may result in the numerical estimates either understating or overstating health risks associated with potential exposures.

Various sources of uncertainty affect the overall estimates of potential ELCRs and noncancer hazard as presented in this RA Update. These sources are generally associated with sampling and analysis, exposure assumptions, toxicity values, and risk characterization. Uncertainties associated with each of these components of the RA Update are discussed below.

6.1 Uncertainties Associated with Sampling and Analysis

This RA Update is based on the sampling results obtained from current (i.e., 2003 to 2006 results) investigations at LF 26. Uncertainties associated with sampling and analysis include the inherent variability (standard error) in the analysis, representativeness of the samples, sampling errors, and heterogeneity of the sample matrix. While the quality assurance/quality control program used in conducting the sampling and analysis serves to reduce errors, it cannot eliminate all errors associated with sampling and analysis. The number and location of samples in the LF 26 area are considered adequate for RA Update purposes. The type of contaminants, and exposure concentrations identified, are also considered representative of potential releases at LF 26.

The groundwater data set that was available for the RA Update consisted of samples collected from 8 different aquifer zones. These samples were collected to characterize potential releases from groundwater sources (see Table 1). Samples were analyzed for several different constituents, including total metals and dissolved metals. Only the total metals results were used in the RA Update. The total metals results may yield an overestimation of the actual risk or hazard, thus introducing some uncertainty in the RA Update results.

Three wells (MW-78, MW-82, and MW-86) are installed in the Refuse Zone of LF 26. These wells are not representative of the groundwater in the surrounding areas around LF 26. The groundwater in the Refuse Zone of LF 26 is not hydraulically linked to the surrounding

aquifers. Including data from these wells may yield an overestimation of the risk or hazard for the hypothetical scenario of using groundwater in the area as a drinking water source.

6.2 Uncertainties Associated with Exposure Assessment

The estimation of exposure requires numerous assumptions to describe potential exposure routes. There are a number of uncertainties regarding the likelihood of exposure, frequency of contact with contaminated media, the concentration of contaminants at exposure points, and the time period of exposure. Assumptions used in this RA Update tend to simplify and approximate actual conditions. In general, these assumptions are intended to be conservative and yield an overestimate of the true risk or hazard.

The risk assessment for residential use of groundwater makes simplifying assumptions about the environmental fate and transport of LF 26 contaminants, specifically that no dilution or reduction in chemical concentration occurs during the assessed exposure duration of 30 years. The evaluation of hypothetical future residential use of groundwater in this RA Update is hypothetical, to provide a conservative frame of reference for decision making by assuming that the concentrations in wells would be consumed by the potential hypothetical future resident under the same exposure conditions for the full 30-year exposure duration (i.e., that over time there is no dilution or reduction in chemical concentrations). As noted above, naphthalene has not been detected in the monitoring wells used for the RA Update since 2003 and was only detected in 3 of 98 samples for the entire RA Update data set. Therefore, future risks may be overestimated using this data set containing samples from 2003 to 2006 and assuming no reduction in chemical concentrations is occurring.

Estimated noncancer and cancer risks for residential use of groundwater were based on typical conservative exposure assumptions for adults and children. The default exposure assumptions for the residential exposure scenarios likely overestimate risk in the LF 26 area.

Most importantly, groundwater in the LF 26 region is not currently used for municipal or domestic drinking water, and there are no plans to do so in the future (CH2M HILL, 2006). According to the requirements contained in California State Water Resources Control Board Resolution 88-63 and the Water Quality Control Plan for the San Francisco Bay Region, groundwater at LF 26 is not suitable for drinking water because of high total dissolved solids and a low sustainable yield, both of which are natural properties of the aquifer. Although groundwater is not currently used and there are no plans to do so in the future, groundwater is evaluated as a hypothetical future exposure pathway.

6.3 Uncertainties Associated with Toxicity Assessment

The toxicological databases used to select toxicity factors were also sources of uncertainty. USEPA has outlined some of the sources of uncertainty in the *Risk Assessment Guidance for Superfund* (USEPA 1989). These sources may include or result from the extrapolation from high to low doses and from animals to humans; the species, gender, age, and strain differences in a toxin's uptake, metabolism, organ distribution, and target facility susceptibility; and are compounded when used to assess risk and hazards to human

populations, with compounding variability with respect to diet, environment, activity patterns, and cultural factors.

USEPA has not published dermal RfDs or slope factors; therefore, oral toxicity factors were used to estimate health impacts from dermal exposure. Dermal exposures are different from oral exposures, because not all of the chemical that comes into contact with a person's skin will travel across the various layers of epidermal tissue, and because the toxic effects produced from this route of exposure may not be the same as when the chemical is ingested. In lieu of available toxicity values for the dermal route, this RA Update uses oral toxicity values to estimate the effects of dermally available chemicals. This may result in an underestimate or overestimate of risks, depending on whether a chemical is more or less toxic by the dermal route versus ingestion.

Toxicity values for TPH (including aviation gas, diesel, gasoline, and waste oil) are not available from USEPA or Cal EPA; therefore, these mixtures of chemicals were not carried forward into the risk quantification process. Although the risks associated with these constituents are not quantifiable, a component of petroleum products (i.e., naphthalene) was quantified in the risk assessment.

Considered collectively, the factors contributing to uncertainty are likely to yield health hazards and risk estimates that are expected to be health-conservative and protective of public health.

6.4 Uncertainties Associated with Risk Characterization

In the risk characterization, the assumption was made that the total risk of developing cancer from exposure to contaminants within the LF 26 area is the sum of the risk attributed to each individual contaminant. Likewise, the potential for the development of noncancer adverse effects is the sum of the HQs estimated for exposure to each individual contaminant. This approach, in accordance with USEPA guidance, did not account for the possibility that constituents act synergistically or antagonistically. Therefore, the overall risk or hazard from these constituents may be overestimated or underestimated.

7.0 Summary

Potential cumulative ELCR associated with the use of offsite groundwater as a drinking water source is approximately 2E-05 for the hypothetical future adult resident, with naphthalene being the main contributor to the potential risks. This result is within the risk management range of 1×10^{-6} to 1×10^{-4}.

The potential HI associated with the use of offsite groundwater as a drinking water source is approximately 1 for the hypothetical future adult resident and 2 for the hypothetical future child resident. Naphthalene is the main contributors to the HI for both the hypothetical future child and adult residents. It is important to note that naphthalene was only detected in three of 98 groundwater samples that make up the RA Update data set. These three detections were in 2003 and naphthalene has not been detected in the monitoring wells used in the RA Update since 2003.

The lifetime incremental cancer risk estimate for oral exposure to carcinogenic contaminants through the ingestion of groundwater from the 1988 risk assessment was 2.2×10^{-5} for the most probable case and 3.24×10^{-4} for the worst case. In comparison, the ELCR in the RA Update for the hypothetical future adult resident is 2E-05 based on LF 26-related COPCs. Most of this risk is from the inhalation exposure route. The HI for ingestion of groundwater by the future adult from the 1988 risk assessment was 9.16 for the most probable case and 39.5 for the worst case. For the hypothetical future child resident from the 1988 risk assessment, the HI for ingestion of groundwater was 32.1 for the most probable case and 138 for the worst case. In comparison, the HI in the RA update for the hypothetical future adult resident is 1 and for the hypothetical future child resident is 2 based on LF 26-related COPCs. The majority of the HI for the hypothetical future adult and child residents is from the inhalation exposure route.

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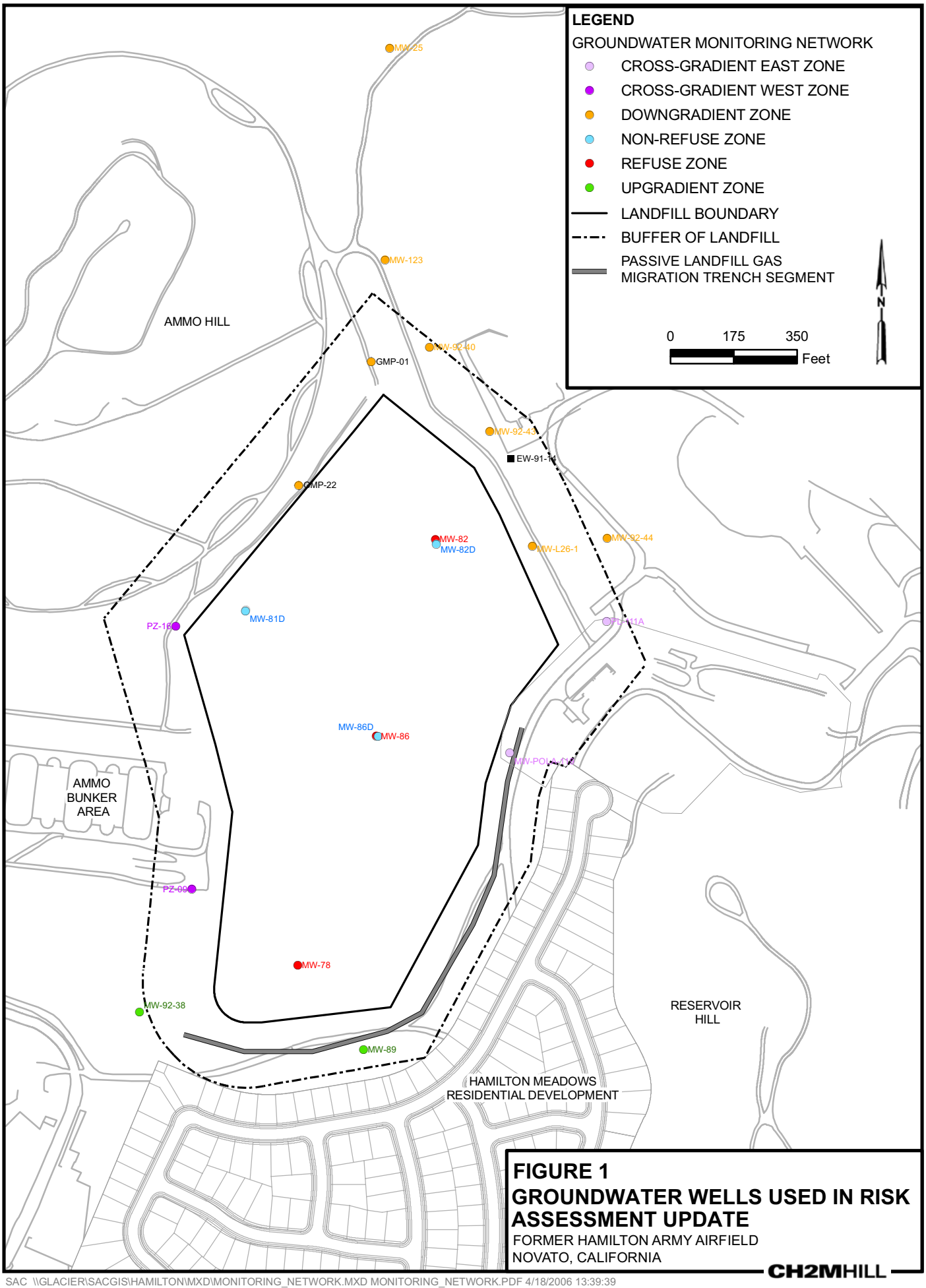

FIGURE 1
GROUNDWATER WELLS USED IN RISK ASSESSMENT UPDATE
FORMER HAMILTON ARMY AIRFIELD
NOVATO, CALIFORNIA

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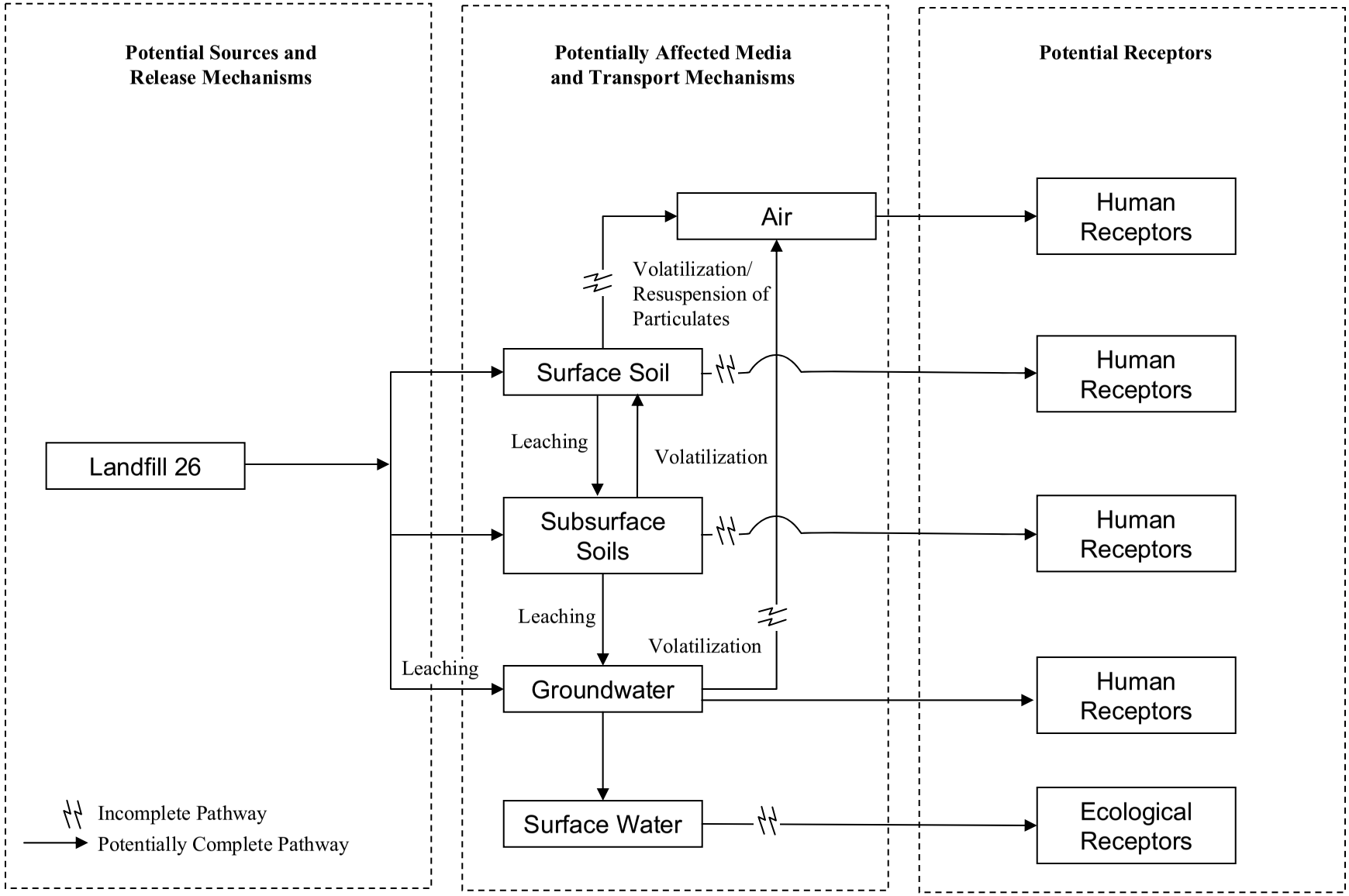

Figure 2
Exposure Pathway Analysis
Risk Assessment Update, Landfill 26
Former Hamilton Army Airfield, Novato, California

Table 1
Groundwater Wells Used in the Risk Assessment Update
Risk Assessment Update, Landfill 26, Former Hamilton Army Airfield, Novato, California

Well	Aquifer Zone	Monitoring Event
EW-91-14	Deep Downgradient	October 2003, April 2004, September 2004, April 2005, September 2006
GMP-01	Shallow Downgradient	October 2003, April 2004, September 2004, April 2005
GMP-22	Shallow Downgradient	October 2003, April 2004, September 2004, April 2005, September 2006
MW-123	Shallow Downgradient	October 2003, April 2004, September 2004, April 2005, September 2006
MW-25	Shallow Downgradient	October 2003, April 2004, September 2004
MW-78	Refuse Zone	January 2003, October 2003, April 2004, September 2004, April 2005, September 2006
MW-81D	Landfill Below Refuse	January 2003, October 2003, April 2004, September 2004, April 2005, September 2006
MW-82	Refuse Zone	January 2003, October 2003, April 2004, September 2004, April 2005, September 2006
MW-82D	Landfill Below Refuse	January 2003, October 2003, April 2004, September 2004, April 2005, September 2006
MW-86	Refuse Zone	January 2003, October 2003, April 2004, September 2004, April 2005, September 2006
MW-86D	Landfill Below Refuse	January 2003, October 2003, April 2004, September 2004, April 2005, September 2006
MW-89	Deeper Upgradient	January 2003, October 2003, April 2004, September 2004, April 2005, September 2006
MW-92-38	Shallow Upgradient	January 2003, October 2003, April 2004, September 2004, April 2005, September 2006
MW-92-40	Deep Downgradient	January 2003, October 2003, April 2004, September 2004, April 2005, September 2006
MW-92-43	Deep Downgradient	January 2003, October 2003, April 2004, September 2004, April 2005, September 2006
MW-92-44	Deep Downgradient	October 2003, April 2004, September 2004, April 2005, September 2006

Table 1
Groundwater Wells Used in the Risk Assessment Update
Risk Assessment Update, Landfill 26, Former Hamilton Army Airfield, Novato, California

Well	Aquifer Zone	Monitoring Event
MW-L26-1	Deep Downgradient	January 2003, October 2003, April 2004, September 2004, April 2005, September 2006
MW-PL-111A	Deep Crossgradient	January 2003, October 2003, April 2004, September 2004, April 2005, September 2006
MW-POLA-119	Deep Crossgradient	January 2003, October 2003, April 2004, September 2004, April 2005, September 2006
PZ-09	Shallow Crossgradient	January 2003, October 2003, April 2004, September 2004, April 2005, September 2006
PZ-16	Shallow Crossgradient	January 2003, October 2003, April 2004, September 2004, April 2005, September 2006

Table 2
Summary Statistics for Chemicals Detected in Groundwater and Tier I Assessment
Risk Assessment Update, Landfill 26, Former Hamilton Army Airfield, Novato, California

Parameter*	Number of Detects	Number of Analyses	Frequency of Detects	Percent Detects	Units	Minimum Detected Value	Maximum Detected Value	Tier I Screening Level (ESL)	MDC > ESL?	Location of Maximum Detected Concentration	Arithmetic Mean Value	Standard Deviation	Exposure Point Concentration	EPC Basis
1,1-Dichloroethene	5	102	5/102	5	ug/L	0.35	0.5			MW-81D	0.494	0.213	0.5	Maximum Result
1,2,4-Trimethylbenzene	1	102	1/102	1	ug/L	0.25	0.25			MW-82D	0.491	0.215	0.25	Maximum Result
1,2-Dichloroethane	3	102	3/102	3	ug/L	0.1	0.51			MW-92-43	0.492	0.217	0.51	Maximum Result
1,2-Dichloropropane	1	102	1/102	1	ug/L	0.08	0.08			PZ-16	0.492	0.216	0.08	Maximum Result
1,4-Dichlorobenzene	7	98	7/98	7	ug/L	0.23	11	5	Yes	MW-82	4.38	1.74	5.14	95% Chebyshev (Mean, Sd) UCL
2-Butanone (Methyl Ethyl Ketone)	4	102	4/102	4	ug/L	0.5	0.6			MW-123	9.69	4.52	0.6	Maximum Result
2-Methylnaphthalene	3	83	3/83	4	ug/L	5.3	9.8			MW-86	5.07	0.537	5.17	95% Student's-t UCL
4,4'-DDD	5	83	5/83	6	ug/L	0.013	0.025			MW-78	0.0246	0.0018	0.025	95% Student's-t UCL
4,4'-DDE	4	83	4/83	5	ug/L	0.011	0.05			MW-86D	0.0248	0.00369	0.0255	95% Student's-t UCL
4,4'-DDT	2	83	2/83	2	ug/L	0.0024	0.007			MW-86D	0.0245	0.00315	0.007	Maximum Result
Acenaphthene	1	83	1/83	1	ug/L	2.4	2.4			MW-86	4.97	0.285	2.4	Maximum Result
Alkalinity (as CaCO3)	23	23	23/23	100	ug/L	118000	1400000			MW-82D	660000	374000	822000	95% Approximate Gamma UCL
Antimony, Dissolved	34	83	34/83	41	ug/L	2	140			MW-123	10.4	21.4	25.1	97.5% Chebyshev (Mean, Sd) UCL
Antimony, Total	41	83	41/83	49	ug/L	2	110			MW-123	10.8	20.3	24.7	97.5% Chebyshev (Mean, Sd) UCL
Arsenic, Dissolved	40	102	40/102	39	ug/L	0.41	130			MW-123	7.39	15.8	17.2	97.5% Chebyshev (Mean, Sd) UCL
Arsenic, Total	46	98	46/98	47	ug/L	1.2	130			MW-123	8.67	15.3	15.4	95% Chebyshev (Mean, Sd) UCL
Barium, Dissolved	92	102	92/102	90	ug/L	12	1400			MW-86	189	292	369	97.5% Chebyshev (Mean, Sd) UCL
Barium, Total	97	98	97/98	99	ug/L	15	1400	1000	Yes	MW-82D	222	329	429	97.5% Chebyshev (Mean, Sd) UCL
Benzene	2	102	2/102	2	ug/L	0.07	0.1			MW-78	0.49	0.219	0.1	Maximum Result
Benzoic acid	4	83	4/83	5	ug/L	3.4	12			MW-92-43	24.1	4.14	12	Maximum Result
Beryllium, Dissolved	8	83	8/83	10	ug/L	0.32	2			EW-91-14	1.26	0.911	1.42	95% Student's-t UCL
Beryllium, Total	6	83	6/83	7	ug/L	0.3	0.68			MW-123	1.24	0.911	0.68	Maximum Result
Butyl benzyl phthalate	16	83	16/83	19	ug/L	3.5	24			EW-91-14	5.83	3.02	6.38	95% Student's-t UCL
Cadmium, Dissolved	5	83	5/83	6	ug/L	1.5	4.6			MW-123	3.17	2.22	3.58	95% Student's-t UCL
Cadmium, Total	8	83	8/83	10	ug/L	0.21	4.4			MW-123	3.12	2.29	4.22	95% Chebyshev (Mean, Sd) UCL
Carbon Dioxide	23	23	23/23	100	ug/L	30000	670000			MW-82	249000	163000	308000	95% Student's-t UCL
Carbon Disulfide	3	19	3/19	16	ug/L	0.09	0.1			MW-86D	0.441	0.52	0.1	Maximum Result
Chlordane (alpha)	1	83	1/83	1	ug/L	0.0074	0.0074			MW-L26-1	0.0248	0.00193	0.0074	Maximum Result
Chlorobenzene	19	117	19/117	16	ug/L	0.19	37	70	No	MW-82	2.64	7.01	6.68	97.5% Chebyshev (Mean, Sd) UCL
Chloromethane	1	102	1/102	1	ug/L	3	3			PZ-09	0.605	0.514	0.69	95% Student's-t UCL
Chromium, Dissolved	15	83	15/83	18	ug/L	2	55			MW-92-43	5.32	9.54	9.88	95% Chebyshev (Mean, Sd) UCL
Chromium, Total	29	83	29/83	35	ug/L	1.4	100			MW-92-44	7.76	15.6	15.2	95% Chebyshev (Mean, Sd) UCL
Cobalt, Dissolved	22	41	22/41	54	ug/L	1	51			MW-L26-1	7.4	10.9	14.8	95% Chebyshev (Mean, Sd) UCL
Cobalt, Total	33	83	33/83	40	ug/L	1	51			MW-L26-1	7.37	10.6	12.4	95% Chebyshev (Mean, Sd) UCL
Copper, Dissolved	32	144	32/144	22	ug/L	0.68	43			MW-92-43	3.73	5.91	5.88	95% Chebyshev (Mean, Sd) UCL
Copper, Total	39	98	39/98	40	ug/L	0.83	51			MW-92-40	4.32	6.36	7.13	95% Chebyshev (Mean, Sd) UCL
Di-n-Octyl phthalate	5	83	5/83	6	ug/L	3.3	7.5			EW-91-14	4.97	0.388	5.04	95% Student's-t UCL
Endosulfan I	1	83	1/83	1	ug/L	0.0059	0.0059			MW-L26-1	0.0248	0.0021	0.0059	Maximum Result
Ethylbenzene	1	102	1/102	1	ug/L	0.08	0.08			MW-86	0.492	0.216	0.08	Maximum Result
Iron, Ferrous	25	25	25/25	100	ug/L	0	8700			MW-86	2020	2130	3880	95% Chebyshev (Mean, Sd) UCL
Lead, Dissolved	16	102	16/102	16	ug/L	0.13	10			GMP-01	2.82	2.53	3.91	95% Chebyshev (Mean, Sd) UCL
Lead, Total	25	98	25/98	26	ug/L	1.7	46			MW-78	4.02	5.17	6.3	95% Chebyshev (Mean, Sd) UCL
Manganese, Total	22	23	22/23	96	ug/L	10	15500			MW-92-40	2820	3870	5000	95% Approximate Gamma UCL
Mercury, Dissolved	6	83	6/83	7	ug/L	0.09	0.14			MW-82	0.24	0.0372	0.14	Maximum Result
Mercury, Total	8	83	8/83	10	ug/L	0.09	1			MW-123	0.271	0.145	0.297	95% Student's-t UCL
Methane	61	102	61/102	60	ug/L	3.6	22000			MW-78	2170	5490	7580	99% Chebyshev (Mean, Sd) UCL
Methyl Tert-Butyl Ether (MTBE)	12	102	12/102	12	ug/L	0.3	910			MW-92-38	51.9	165	215	99% Chebyshev (Mean, Sd) UCL
Molybdenum, Dissolved	34	83	34/83	41	ug/L	5	89			MW-92-44	10.8	18.6	23.5	97.5% Chebyshev (Mean, Sd) UCL
Molybdenum, Total	36	83	36/83	43	ug/L	5	91			EW-91-14	10.8	18.5	23.5	97.5% Chebyshev (Mean, Sd) UCL
Naphthalene	3	98	3/98	3	ug/L	0.15	6.3	17	No	MW-82	4.37	1.62	5.08	95% Chebyshev (Mean, Sd) UCL
Nickel, Dissolved	53	83	53/83	64	ug/L	1	1400			MW-92-44	46.3	172	164	97.5% Chebyshev (Mean, Sd) UCL

Table 2
Summary Statistics for Chemicals Detected in Groundwater and Tier I Assessment
Risk Assessment Update, Landfill 26, Former Hamilton Army Airfield, Novato, California

Parameter*	Number of Detects	Number of Analyses	Frequency of Detects	Percent Detects	Units	Minimum Detected Value	Maximum Detected Value	Tier I Screening Level (ESL)	MDC > ESL?	Location of Maximum Detected Concentration	Arithmetic Mean Value	Standard Deviation	Exposure Point Concentration	EPC Basis
Nickel, Total	58	83	58/83	70	ug/L	1	1300			MW-92-44	49.6	169	165	97.5% Chebyshev (Mean, Sd) UCL
Nitrate as N	4	23	4/23	17	ug/L	720	65900			MW-92-40	7600	15400	39500	99% Chebyshev (Mean, Sd) UCL
Oxygen, Dissolved	138	138	138/138	100	ug/L	0	9760			GMP-01	1240	1540	1820	95% Chebyshev (Mean, Sd) UCL
Selenium, Dissolved	30	83	30/83	36	ug/L	2.7	28			MW-92-40	7.4	7.25	10.9	95% Chebyshev (Mean, Sd) UCL
Selenium, Total	32	83	32/83	39	ug/L	3	30			MW-86	7.54	7.34	11.1	95% Chebyshev (Mean, Sd) UCL
Silver, Dissolved	6	83	6/83	7	ug/L	0.7	2.8			MW-123	0.711	0.543	0.81	95% Student's-t UCL
Silver, Total	3	83	3/83	4	ug/L	2	3.2			MW-123	0.701	0.562	0.804	95% Student's-t UCL
Sulfate	18	23	18/23	78	ug/L	16700	2140000			MW-92-44	477000	759000	1030000	95% Adjusted Gamma UCL
TPH-Diesel	55	119	55/119	46	ug/L	17	2500	210	Yes	MW-82	163	271	319	97.5% Chebyshev (Mean, Sd) UCL
TPH-Gas	6	102	6/102	6	ug/L	42	190			MW-86	29.1	20.3	32.4	95% Student's-t UCL
TPH-Motor Oil	18	104	18/104	17	ug/L	150	950			MW-82	250	102	267	95% Student's-t UCL
Thallium, Dissolved	6	83	6/83	7	ug/L	4.8	36			MW-92-40	3.84	4.31	5.9	95% Chebyshev (Mean, Sd) UCL
Thallium, Total	10	83	10/83	12	ug/L	2	38			MW-92-40	4.46	5.75	7.21	95% Chebyshev (Mean, Sd) UCL
Toluene	10	102	10/102	10	ug/L	0.07	0.58			MW-92-43	0.476	0.228	0.514	95% Student's-t UCL
Trichloroethene	10	102	10/102	10	ug/L	0.9	6.1			MW-81D	0.78	1.12	1.26	95% Chebyshev (Mean, Sd) UCL
Vanadium, Dissolved	38	83	38/83	46	ug/L	0.85	12			MW-25	2.84	2.62	4.09	95% Chebyshev (Mean, Sd) UCL
Vanadium, Total	40	83	40/83	48	ug/L	0.73	37			GMP-01	3.61	4.81	5.91	95% Chebyshev (Mean, Sd) UCL
Xylenes, total	10	60	10/60	17	ug/L	0.1	0.44			GMP-22	1.01	0.614	0.44	Maximum Result
Zinc, Dissolved	29	102	29/102	28	ug/L	3.2	1100			MW-86	53.7	130	134	97.5% Chebyshev (Mean, Sd) UCL
Zinc, Total	42	98	42/98	43	ug/L	7	4000			MW-92-40	126	446	408	97.5% Chebyshev (Mean, Sd) UCL
bis(2-Ethylhexyl)phthalate	4	83	4/83	5	ug/L	3.2	3.6			MW-81D	4.93	0.331	3.6	Maximum Result
cis-1,2-Dichloroethene	12	102	12/102	12	ug/L	0.1	8.4			MW-81D	0.872	1.38	1.47	95% Chebyshev (Mean, Sd) UCL
trans-1,2-Dichloroethene	1	102	1/102	1	ug/L	0.19	0.19			MW-81D	0.491	0.216	0.19	Maximum Result

* Parameters highlighted in ***Bold Italics*** are LF-26 related chemicals (see Section 2,2)
NA = Not available.
MDC = maximum detected concentration.
UCL = upper confidence limit on the mean.
ESL = environmental screening level.
EPC = exposure point concentration.

Table 3
Exposure Point Concentrations for Groundwater
Risk Assessment Update, Landfill 26, Former Hamilton Army Airfield, Novato, California

Chemical of Potential Concern	Units	Exposure Point Concentration	EPC Basis
1,4-Dichlorobenzene	mg/L	5.1E-03	95% Chebyshev (Mean, Sd) UCL
Barium, Total	mg/L	4.3E-01	97.5% Chebyshev (Mean, Sd) UCL
Chlorobenzene	mg/L	6.7E-03	97.5% Chebyshev (Mean, Sd) UCL
Naphthalene	mg/L	5.1E-03	95% Chebyshev (Mean, Sd) UCL

EPC = exposure point concentration.
UCL = upper confidence limit on the mean.

Table 4
Groundwater Exposure Assumptions
Risk Assessment Update, Landfill 26, Former Hamilton Army Airfield, Novato, California

Exposure Parameter			Adult Future Resident Groundwater	Source	Child Future Resident Groundwater	Source
Exposure Frequency	EF	days/yr	350	DTSC, 2005	350	DTSC, 2005
Exposure Time for dermal exposure	ET_d	hr/day	0.58	DTSC, 2005	1.0	DTSC, 2005
Exposure Time for inhalation of volatiles	ET_i	hr/day	24	USEPA, 1989	24	USEPA, 1989
Exposure Duration	ED	years	24	DTSC, 2005	6	DTSC, 2005
Ingestion Rate	IngR	L/day	2	DTSC, 2005	1	DTSC, 2005
Inhalation Rate	InhR	m^3/hr	0.83	DTSC, 2005	0.42	DTSC, 2005
Volatilization Factor	VFw	L/m^3	0.5	USEPA, 2002b	0.5	USEPA, 2002b
Skin Surface Area	SA	cm^2	18,000	DTSC, 2005	6,600	DTSC, 2005
Body Weight	BW	kg	70	DTSC, 2005	15	DTSC, 2005
Averaging Time for carcinogens	ATc	yr	70	DTSC, 2005	70	DTSC, 2005
Averaging Time for noncarcinogens	ATnc	yr	24	DTSC, 2005	6	DTSC, 2005
Conversion Factor 1	CF1	L/cm^3	0.001		0.001	
Conversion Factor 2	CF2	cm^3/m^3	1.0E+06		1.0E+06	
Conversion Factor 3	CF3	yr/day	2.7E-03		2.7E-03	
Constituent Specific Permeability Constant	Kp	cm/hr	Chemical Specific	USEPA, 2004b	Chemical Specific	USEPA, 2004b

Notes:
ATc = 70 years x 365 days/year
ATnc = ED (years) x 365 days/year
Inhalation rate (m^3/day): Adult Resident (20m^3/day); Child Resident (10m^3/day)

Sources:
DTSC, HERD, 2005. Recommended DTSC Default Exposure Factors for Use in Risk Assessment at California Military Facilities.
USEPA, 1989: Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals). USEPA OERR. December
USEPA, 2002b: User's Guide and Background Technical Document for Preliminary Remediation Goals Table. Region 9. October.
USEPA, 2004b: Risk Assessment Guidance for Superfund: Volume I Human Health Evaluation Manual. (Part E, Supplemental Guidance for Dermal Risk Assessment, Final). July.

Table 5
Dermal Permeability Constants and Volatile Compounds - Groundwater
Risk Assessment Update, Landfill 26, Former Hamilton Army Airfield, Novato, California

Chemical	Kp[a] (cm/hr)	Volatility[b]
1,4-Dichlorobenzene	4.2E-02	V
Barium, Total	1.0E-03	NV
Chlorobenzene	2.8E-02	V
Naphthalene	4.7E-02	V

Notes:
NV = Nonvolatile, V = Volatile
[a] EPA RAGS Part E, 2004
[b] EPA Region 9 PRGs, 2004

Table 6
Cancer and Noncancer Toxicity Values for COPCs
Risk Assessment Update, Landfill 26, Former Hamilton Army Airfield, Novato, California

Chemical of Potential Concern	Oral RfD (mg/kg-day)	References	Inhalation RFD (mg/kg-day)	References	Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	References	Inhalation Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	References
1,4-Dichlorobenzene	3.00E-02	EPA, 2004	2.29E-01	Cal EPA, 2005b	2.40E-02	USEPA, 2004a	4.00E-02	Cal EPA, 2005a
Barium, Total	2.00E-01	EPA, 2004	1.40E-04	USEPA, 2004a				
Chlorobenzene	2.00E-02	EPA, 2004	1.70E-02	USEPA, 2004a				
Naphthalene	2.00E-02	EPA, 2004	8.57E-04	USEPA, 2004a	1.20E-01	Cal EPA, 2005b	1.20E-01	Cal EPA, 2005a

References
USEPA, 2004a: EPA Region 9 PRG Table, 2004 (Note: The toxicity values in the Region 9 table were updated with revisions to IRIS since 2004).
Cal EPA, 2005a: California Cancer Potency Values. August. http://www.oehha.ca.gov/risk/chemicalDB/index.asp
Cal EPA, 2005b: Office of Enviornmental Health Hazard Assessment (OEHHA). Chronic Reference Exposure Levels. February, http://www.oehha.ca.gov/air/chronic_rels/allchrels.html
Shaded cells indicate analyte is a surrogate and toxicity values are from the parent analyte.
RfD = reference dose.

Table 7
Summary of Risk Calculations - Residential Exposure Scenario - Groundwater
Risk Assessment Update, Landfill 26, Former Hamilton Army Airfield, Novato, California

Exposure Scenario/ Receptor	Reasonable Maximum Exposure			
	Cancer	Cancer Risk Drivers	NonCancer	NonCancer Risk Drivers
Groundwater				
Future Adult Resident (24 years)	5.E-05	Naphthalene (77%)	1	Naphthalene (86%)
Future Child Resident (6 years)	--	--	2	Naphthalene (86%)

-- Cancer risk was not calculated for the future child resident scenario.

Attachment 1
Risk Calculation Data Sheets

Table A1-1
Risk Calculation Worksheet for Groundwater - Carcinogenic Effects - Residential Exposure Scenario - Future Adult Resident
Risk Assessment Update, Landfill 26, Former Hamilton Army Airfield, Novato, California

Exposure Scenario Information		
	Exposure Scenario:	Residential
	Scenario Timeframe:	Chronic
	Exposure Medium:	Groundwater
	Exposure Point:	OnSite
	Receptor Population:	Future Adult Resident
	Receptor Age:	Adult

Exposure Scenario/Exposure Area Description

Landfill 26 Monitoring Wells

Exposure Parameter	Variable	Value	Units
Exposure Frequency	EF	350	days/yr
Exposure Time for dermal exposure	ET_d	0.58	hr/day
Exposure Time for inhalation of volatiles	ET_i	24	hr/day
Exposure Duration	ED	24	years
Ingestion Rate	IngR	2	L/day
Inhalation Rate	InhR	0.83	m3/hr
Volatilization Factor	VFw	0.5	L/m3
Skin Surface Area	SA	18000	cm2
Body Weight	BW	70	kg
Averaging Time for carcinogens	ATc	70	yr
Averaging Time for noncarcinogens	ATnc	24	yr
Conversion Factor 1	CF1	1.00E-03	L/cm3
Conversion Factor 2	CF2	1.00E+06	cm3/m3
Conversion Factor 3	CF3	2.74E-03	yr/day
Constituent Specific Permeability Constant	Kp	Chemical Specific	cm/hr

Risk Calculations

		Exposure Route = Oral			Exposure Route = Dermal			Exposure Route = Inhalation			
Chemical of Potential Concern	EPC Value, Cw [mg/L]	Chronic Daily Intake [mg/kg/day]	Cancer Slope Factor, SF [mg/kg/day]-1	Cancer Risk [-]	Chronic Daily Intake [mg/kg/day]	Cancer Slope Factor, SF [mg/kg/day]-1	Cancer Risk [-]	Chronic Daily Intake [mg/kg/day]	Cancer Slope Factor, SF [mg/kg/day]-1	Cancer Risk [-]	Total Cancer Risk [-]
1,4-Dichlorobenzene	5.1E-03	4.83E-05	2.40E-02	1.16E-06	3.21E-05	2.40E-02	7.71E-07	2.40E-04	4.00E-02	9.62E-06	**1.15E-05**
Barium, Total	4.3E-01	4.03E-03			2.10E-05			NV			
Chlorobenzene	6.7E-03	6.27E-05			2.23E-05			3.12E-04			
Naphthalene	5.1E-03	4.77E-05	1.20E-01	5.73E-06	3.15E-05	1.20E-01	3.78E-06	2.38E-04	1.20E-01	2.85E-05	**3.80E-05**
			Total Risk:	6.88E-06		**Total Risk:**	4.55E-06		**Total Risk:**	3.81E-05	**4.96E-05**

Total Estimated Carcinogenic Risk Across All Exposure Routes : **5.E-05**

Notes:
blank cell = one or more of the following: no toxicity value available in standard U.S. EPA toxicity value databases; no Kp value available; no Henry's Law constant.
EPC = exposure point concentration.
NV = Chemical classified as Nonvolatile thus no CDI was calculated.

Table A1-2
Risk Calculation Worksheet for Groundwater - Noncarcinogenic Effects - Residential Exposure Scenario - Future Adult Resident
Risk Assessment Update, Landfill 26, Former Hamilton Army Airfield, Novato, California

Exposure Scenario Information		
	Exposure Scenario:	Residential
	Scenario Timeframe:	Chronic
	Exposure Medium:	Groundwater
	Exposure Point:	OnSite
	Receptor Population:	Future Adult Resident
	Receptor Age:	Adult

Exposure Scenario/Exposure Area Description

Landfill 26 Monitoring Wells

Exposure Parameter	Variable	Value	Units
Exposure Frequency	EF	350	days/yr
Exposure Time for dermal exposure	ET_d	0.58	hr/day
Exposure Time for inhalation of volatiles	ET_i	24	hr/day
Exposure Duration	ED	24	years
Ingestion Rate	IngR	2	L/day
Inhalation Rate	InhR	0.83	m3/hr
Volatilization Factor	VFw	0.5	L/m3
Skin Surface Area	SA	18000	cm2
Body Weight	BW	70	kg
Averaging Time for carcinogens	ATc	70	yr
Averaging Time for noncarcinogens	ATnc	24	yr
Conversion Factor 1	CF1	1.00E-03	L/cm3
Conversion Factor 2	CF2	1.00E+06	cm3/m3
Conversion Factor 3	CF3	2.74E-03	yr/day
Constituent Specific Permeability Constant	Kp	Chemical Specific	cm/hr

Risk Calculations

		Exposure Route = Oral			Exposure Route = Dermal			Exposure Route = Inhalation			
Chemical of Potential Concern	RME Medium EPC Value, Cw [mg/L]	Chronic Daily Intake [mg/kg/day]	Reference Dose [mg/kg/day]	Hazard Quotient	Chronic Daily Intake [mg/kg/day]	Reference Dose [mg/kg/day]	Hazard Quotient	Chronic Daily Intake [mg/kg/day]	Reference Dose [mg/kg/day]	Hazard Quotient	Total Hazard Quotient [-]
1,4-Dichlorobenzene	5.14E-03	1.41E-04	3.00E-02	4.69E-03	9.37E-05	3.00E-02	3.12E-03	7.01E-04	2.29E-01	3.07E-03	1.09E-02
Barium, Total	4.29E-01	1.18E-02	2.00E-01	5.88E-02	6.14E-05	2.00E-01	3.07E-04	NV	1.40E-04		5.91E-02
Chlorobenzene	6.68E-03	1.83E-04	2.00E-02	9.15E-03	6.51E-05	2.00E-02	3.25E-03	9.11E-04	1.70E-02	5.36E-02	6.60E-02
Naphthalene	5.08E-03	1.39E-04	2.00E-02	6.96E-03	9.18E-05	2.00E-02	4.59E-03	6.93E-04	8.57E-04	8.09E-01	**8.20E-01**
			Total Risk:	0.1		**Total Risk:**	0.01		**Total Risk:**	1	**1**

Total Estimated Non-carcinogenic Risk (Hazard Index) Across All Exposure Routes : **1**

Notes:
blank cell = one or more of the following: no toxicity value available in standard U.S. EPA toxicity value databases; no Kp value available; no Henry's Law constar
EPC = exposure point concentration.
NV = Chemical classified as Nonvolatile thus no CDI was calculated.

Table A1-3
Risk Calculation Worksheet for Groundwater - Noncarcinogenic Effects - Residential Exposure Scenario - Future Child Resident
Risk Assessment Update, Landfill 26, Former Hamilton Army Airfield, Novato, California

Exposure Scenario Information		
	Exposure Scenario:	Residential
	Scenario Timeframe:	Chronic
	Exposure Medium:	Groundwater
	Exposure Point:	OnSite
	Receptor Population:	Future Child Resident
	Receptor Age:	Child

Exposure Scenario/Exposure Area Description

Landfill 26 Monitoring Wells

Exposure Parameter	Variable	Value	Units
Exposure Frequency	EF	350	days/yr
Exposure Time for dermal exposure	ET_d	1	hr/day
Exposure Time for inhalation of volatiles	ET_i	24	hr/day
Exposure Duration	ED	6	years
Ingestion Rate	IngR	1	L/day
Inhalation Rate	InhR	0.42	m3/hr
Volatilization Factor	VFw	0.5	L/m3
Skin Surface Area	SA	6600	cm2
Body Weight	BW	15	kg
Averaging Time for carcinogens	ATc	70	yr
Averaging Time for noncarcinogens	ATnc	6	yr
Conversion Factor 1	CF1	1.00E-03	L/cm3
Conversion Factor 2	CF2	1.00E+06	cm3/m3
Conversion Factor 3	CF3	2.74E-03	yr/day
Constituent Specific Permeability Constant	Kp	Chemical Specific	cm/hr

Risk Calculations

		Exposure Route = Oral			Exposure Route = Dermal			Exposure Route = Inhalation			
Chemical of Potential Concern	RME Medium EPC Value, Cw [mg/L]	Chronic Daily Intake [mg/kg/day]	Reference Dose [mg/kg/day]	Hazard Quotient	Chronic Daily Intake [mg/kg/day]	Reference Dose [mg/kg/day]	Hazard Quotient	Chronic Daily Intake [mg/kg/day]	Reference Dose [mg/kg/day]	Hazard Quotient	Total Hazard Quotient [-]
1,4-Dichlorobenzene	5.14E-03	3.29E-04	3.00E-02	1.10E-02	2.11E-04	3.00E-02	7.02E-03	1.66E-03	2.29E-01	7.25E-03	2.52E-02
Barium, Total	4.29E-01	2.74E-02	2.00E-01	1.37E-01	1.81E-04	2.00E-01	9.05E-04	NV	1.40E-04		**1.38E-01**
Chlorobenzene	6.68E-03	4.27E-04	2.00E-02	2.14E-02	1.46E-04	2.00E-02	7.31E-03	2.15E-03	1.70E-02	1.27E-01	**1.55E-01**
Naphthalene	5.08E-03	3.25E-04	2.00E-02	1.62E-02	2.06E-04	2.00E-02	1.03E-02	1.64E-03	8.57E-04	1.91E+00	**1.94E+00**
			Total Risk:	0.2		**Total Risk:**	0.03		**Total Risk:**	2	**2**

Total Estimated Non-carcinogenic Risk (Hazard Index) Across All Exposure Routes : **2**

Notes:
blank cell = one or more of the following: no toxicity value available in standard U.S. EPA toxicity value databases; no Kp value available; no Henry's Law constant.
EPC = exposure point concentration.
NV = Chemical classified as Nonvolatile thus no CDI was calculated.

Table A1-4
Model for Estimating Dermal Exposure from Contact with Chemicals in Water - Future Adult Resid
Risk Assessment Update, Landfill 26, Former Hamilton Army Airfield, Novato, California

Source: EPA, 2004. RAGS Part E

ORGANICS

If $t_{event} \leq t^*$:

$$DA_{event_1} = 2 \times FA \times K_p \times C_v \sqrt{\frac{6 \times tau \times t_{event}}{\Pi}}$$

If $t_{event} > t^*$:

$$DA_{event_2} = FA \times K_p \times C_v \left[\frac{t_{event}}{1+B} + 2 \times tau \times \left(\frac{1+3B+3B^2}{(1+B)^2} \right) \right]$$

INORGANICS

$$DA_{event} = K_p \times C_v \times t_{event}$$

$$DAD = \frac{DA_{event} \times EV \times ED \times EF \times SA}{BW \times AT \times 365\, days/year}$$

$$\log K_p = -2.8 + 0.66 \log K_{ow} - 0.0056 MW$$

$$B = K_p \frac{\sqrt{MW}}{2.6}$$

$$If\ B \leq 0.6\ then\ t^* = 2.4\tau$$

$$If\ B > 0.6\ then\ t^* = 6\left(b - \sqrt{b^2 - c^2}\right)\tau$$

$$b = \frac{2}{\pi}(1+B)^2 - c$$

$$c = \frac{1+3B+3B^2}{3(1+B)}$$

$$\log \frac{D_{sc}}{l_{sc}} = -2.80 - 0.0056\, MW$$

$$\tau = \frac{l_{sc}^2}{6\, D_{sc}}$$

Dermally-absorbed dose	DAD	calculated	mg/kg-day
Concentration in water	Conc (Cv)	chem-specific	mg/cm3
permeability coefficient	Kp	calculated	cm/hr
Lag time per event (hours)	*tau (τ)*	calculated	hours
Time to reach steady-state (hours)	t*	calculated	hours
Dimensionless coefficient	B	calculated	
Pi	π	3.1416	
Exposure Time	t_event	0.58	hr/event
Number of exposure events	EV	1	event/day
Exposure Duration	ED	24	year
Exposure Frequency	EF	350	days/year
Exposed Skin Surface Area	SA	18000	cm2
Body Weight	BW	70	kg
Averaging time - noncarcinogenic	AT_N	24	years
Averaging time - carcinogenic	AT_C	70	years
Conversion Factor		0.001	mg/ug

Thickness of stratum corneum	*lsc* (cm)	0.001
Molecular Weight	g/mol	chem-specific
log octanol-water partition coefficient	Log Kow	chem-specific
log permeability coefficient	log Kp	calculated
Permeability coefficient (cm/hr)	Kp	calculated
Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis	B	calculated
across the stratum corneum (cm2/hr)	Dsc	calculated
Lag time per event (hours)	*τ*	calculated
Time to reach steady-state (hours)	t*	calculated
USEPA's methodology (see equations A7 and A8,	b,c	calculated

Constituent	Conc (mg/L)	Conc (mg/cm3)	MW	FA	Log Kow	Kp (cm/hr) Select	Log Kp	B	Dsc/lsc	Dsc (cm2/hr)	τ (hours)	b	c	t* (hours)	DA_inorg (mg/cm2-event)	DA_1 (mg/cm2-event)	DA_2 (mg/cm2-event)	Selected DA (mg/cm2-event)
1,4-Dichlorobenzene	5.1E-03	5.1E-06	1.5E+02	1.0	3.4E+00	4.20E-02	-1.39E+00	1.96E-01	2.38E-04	2.38E-07	7.00E-01	0.4	0.47	1.68E+00	NA	3.80E-07	4.65E-07	3.80E-07
Barium, Total	4.3E-01	4.3E-04	NA	1.0	NA	1.00E-03	NA	NA	NA	NA	NA	NA	NA	NA	2.49E-07	NA	NA	2.49E-07
Chlorobenzene	6.7E-03	6.7E-06	1.1E+02	1.0	2.8E+00	2.80E-02	-1.56E+00	1.14E-01	3.71E-04	3.71E-07	4.49E-01	0.4	0.41	1.08E+00	NA	2.64E-07	2.84E-07	2.64E-07
Naphthalene	5.1E-03	5.1E-06	1.3E+02	1.0	3.3E+00	4.70E-02	-1.34E+00	2.05E-01	3.03E-04	3.03E-07	5.49E-01	0.4	0.48	1.32E+00	NA	3.72E-07	4.29E-07	3.72E-07

Table A1-5
Model for Estimating Dermal Exposure from Contact with Chemicals in Water - Future Child Resident
Risk Assessment Update, Landfill 26, Former Hamilton Army Airfield, Novato, California

Source: EPA, 2004. RAGS Part E

ORGANICS

If $t_{event} \leq t^*$:

$$DA_{event_1} = 2 \times FA \times K_p \times C_v \sqrt{\frac{6 \times tau \times t_{event}}{\Pi}}$$

If $t_{event} > t^*$:

$$DA_{event_2} = FA \times K_p \times C_v \left[\frac{t_{event}}{1+B} + 2 \times tau \times \left(\frac{1+3B+3B^2}{(1+B)^2} \right) \right]$$

INORGANICS

$$DA_{event} = K_p \times C_v \times t_{event}$$

$$DAD = \frac{DA_{event} \times EV \times ED \times EF \times SA}{BW \times AT \times 365\, days/year}$$

$$\log K_p = -2.8 + 0.66 \log K_{ow} - 0.0056 MW$$

$$B = K_p \frac{\sqrt{MW}}{2.6}$$

$$If\ B \leq 0.6\ then\ t^* = 2.4\tau$$

$$If\ B > 0.6\ then\ t^* = 6\left(b - \sqrt{b^2 - c^2}\right)\tau$$

$$b = \frac{2}{\pi}(1+B)^2 - c \qquad c = \frac{1+3B+3B^2}{3(1+B)}$$

$$\log \frac{D_{sc}}{l_{sc}} = -2.80 - 0.0056\, MW$$

$$\tau = \frac{l_{sc}^2}{6\, D_{sc}}$$

Dermally-absorbed dose	DAD	calculated	mg/kg-day
Concentration in water	Conc (Cv)	chem-specific	mg/cm3
permeability coefficient	Kp	calculated	cm/hr
Lag time per event (hours)	*tau (τ)*	calculated	hours
Time to reach steady-state (hours)	t*	calculated	hours
Dimensionless coefficient	B	calculated	
Pi	π	3.141592654	
Exposure Time	t_event	1	hr/event
Number of exposure events	EV	1	event/day
Exposure Duration	ED	6	year
Exposure Frequency	EF	350	days/year
Exposed Skin Surface Area	SA	6600	cm2
Body Weight	BW	15	kg
Averaging time - noncarcinogenic	AT_N	6	years
Averaging time - carcinogenic	AT_C	70	years
Conversion Factor		0.001	mg/ug

Thickness of stratum corneum	*lsc* (cm)	0.001
Molecular Weight	g/mol	chem-specific
log octanol-water partition coefficient	Log Kow	chem-specific
log permeability coefficient	log Kp	calculated
Permeability coefficient (cm/hr)	Kp	calculated
Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis	B	calculated
across the stratum corneum (cm2/hr)	Dsc	calculated
Lag time per event (hours)	τ	calculated
Time to reach steady-state (hours)	t*	calculated
methodology (see equations A7 and A8, USEPA, 2001)	b,c	calculated

Constituent	Conc (mg/L)	Conc (mg/cm3)	MW	FA	Log Kow	Kp (cm/hr) Select	Log Kp	B	Dsc/lsc	Dsc (cm2/hr)	τ (hours)	b	c	t* (hours)	DA_inorg (mg/cm2-event)	DA_1 (mg/cm2-event)	DA_2 (mg/cm2-event)	Selected DA (mg/cm2-event)
1,4-Dichlorobenzene	5.1E-03	5.1E-06	1.5E+02	1.0	3.4E+00	4.20E-02	-1.39E+00	1.96E-01	2.38E-04	2.38E-07	7.00E-01	0.4	0.47	1.68E+00	NA	4.99E-07	5.40E-07	4.99E-07
Barium, Total	4.3E-01	4.3E-04	NA	1.0	NA	1.00E-03	NA	NA	NA	NA	NA	NA	NA	NA	4.29E-07	NA	NA	4.29E-07
Chlorobenzene	6.7E-03	6.7E-06	1.1E+02	1.0	2.8E+00	2.80E-02	-1.56E+00	1.14E-01	3.71E-04	3.71E-07	4.49E-01	0.4	0.41	1.08E+00	NA	3.46E-07	3.55E-07	3.46E-07
Naphthalene	5.1E-03	5.1E-06	1.3E+02	1.0	3.3E+00	4.70E-02	-1.34E+00	2.05E-01	3.03E-04	3.03E-07	5.49E-01	0.4	0.48	1.32E+00	NA	4.89E-07	5.13E-07	4.89E-07