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FEASIBILITY STUDY REPORT FOR OPERABLE UNIT 10 (OU 10) SITE 25 FORMER TRANSFORMER STORAGE YARD NAS CECIL FIELD FL

10/1/2001

TETRA TECH NUS INC

Feasibility Study Report
for
Operable Unit 10, Site 25
Former Transformer Storage Yard

Naval Air Station Cecil Field
Jacksonville, Florida

Southern Division
Naval Facilities Engineering Command
Contract Number N62467-94-D-0888

Contract Task Order 0078

October 2001

FEASIBILITY STUDY REPORT
FOR
OPERABLE UNIT 10, SITE 25
FORMER TRANSFORMER STORAGE YARD

NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

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This document that describes the Feasibility Study for Operable Unit 10, Site 25, Former Transformer Storage Yard, Naval Air Station Cecil Field, Jacksonville, Florida, has been prepared under the direction of a Florida-registered professional engineer. The work and professional opinions rendered in this report were conducted or developed in accordance with commonly accepted procedures consistent with applicable standards of practice.

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LIST OF ACRONYMS AND ABBREVIATIONS

ABB-ES	ABB Environmental Services, Inc.
AOI	Area of Interest
ARAR	Applicable or Relevant and Appropriate Requirement
AWQC	Ambient Water Quality Criteria (USEPA's)
BCT	BRAC Closure Team
bgs	below ground surface
BHC	benzene hexachloride
BOD	biochemical oxygen demand
BRAC	Base Realignment and Closure
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CLEAN	Comprehensive Long-Term Environmental Action Navy
COC	chemical of concern
CSF	Cancer Slope Factor (USEPA's)
CTO	Contract Task Order
CWA	Clean Water Act
DPT	direct push technology
EBCT	empty bed contact time
FAC	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FS	Feasibility Study
ft	foot or feet
ft^2	square foot or square feet
ft^3	cubic foot ot cubic feet
GAC	granular activated carbon
GCTL	Groundwater Cleanup Target Levels (FDEP's)
gpm	gallon(s) per minute
GRA	General Response Action
HLA	Harding Lawson Associates
HRC®	hydrogen release compound
IBDS	Inorganic Background Data Set
IR	Installation Restoration
IWTP	industrial wastewater treatment plant
KAG	Kerosene Analyte Group (FDEP's)
MCLs	Maximum Contaminant Levels (USEPA's)

µg/L	microgram(s) per liter
NAS	Naval Air Station
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
O&M	operation and maintenance
ORC®	oxygen release compound
OSHA	Occupational Safety and Health Act
OU	Operable Unit
PAH	polynuclear or polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PFD	process flow diagram
PPE	personal protection equipment
POTW	publicly-owned treatment works
PRB	permeable reactive barrier
PRE	Preliminary Risk Evaluation
PRG	Preliminary Remedial Action Goal
PSC	Potential Source of Contamination
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RfD	Reference Dose (USEPA's)
RI	Remedial Investigation
SCTL	Soil Cleanup Target Level (FDEP's)
SDWA	Safe Drinking Water Act
SMCL	Secondary Maximum Contaminant Level (USEPA's)
SOUTHDIVNAVFACENGCOM	Southern Division Naval Facilities Engineering Command
SPECAP	specific capacity (test)
STP	sewage treatment plant
SVOC	semivolatile organic compound
SWMU	solid waste management unit
TAL	Target Analyte List
TBC	To Be Considered (criterion)
TCE	trichloroethene
TCL	Target Compound List
TRPH	total recoverable petroleum hydrocarbons
TSD	treatment, storage, disposal (facility)
TSS	total suspended solids

TtNUS	Tetra Tech NUS, Inc.
UCL	Upper Confidence Limit
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
VOCs	volatile organic compounds

EXECUTIVE SUMMARY

E.1 PURPOSE OF THE REPORT

The purpose of this Feasibility Study (FS) Report is to develop and evaluate options for the remediation of contaminated groundwater for Operable Unit (OU) 10, Site 25, Former Transformer Storage Yard (Site 25) at the former Naval Air Station (NAS) Cecil Field in Jacksonville, Florida. The Remedial Investigation (RI) prepared for this site concluded that no further action was required for soil [Tetra Tech NUS (TtNUS), 2001].

E.2 SITE DESCRIPTION AND HISTORY

OU10, Site 25, Former Transformer Storage Yard, is located in the Transportation and Fuel Management Compound/Public Works Maintenance Area, north of Cecil Pines Street (formerly 9th Street) and east of New World Avenue (formerly "D" Avenue). The site itself is to the north of Building 81 and includes Buildings 101 and 247 as well as several oil-water separators (80-OW1, 80-OW2, and 80-OW4). The site is primarily unpaved and covers about 0.6 acres.

The buildings in the immediate area of the site have always been associated with the Public Works Center [ABB Environmental Services, Inc.(ABB-ES), 1994]. Building 81, the main building in the area, was built in 1953. Building 100 was constructed in 1961. Building 247 was constructed in 1956. Activities at Site 25 have included the storage of pesticides and the storage of old transformers (ABB-ES, 1994). There are no details on the operation of the wash rack, and what types of equipment were serviced.

The name of Site 25 has been changed over the course of the investigations. For the Base Realignment and Closure (BRAC) investigation, the site was designated as Area of Interest (AOI) 25. When it was determined that soil contamination was present over a large area, the area was redesignated Potential Source of Contamination (PSC) 25 in January 1999. When the presence of groundwater contamination was confirmed, the area was designated as Installation Restoration (IR) Site 25 in February 2000.

Several environmental investigations were performed at Site 25, starting with the Phase II Investigation of Transportation and Fuel Management and Public Works Maintenance Contractor Area in February 1997 through the RI of Site 25 in April 2000. These investigations showed that soil was contaminated with polynuclear aromatic hydrocarbons (PAHs), total recoverable petroleum hydrocarbons (TRPHs), and pesticides. The contaminated soil was excavated and disposed off-site. These investigations also

showed that groundwater is contaminated with isomers of the pesticide benzene hexachloride (BHC) and aluminum. Evaluation of that contamination was the primary objective of the RI.

E.3 SUMMARY OF THE INVESTIGATIONS FINDINGS

Alpha- and beta-BHC were detected in groundwater samples collected from a single well (CEF-P25-01S) at concentrations greater than their respective Florida Department of Environmental Protection (FDEP) Groundwater Cleanup Target Levels (GCTLs) of 0.006 and 0.02 micrograms per liter (µg/L) (FDEP, 1999a). The horizontal extent of the BHC contaminant plume, as defined by exceedances of the GCTL, was determined to be approximately 100 feet (ft) in diameter, centered on monitoring well CEF-P25-01S. The vertical extent of contamination was assumed not to exceed approximately 15 ft below ground surface (bgs).

Aluminum was also detected at concentrations greater than its GCTL (200 µg/L) and its NAS Cecil Field site-specific Inorganic Background Data Set (IBDS) value (13,100 µg/L) [Harding Lawson Associates (HLA), 1998] during the pre-RI sampling of well CEF-080-03S. However, these exceedances were not confirmed by the results from the sampling of that same well during the RI.

The Preliminary Risk Assessment (PRE) performed as part of the RI identified alpha- and beta-BHC as the only chemicals of concern (COCs) for the Site 25 groundwater.

The ecological risk assessment performed as part of the RI established that Site 25 consists primarily of buildings and parking lots which provides an ecological habitat of marginal quality that can be of little use to terrestrial wildlife. Therefore, the RI concluded that Site 25 does not present any significant ecological risk.

E.4 REMEDIAL ACTION OBJECTIVES, PRELIMINARY REMEDIAL ACTION GOALS, AND VOLUME OF CONTAMINATED GROUNDWATER

The Remedial Action Objectives (RAO) identified for the Site 25 groundwater is as follows:

- Prevent ingestion of groundwater contaminated with alpha- and beta-BHC concentrations greater than 0.006 and 0.02 µg/L, respectively.

The Preliminary Remedial Action Goals (PRGs) for alpha- and beta-BHC in the Site 25 groundwater were established as 0.006 and 0.02 µg/L, respectively, which are the FDEP's GCTLs.

Based on groundwater table elevation of 5 ft bgs and a saturated zone porosity of 0.25, both of which are typical at NAS Cecil Field, the volume of contaminated groundwater at Site 25 is estimated at approximately 19,635 cubic feet (ft^3) or 147,000 gallons.

E.5 SCREENING OF GENERAL RESPONSE ACTIONS, REMEDIATION TECHNOLOGIES, AND PROCESS OPTIONS

General Response Actions (GRAs) and the remediation technologies and process options associated to these GRAs were screened for effectiveness, implementability, and cost. Remediation technologies that were determined to be ineffective or too difficult to implement were eliminated from further consideration. The following GRAs, remediation technologies, and process options were retained to develop groundwater remedial alternatives for Site 25:

General Response Action	Remediation Technology	Process Options
No Action	None	Not Applicable
Limited Action	Monitoring	Sampling and Analysis
	Institutional Controls	Groundwater Use Restrictions
	Natural Attenuation	Naturally-Occurring Biodegradation, Dispersion, and Dilution
Removal	Groundwater Extraction	Extraction Wells
In-Situ Treatment	Biological	Enhanced Biodegradation (HRC®/ORC®)
Ex-situ Treatment	Physical	Filtration
		Liquid-Phase Granular Activated Carbon (GAC) Adsorption
Discharge/Disposal	Onsite Surface Discharge	Direct Discharge (NPDES)

E.6 DEVELOPMENT OF REMEDIAL ALTERNATIVES

The following remedial alternatives were developed for the Site 25 groundwater:

- **Alternative 1: No Action**. No action would be taken. Retained as a baseline for comparison with other alternatives.

- **Alternative 2: Natural Attenuation, Institutional Controls, and Monitoring**. Natural attenuation would consist of implementing a long-term groundwater sampling and analysis program to evaluate the reduction in the concentrations of groundwater COCs through naturally-occurring processes. Institutional controls would consist of preventing the use of groundwater until the BHC PRGs has been met. Monitoring would consist of regularly collecting and analyzing groundwater samples both from within the contaminant plume to assess natural attenuation and downgradient of leading edge of the plume to evaluate potential contaminant migration.

- **Alternative 3: In-Situ Enhanced Biodegradation, Institutional Controls, and Monitoring**. This alternative would consist of applying an hydrogen release compound (HRC®), such as lactic acid, through direct push technology (DPT) to enhance the anaerobic biodegradation of BHC. Prior to this application, a treatability study would be performed to verify the effectiveness of the HRC® and determine whether an oxygen release compound (ORC®), such as magnesium peroxide, might also have to be applied to complete the aerobic biodegradation of BHC metabolites. Institutional controls and monitoring would be the same as for Alternative 2.

- **Alternative 4: Extraction, On-Site Treatment, Surface Discharge, Institutional Controls, and Monitoring**. This alternative would consist of extracting the contaminated groundwater through two new extraction wells pumping at a combined rate of 15 gallons per minute (gpm). The extracted groundwater would be treated by liquid-phase GAC adsorption to remove dissolved BHC prior to discharge to surface water. Institutional controls and monitoring would be the same as for Alternatives 2 and 3.

E.7 DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

The remedial alternatives were analyzed in detail using seven of the nine criteria provided in the National Contingency Plan (NCP) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). These seven criteria are as follows:

- Overall Protection of Human Health and the Environment,
- Compliance with Applicable or Relevant and Appropriate Requirements (ARARs) and To-Be-Considered (TBCs) guidance criteria,
- Long-term Effectiveness and Permanence,
- Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment,
- Short-term Effectiveness,
- Implementability, and
- Cost

Two other criteria, State and Community Acceptance were not evaluated in this report. They will be evaluated after regulatory and public comments are available.

E.8 COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

The remedial alternatives were compared to each other using the same criteria that were used for detailed analysis. The following is a summary of these comparisons:

- **Overall Protection of Human Health and Environment**

Alternative 1 would not be protective of human health and the environment since alpha- and beta-BHC would remain above their PRGs, no institutional controls would be implemented to prevent unacceptable risk from ingestion of contaminated groundwater, and no monitoring would be performed to evaluate the progress of natural attenuation or the potential migration of contaminants.

Alternative 2 would be protective of human health and the environment. Although no active remediation would take place, natural attenuation would dissipate the contaminant plume, institutional controls would prevent unacceptable exposure to contaminated groundwater, and monitoring would evaluate the progress of natural attenuation and verify that unacceptable migration of contaminants is not taking place.

Alternatives 3 and 4 would be more protective of human health and the environment than Alternative 2 because, in addition to institutional controls and monitoring, these alternatives would accelerate the remediation of the site through active treatment processes.

- **Compliance with ARARs and TBCs**

Alternative 1 would not comply with chemical- or location-specific ARARs and TBCs. No action-specific ARARs or TBCs would apply to this alternative. Alternatives 2, 3, and 4 would comply with location- and action-specific ARARs and TBCs and, eventually, with chemical-specific ARARs and TBCs as well. It is anticipated that compliance with chemical-specific ARARs and TBCs would first be achieved by Alternative 3.

- **Long-term Effectiveness and Permanence**

Alternative 1 would have no long-term effectiveness and permanence since no action would be taken to reduce contamination, or control exposure to contaminated groundwater, or monitor progress of natural attenuation and detect potential migration of contaminants.

Alternative 2 would have long-term effectiveness and permanence because institutional controls and monitoring would effectively prevent unacceptable exposure to contaminated groundwater until the BHC PRGs has been met through natural attenuation.

Alternative 3 would be more long-term effective and permanent than Alternative 2 because, in addition to controlling risk of unacceptable exposure and monitoring the progress of natural attenuation and the possibility of contaminant migration, this alternative would effectively and irreversibly remediate the

contaminant plume through in-situ treatment to achieve the BHC PRGs. However, the effectiveness of the proposed in-situ treatment technology, i.e., HRC®-enhanced anaerobic biodegradation would have to be verified through a treatability study.

Alternative 4 would be the most long-term effective and permanent because it would achieve the same results as Alternative 3 through the use of technologies that do not require treatability testing to verify their effectiveness, i.e., groundwater extraction and liquid-phase GAC adsorption.

- **Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment**

Alternatives 1 and 2 would not reduce contaminant toxicity, mobility, or volume through treatment. Under these alternatives, contaminant toxicity and volume would be reduced through natural attenuation but only Alternative 2 would monitor this reduction.

Alternatives 3 and 4 would significantly reduce contaminant toxicity and volume through treatment. Both of these alternatives would be designed to irreversibly remove an estimated 0.0006 pounds of BHC from the contaminant plume.

- **Short-term Effectiveness**

There would be no short-term effectiveness concerns and no impact to the surrounding community associated with Alternative 1 since no action would be taken.

Alternatives 2, 3, and 4 would also not impact the surrounding community but there would be some short-term effectiveness concerns associated with their implementation because of the risk of workers being exposed to contaminated groundwater. The magnitude of this risk would be proportional to the extent of remedial activities, e.g., it would be minimal for Alternative 2, moderate for Alternative 3, and significant for Alternative 4. However, regardless of its magnitude, the risk of exposure would be properly mitigated through implementation of proper engineering controls, and adherence to applicable Occupational Safety and Health Act (OSHA) regulations and to the site-specific health and safety procedures, including the wearing of appropriate personal protective equipment (PPE).

Alternative 1 would not achieve the RAO and, although the BHC PRGs would eventually be attained through natural attenuation, there would be no means of determining when this had occurred. Alternatives 2, 3, and 4 would achieve the RAO immediately upon implementation of institutional controls. It is estimated that Alternative 2 would attain the BHC PRGs within 16 (β-BHC) to 32 months (α-BHC). It is also estimated that Alternatives 3 and 4 would attain the BHC PRGs within 36 and 25 months, respectively.

- **Implementability**

Alternative 1 would be easiest to implement since there would be no activities to implement.

Technically, the monitoring component of Alternatives 2, 3, and 4 would be relatively simple to implement.

The technical implementability of Alternative 3 would be slightly more difficult than that of Alternative 2 and that of Alternative 4 would be most difficult. In addition to monitoring, Alternative 3 would require the performance of a treatability study, the installation of DPT injection points and the application of HRC®. In addition to monitoring, Alternative 4 would require the installation and operation and maintenance of a relatively small groundwater extraction and on-site treatment system (15 gpm).

Alternatives 2, 3, and 4 would be administratively implementable. The institutional controls component of these alternatives would be simple to implement. As part of the transfer of property from military to private ownership, appropriate provisions were incorporated in the property transfer documents to ensure continued enforcement of controls. Alternatives 2, 3, and 4 would require permits for the installation of new monitoring wells. Alternative 4 would also require construction permits for the installation of groundwater extraction wells and an on-site treatment system. Alternative 4 would also have to meet the substantive requirements of a National Pollutant Discharge Elimination System (NPDES) permit for discharge of treated groundwater to surface water. These requirements would be readily implementable.

- **Cost**

The capital and operation and maintenance (O&M) costs and net present worth (NPW) of the groundwater remedial alternatives were estimated to be as follows:

Alternative	Capital ($)	30-Year NPW of O&M ($)	30-Year NPW ($)
1	0	0	0
2	5,000	84,000	89,000
3	485,000	93,000 (5-Year)	578,000 (5-Year)
4	423,000	279,000 (5-Year)	702,000 (5-Year)

The above cost figures have been rounded to the nearest $1,000 to reflect the preliminary nature of these estimates. A detailed breakdown of cost estimates is provided in Appendix C.

1.0 INTRODUCTION

This Feasibility Study (FS) report for Operable Unit (OU) 10, Site 25, Former Transformer Yard at the former Naval Air Station (NAS) Cecil Field, Jacksonville, Florida has been prepared by Tetra Tech NUS, Inc. (TtNUS) for Southern Division Naval Facilities Engineering Command (SOUTHDIVNAVFACENGCOM) under the Navy Comprehensive Long-Term Environmental Action Navy (CLEAN) Program, Contract Number N62467-94-D-0888, Contract Task Order (CTO) 0078. This FS report describes the formulation and evaluation of remedial alternatives for contaminated groundwater at OU 10, Site 25. The Remedial Investigation (RI) for this site concluded that no further action is required for soil (TtNUS, 2001).

The FS was conducted to establish Remedial Action Objectives (RAOs) and Preliminary Remedial Action Goals (PRGs); screen remedial technologies; and assemble, evaluate, and compare remedial alternatives. The FS focuses on the groundwater plume that has been identified during the RI and previous investigations.

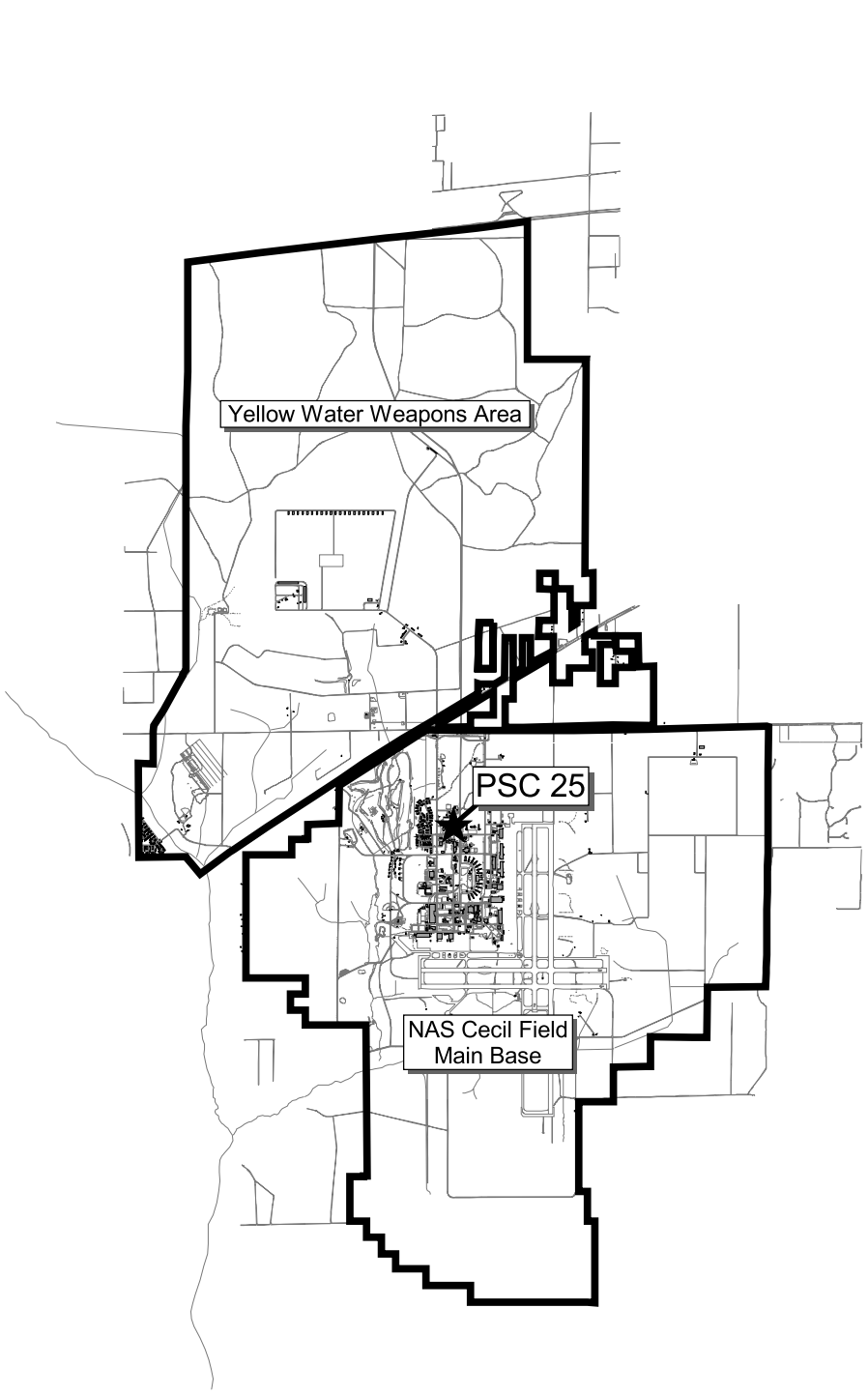
1.1 SITE BACKGROUND

The following paragraphs describe the background of OU 10, Site 25. Figure 1-1 provides a site location map. Figure 1-2 shows the vicinity of the site. Figure 1-3 provides the current general arrangement of the site.

1.1.1 Site Description

OU 10, Site 25, the Former Transformer Storage Yard, is located in the Transportation and Fuel Management Compound/Public Works Maintenance Area, north of Cecil Pines Street (formerly 9th Street) and east of New World Avenue (formerly “D” Avenue). The site itself is to the north of Building 81. The site includes Buildings 101 and 247. The study area also includes Oil-Water Separators 80-OW1, 80-OW2, and 80-OW4.

The site is primarily unpaved and covers about 0.6 acres. Building 100 forms the north border of the site. Access roads around Building 81 form the east and south borders. The fence between the Transportation and Fuel Management Compound and Public Works Maintenance Contractor Area forms the west border. Oil-Water Separators 80-OW1 and 80-OW2 are located to the west of the fence. In addition, the unpaved strip between the Transportation and Fuel Management Compound and Public Works Maintenance Contractor Area is included in the site [Harding Lawson Associates (HLA), 1999b].



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CHECKED BY	DATE		APPROVED BY DATE
COST/SCHEDULE-AREA			APPROVED BY DATE
SCALE AS NOTED			DRAWING NO. FIGURE 1-1 / REV 0

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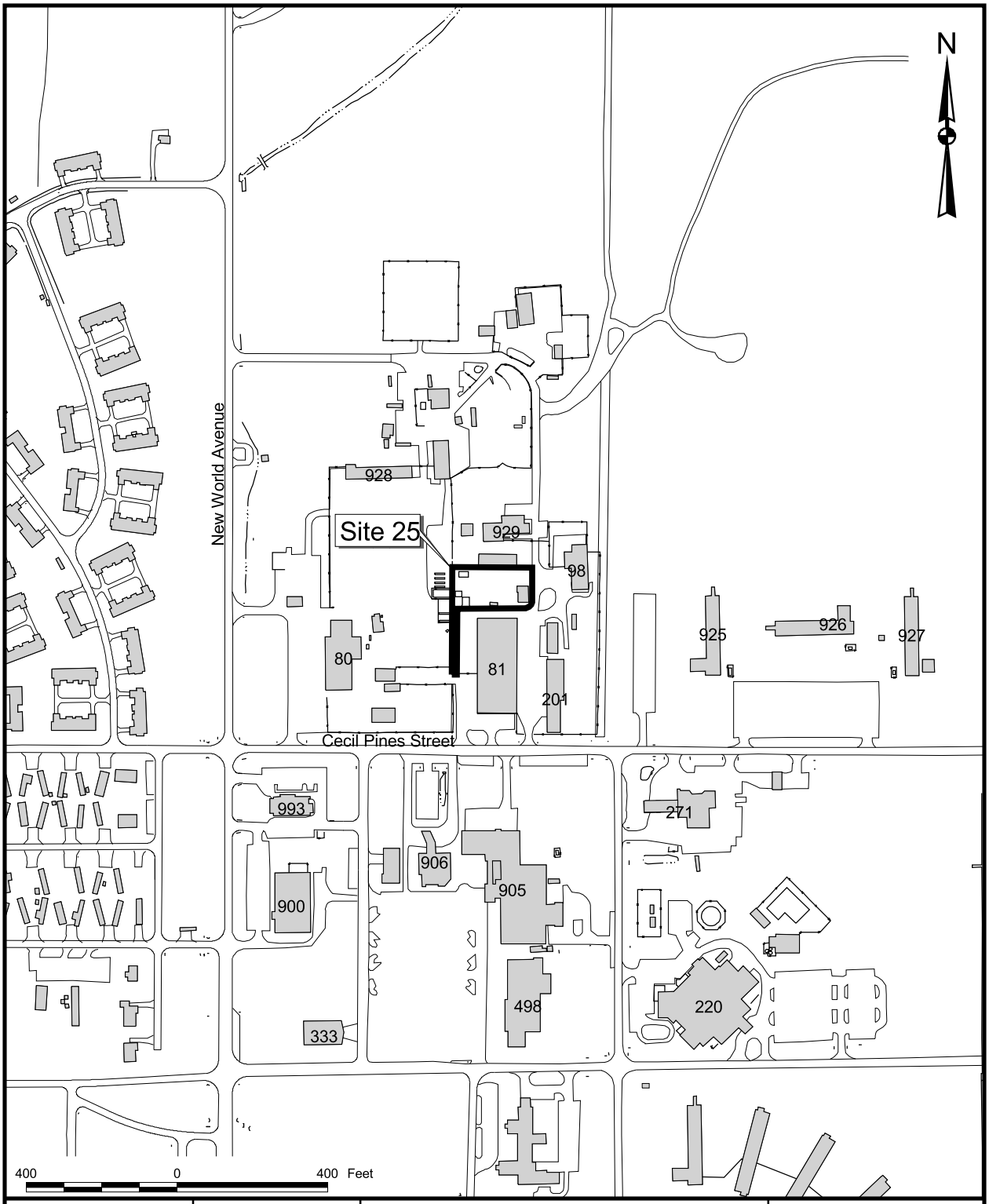

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COST/SCHEDULE-AREA			APPROVED BY DATE
SCALE AS NOTED			DRAWING NO. FIGURE 1-2 / REV 0

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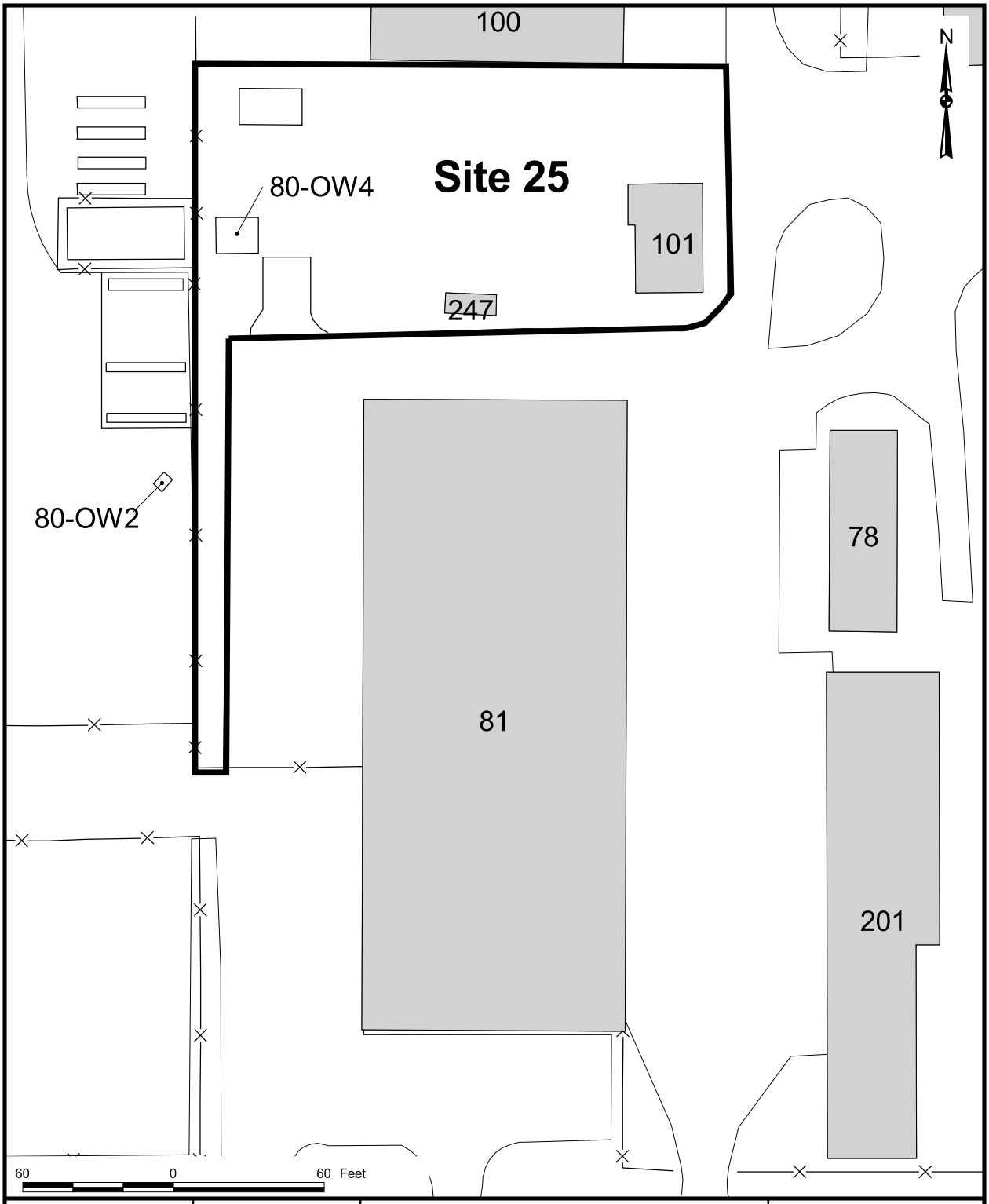

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SCALE AS NOTED			DRAWING NO. FIGURE 1-3 / REV 0

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The site was originally designated as Area of Interest (AOI) 25. This AOI has been associated both as part of Building 100 and as part of Building 81. The unpaved area was used to store several hundred transformers and other pieces of electrical equipment. Some of the transformers were reported to have contained polychlorinated biphenyl (PCB) fluids. The transformers and equipment are no longer present and were removed in the early 1990s. Building 100 is a Quonset hut storage building and was used to store electrical and plumbing supplies. The building was constructed in 1961. Building 247 is a metal shed that was originally constructed in 1956 for the storage of pesticides. Pesticide storage ceased in this building in 1975 after the construction of Building 101. The building's most recent use was the storage of fluorescent lights. Building 101 served as an office and an insecticide storage area for the pest control subcontractor. The building was constructed in 1975. Although the building had a mixing area, the area was reportedly never used for mixing [ABB Environmental Services (ABB-ES), 1994].

The investigation of three oil-water separators that are in the vicinity of Site 25 is also described in this report. Oil-Water Separator 80-OW1 is a portable unit that is located on a concrete pad on the west side of the fence. Oil-Water Separator 80-OW2 is an underground unit located on the west side of the fence and serviced the automotive and repair shop at Building 80 (HLA, 1999a). Oil-Water Separator 80-OW4 is located within Site 25 and appears to have been connected to the discharge of the containment area on the west side of the fence (HLA, 1999c).

A paved roadway and abandoned wash rack are in the west part of the site. A storm sewer catch basin is located on the roadway (HLA, 1999b).

Soil contaminated with PCBs, polycyclic aromatic hydrocarbons (PAHs), total recoverable petroleum hydrocarbons (TRPHs), and pesticides was delineated during earlier investigations. The contaminated soil was excavated and disposed of off-site (TtNUS, 2001). Groundwater contaminated by benzene hexachloride (BHC) isomers and aluminum was also identified in earlier studies, and this contamination is the subject of this FS. These investigations are further described elsewhere in this report.

The name of Site 25 has been changed over the course of the investigations. For the Base Realignment and Closure (BRAC) investigation, the site was designated as AOI 25. When it was determined that soil contamination was present over a large area, the area was redesignated Potential Source of Contamination (PSC) 25 in January 1999. When the presence of groundwater contamination was confirmed, the area was designated as Installation Restoration (IR) Site 25 in February 2000.

1.1.2 Site History

The buildings in the immediate area of the site have always been associated with the Public Works Center (ABB-ES, 1994). Building 81, the main building in the area, was built in 1953. Building 100 was

constructed in 1961. Building 247 was constructed in 1956. The age of the oil-water separators is unknown. The age and duration of use of the wash rack is also not known. Activities at Site 25 have included the storage of pesticides and the storage of old transformers (ABB-ES, 1994). There are no details on the operation of the wash rack, and what types of equipment were serviced.

1.1.3 Site Investigations

The following investigations and studies have been conducted in and around Site 25:

- February 1997 – Phase II Investigation of Transportation and Fuel Management Compound and Public Works Maintenance Contractor Area was initiated. Eight surface soil samples were collected in AOI 25 and analyzed for Target Compound List (TCL) volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides and PCBs, and Target Analyte List (TAL) inorganic compounds. One well was installed in AOI 25 and two others were installed nearby. The groundwater samples were analyzed for TCL VOCs, SVOCs, pesticides and PCBs, and TAL inorganic compounds (HLA, 1999b).

- December 1998 – Phase II Investigation of Transportation and Fuel Management Compound and Public Works Maintenance Contractor Area was continued to delineate contaminated areas. Five surface soil samples were collected in AOI 25 and analyzed for TCL pesticides and PCBs. No groundwater samples were collected (HLA, 1999b).

- March 1997 and February 1999 – Confirmatory sampling investigation of Oil-Water Separator 80-OW2 was performed. Four soil borings for headspace analysis were advanced. One soil sample and one groundwater sample were analyzed for the Florida Department of Environmental Protection (FDEP) Kerosene Analytical Group (KAG) parameters (HLA, 1999a).

- January 1999 through May 1999 – Confirmatory sampling investigation of Oil-Water Separator 80-OW4 was performed. Eleven soil borings for headspace analysis were advanced. Five soil samples were analyzed for Florida Used Oil parameters and one groundwater sample was analyzed for the FDEP KAG parameters (HLA, 1999c).

- June 1999 through March 2000 – Investigation of PSC 25. Samples were collected to delineate soil and groundwater contamination. Forty-two surface soil samples and fourteen subsurface soil samples were collected. One well was installed and sampled. The analyses were narrowed to the contaminants that had been detected in other investigations. Typically, samples were analyzed for pesticides, PCBs, TRPH, and PAHs. Samples were collected to delineate contamination associated with AOI 25, 80-OW2, and 80-OW4. The results were used to delineate the soil contamination for

excavation and disposal. Approximately 1,235 cubic yards of contaminated soil were identified as requiring excavation and off-site disposal. The groundwater investigation identified one well with BHC isomers at concentrations greater than the FDEP criteria (TtNUS, 2000).

- February 1999 – Confirmatory sampling investigation of Oil-Water Separator 80-OW1 was performed. One soil boring for headspace analysis was advanced. One soil sample was analyzed for Florida Used Oil parameters.

- April 2000 through October 2000 – Site 25 RI. Samples were collected from two existing monitoring wells to further delineate BHC and aluminum contamination in groundwater (TtNUS, 2001a). One round of samples was collected from well CEF-P25-01S, where elevated BHC concentrations had previously been detected, and analyzed for TCL pesticides and PCBs. One round of samples was collected from well CEF-80-03S, where elevated aluminum concentrations had previously been detected, and analyzed for aluminum. In addition, specific capacity (SPECAP) tests were performed on two other existing monitoring wells (CEF-81-2S, CEF-81-8S) in order to estimate hydraulic conductivity and transmissivity in the shallow zone of the surficial aquifer.

- June 2000 – A bench-scale treatability study was performed to verify the effectiveness of in-situ/ex-situ enhanced oxidation processes for the removal of BHC from groundwater at Site 25. Samples of groundwater were collected from well CEF-P25-01S and submitted to technology vendors for the testing of enhanced oxidation with Fenton Reagent (Geo-Cleanse) and potassium permanganate (Carus). These tests were not successful as neither reagent was able of reducing detected concentrations of BHC to below FDEP criteria.

- February 2001 – Site 25 draft FS report (TtNUS, 2001b). Based on the results of previous investigations, groundwater chemicals of concern (COCs) were identified and Preliminary Remedial Goals (PRGs) established. Groundwater remedial technologies were screened and remedial alternatives were assembled, analyzed, and compared.

- July 2001 – An Interim Removal Action (IRA) was performed. Approximately 5,234 tons of contaminated soil were excavated and disposed offsite (CH_2M Hill, 2001).

1.1.4 Summary of Investigations Findings

1.1.4.1 Nature and Extent of Groundwater Contamination

Tables 1-1 and 1-2 provide summaries of the positive detections in groundwater for the pre-RI and RI sampling events, respectively.

TABLE 1-1

SUMMARY OF POSITIVE DETECTIONS IN GROUNDDWATER
PRE-RI SAMPLINGS
SITE 25 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

SAMPLING LOCATION	CEF-081-03S	CEF-080-03S	CEF-080-03S	CEF-080-13S	CEF-081-06S	CEF-081-06S	CEF-081-07S	CEF-081-08S
SAMPLING DATE	02/04/97	02/06/97	02/06/97	05/19/99	06/17/98	06/17/98	06/17/98	11/19/98
DEPTH, FEET	15	15	15	15	15	15	13	14
Volatile Organic Compounds (ug/L)								
1,1-Dichloroethane	10 U	10 U	10 U	1 U	1.7	1.4	1 U	1 U
1,1-Dichloroethene	10 U	10 U	10 U	1 U	1	1.1	1 U	1 U
1,2,4-Trichlorobenzene								10 U
Chlorobenzene	10 U	4 J	5 J	1 U	1 U		1 U	1 U
cis-1,2-Dichloroethene				1 U				
Dichlorodifluoromethane					3.1	3	1 U	
Ethylbenzene	10 U	10 U	10 U	1 U	1 U		1 U	1 U
Trichloroethene	10 U	10 U	10 U	1 U	2.4	2	1 U	1 U
Semivolatile Organic Compounds (ug/L)								
1,3-Dichlorobenzene	10 U	3 J	4 J		1 U		1 U	10 U
1,4-Dichlorobenzene	10 U	3 J	4 J		1 U		1 U	10 U
2-Methylnaphthalene	10 U	10 U	10 U	10 U	1 U		1 U	10 U
Bis(2-ethylhexyl)phthalate	10 U	10 U	1 J					
Pesticides/PCBs (ug/L)								
Heptachlor Epoxide	0.05 U	0.05 U	0.013 J					0.05 U
Alpha-BHC	0.05 U	0.05 U	0.05 U					0.05 U
Beta-BHC	0.05 U	0.05 U	0.05 U					0.05 U
Delta-BHC	0.05 U	0.05 U	0.05 U					
Gamma-BHC (Lindane)	0.05 U	0.05 U	0.05 U					0.05 U
Inorganics (ug/L)								
Aluminum	415	**36400**	224					0.05 U
Arsenic	2 U	2 U	2 U	10 U				10 U
Barium	11.4 J	45.4 J	18.8 J	100 U				100 U
Calcium	7480	87500	83100					28000
Chromium	1 U	26.1	1 U	10 U				10 U
Cobalt	1 U	2.6 J	1 U					50 U
Copper	1 U	5.4 J	1 U					50 U
Cyanide	1.8 J	1.2 U	1.2 U					
Iron	48.9 J	4590	51.4 J					7400
Lead	1 U	13.9	1 U	6 J				5 U
Magnesium	1340 J	5250	4140 J					5600
Manganese	36	28.3	3.5 J					**160**
Nickel	2 U	10.8 J	2 U					10 U
Potassium	266 J	2460 J	1500 J					500 U
Selenium	4 U	6.4	4 U	10 U				10 U
Sodium	1800 J	18300	16800					4500
Thallium	3.3 J	3 U	3 U					4 U
Vanadium	2.5 J	30 J	4.9 J					10 U
Zinc	7.3 J	18.6 J	2.1 J					0.1 U
Petroleum Hydrocarbons (mg/L)								
TPH								

NOTES:
Blank means not analyzed.
Shaded/bolded results are greater than FDEP GCTLs or IBDS value.
GCTL: Groundwater Cleanup Target Level (FDEP, 1999)
IBDS: Inorganic Background Data Set (HLA, 1998)

TABLE 1-1

SUMMARY OF POSITIVE DETECTIONS IN GROUNDDWATER
PRE-RI SAMPLINGS
SITE 25 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

SAMPLING LOCATION SAMPLING DATE DEPTH, FEET	CEF-P25-01S 07/29/99 12	CEF-P25-01S 07/29/99 12	CEF-080-03S 03/20/97 15	FDEP GCTL	NAS Cecil Field IBDS Value
Volatile Organic Compounds (ug/L)					
1,1-Dichloroethane			1 U	70	no criterion
1,1-Dichloroethene			1 U	7	no criterion
1,2,4-Trichlorobenzene				70	no criterion
Chlorobenzene			1.7	100	no criterion
cis-1,2-Dichloroethene			1.9	70	no criterion
Dichlorodifluoromethane			1 U	1400	no criterion
Ethylbenzene			1.6	700	no criterion
Trichloroethene			1 U	3	no criterion
Semivolatile Organic Compounds (ug/					
1,3-Dichlorobenzene			10 U	10	no criterion
1,4-Dichlorobenzene			10 U	75	no criterion
2-Methylnaphthalene			4.1	20	no criterion
Bis(2-ethylhexyl)phthalate			10 U	6	no criterion
Pesticides/PCBs (ug/L)					
Heptachlor Epoxide	0.05 U	0.05 U		0.2	no criterion
Alpha-BHC	**0.12**	**0.12**		6	no criterion
Beta-BHC	**0.12**	**0.12**		20	no criterion
Delta-BHC	0.057	0.059		2100	no criterion
Gamma-BHC (Lindane)	**0.43**	**0.42**		0.2	no criterion
Inorganics (ug/L)					
Aluminum				200	13100
Arsenic			13.1	50	7.1
Barium				2000	88.2
Calcium				no criterion	81100
Chromium			50 U	100	18
Cobalt				420	12.8
Copper				1000	12.5
Cyanide				200	22
Iron				300	7760
Lead			5 U	15	5.35
Magnesium				no criteria	10000
Manganese				50	150
Nickel				100	24.5
Potassium				no criteria	4330
Selenium				50	7
Sodium				160000	16500
Thallium				2	13.3
Vanadium				49	20.2
Zinc				5000	76.8
Petroleum Hydrocarbons (mg/L)					
TPH			1.5	5	

NOTES:
Blank means not analyzed.
Shaded/bolded results are greater than FDEP GCTLs or IBDS value.
GCTL: Groundwater Cleanup Target Level (FDEP, 1999)
IBDS: Inorganic Background Data Set (HLA, 1998)

TABLE 1-2

SUMMARY OF POSITIVE DETECTIONS IN GROUNDWATER
REMEDIAL INVESTIGATION SAMPLINGS
SITE 25 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

Sampling Location	CEF-080-03S	CEF-P25-01S		FDEP GCTLs	NAS Cecil Field IBDS Value
Sampling Date	10/05/00	04/21/00			
Depth, feet bgs	15	12			
Pesticides/PCBs (µg/L)					
Alpha-BHC		**0.058 J**	**0.06**	0.006	NA
Beta-BHC		**0.074**	**0.069**	0.02	NA
Delta-BHC		0.06 U	0.055 U	2.1	NA
Gamma-BHC (Lindane)		0.16	0.16	0.2	NA
Heptachlor Epoxide		0.06 U	0.055 U	0.2	NA
Total Inorganics (µg/L)					
Aluminum	287			200	13100
Filtered Inorganics (µg/L)					
Aluminum	99 U			200	13100

NOTES:

Shaded/bolded results denote exceedance of FDEP GCTLs or NAS Cecil Field IDBS
Blank means not analyzed

bgs below ground surface
FDEP Florida Department of Environmental Protection
GCTL Groundwater Cleanup Target Level (FDEP, 1999)
IDBS NAS Cecil Field Inorganic Background Data Set (HLA, 1998)
J estimated value
U not detected at indicated detection limit

As shown on Table 1-1, a total of five chemicals, including alpha-, beta-, and gamma-BHC, aluminum, and manganese, were detected during the pre-RI sampling events at concentrations in excess of either FDEP Groundwater Cleanup Target Level (GCTLs) (FDEP, 1999a) or NAS Cecil-Field site-specific Inorganic Background Data Set (IBDS) values (HLA, 1998). Maximum detected concentrations were 0.12 micrograms per liter (µg/L) for alpha- and beta-BHC (well CEF-P25-01S), 0.43 µg/L for gamma-BHC (well CEF-P25-01S), 36,400 µg/L for aluminum (well CEF-080-03S), and 160 µg/L for manganese (well CEF-081-08S). Because exceedances of manganese were only slight and did not result in unacceptable risks, only BHC and aluminum contamination were further investigated during the RI.

As shown on Table 1-2, alpha- and beta-BHC were detected at concentrations greater than their FDEP GCTLs in the samples collected from monitoring well CEF-P25-01S. Alpha-BHC was detected at a concentration of 0.06 µg/L and beta-BHC was detected at a concentration of 0.07 µg/L. The respective GCTLs for these two BHC isomers are 0.006 and 0.02 µg/L.

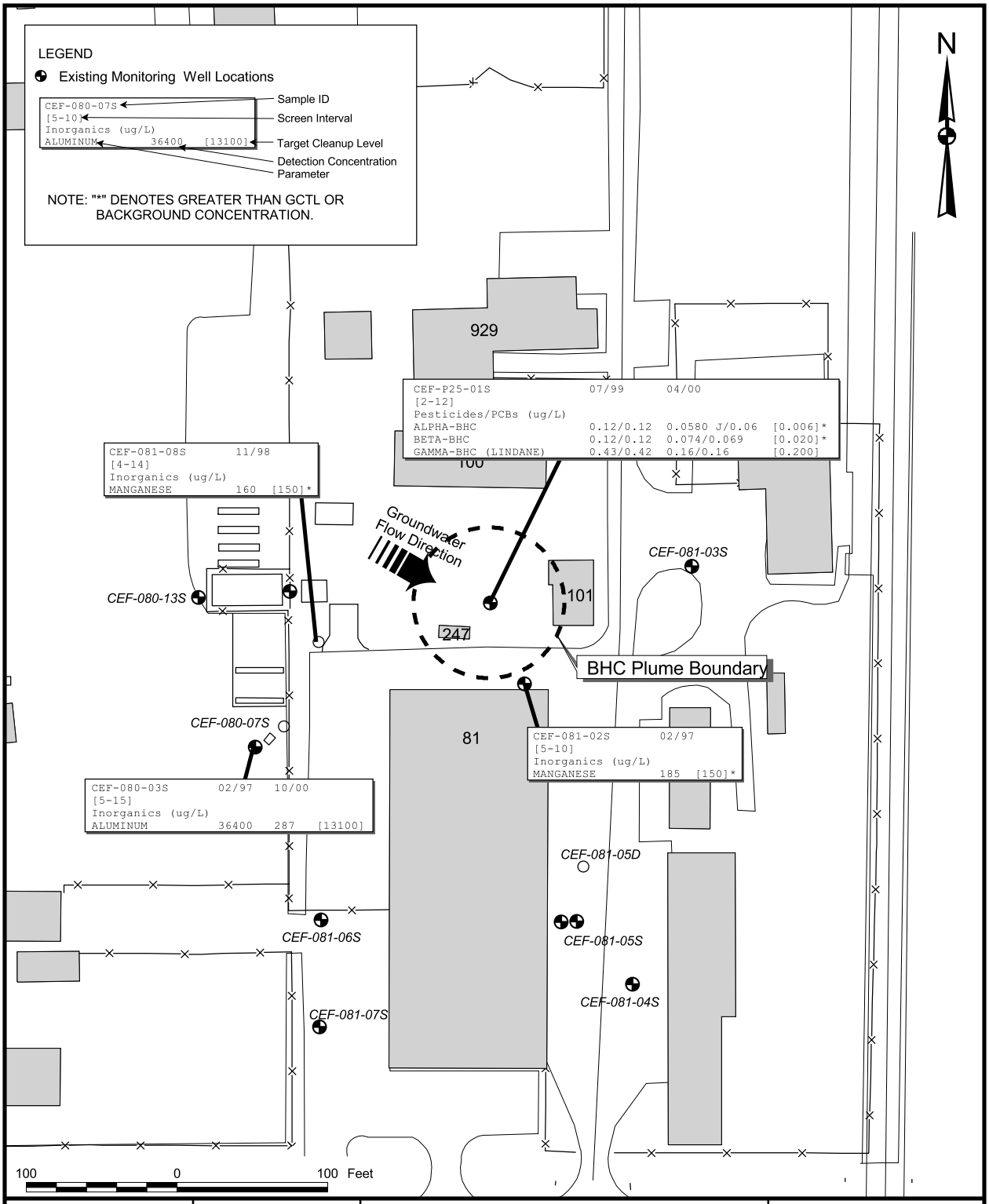
Aluminum was detected at a total concentration of 287 µg/L in the sample collected from monitoring well CEF-080-03S (the same well where it had previously detected at 36,400 µg/L). This detection is in excess of the FDEP GCTL of 200 µg/L but well below its NAS Cecil Field site-specific IDBS value of 13,100 µg/L. Also, the dissolved aluminum concentration measured in the filtered sample from well CEF-080-03S was 99 µg/L, which is below the GCTL and suggest that detected aluminum concentrations are primarily associated with suspended solids.

The Site 25 groundwater contaminant plume, as defined by the GCTLs for alpha- and beta-BHC, is less than 100 feet (ft) across and is illustrated on Figure 1-4. The contaminants appear to be limited to the shallow zone of the surficial aquifer, i.e., no deeper than approximately 15 ft below ground surface (bgs). Because of the low contaminant concentrations, the low mobility of the contaminants, and based on observations of groundwater contaminant plumes at other NAS Cecil Field sites, the installation of deeper wells to delineate vertical extent of contamination was determined to be unnecessary by the BRAC Cleanup Team (BCT).

The source of the BHC in the groundwater appears to be from the soil in the unsaturated zone. BHC isomers were not detected in soil samples, but their presence could have been masked by other contaminants. The origin of the BHC is probably related to activities at the former pesticide storage building, Building 247, which is located about 20 ft from well CEF-P25-01S.

1.1.4.2 Contaminant Fate and Transport

BHC isomers were detected at concentrations greater than the FDEP criterion in the groundwater sample collected from one monitoring well. BHC was not detected in the soil. These findings are consistent with



DRAWN BY MJJ	DATE 03Oct00	GROUNDWATER RESULTS SITE 25 FEASIBILITY STUDY REPORT NAVAL AIR STATION CECIL FIELD JACKSONVILLE, FLORIDA	CONTRACT NUMBER 0039
CHECKED BY	DATE		APPROVED BY DATE
COST/SCHEDULE-AREA			APPROVED BY DATE
SCALE AS NOTED			DRAWING NO. FIGURE 1-4 / REV 0

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expectations that these elements are relatively mobile. Failure to detect in groundwater the PAHs, PCBs, and TRPH which were detected in soil is also consistent with expectations in that these compounds are relatively immobile in the soil.

1.1.4.3 Human Health Risk Assessment

The Preliminary Risk Assessment (PRE) performed as part of the RI indicated that exposure to OU 10, Site 25 groundwater could potentially result in adverse health effects. These adverse effects are associated with exceedances of the FDEP GCTL for alpha- and beta-BHC.

Because of the soil removal action, exposure to soil no longer represents a human health risk. The Upper Confidence Limit (UCL) of the concentrations of the soil remaining at the site is less than the FDEP residential Soil Cleanup Target Levels (SCTLs).

1.1.4.4 Ecological Risk Assessment

The ecological risk assessment performed as part of the RI established that Site 25 consists primarily of buildings and parking lots that provide an ecological habitat of marginal quality and of little use to terrestrial wildlife. Therefore, the soil exposure pathway is negligible and soil contaminants were not investigated.

1.2 DOCUMENT ORGANIZATION

This FS Report has been organized with the intent of meeting the general format requirements specified in the RI/FS Guidance Document [United States Environmental Protection Agency (USEPA), 1988]. This report features the following five section:

- Section 1.0, Introduction, summarizes the purpose of the report, provides site background information, summarizes findings of the RI, and provides the report outline.

- Section 2.0, Remedial Action Objectives (RAOs) and General Response Actions (GRAs), presents the RAO, identifies Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered (TBC) criteria, develops groundwater Preliminary Remedial Action Goals (PRGs) and associated GRAs, and provides an estimate of the volume of contaminated groundwater to be remediated.

- Section 3.0, Screening of Remediation Technologies and Process Options, provides a two-tiered screening of potentially applicable groundwater remediation technologies and identifies the technologies that will be assembled into remedial alternatives.

- Section 4.0, Assembly and Detailed Analysis of Remedial Alternatives, assembles the remedial technologies retained from the Section 3.0 screening process into multiple groundwater remedial alternatives, describes these alternatives, and performs a detailed analysis of these alternatives in accordance to seven Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) criteria.

- Section 5.0, Comparative Analysis of Remedial Alternatives, compares the groundwater remedial alternatives on a criterion-by-criterion basis, for each of the seven CERCLA analysis criteria used in Section 4.

2.0 REMEDIAL ACTION OBJECTIVES AND GENERAL RESPONSE ACTIONS

This section develops RAOs and derives PRGs for the contaminated media. The regulatory requirements and guidances (e.g., ARARs) that may potentially govern remedial activities are presented in this section. In addition, this section presents the COCs identified in Section 1.0, the conceptual pathways through which these chemicals may affect human health, and derives the environmental media of concern. The PRGs for the contaminated media are developed in this section, and GRAs that may be suitable to achieve the PRGs are presented. Finally, this section presents an estimate of the volumes of contaminated media.

2.1 REMEDIAL ACTION OBJECTIVES

The purpose of this section is to develop RAOs for Site 25 at the former NAS Cecil Field, Jacksonville, Florida. Development of RAOs is an important step in the FS process. The RAOs are medium-specific goals that define the objective of conducting remedial actions to protect human health and the environment. The RAOs specify the COCs, potential exposure routes and receptors, and an acceptable range contaminant level (i.e., PRGs) for the site.

The development of PRGs takes into consideration ARARs and TBCs. Section 2.1.2 identifies the ARARs and TBCs, Section 2.1.3 identifies the media of concern, and Section 2.1.4 identifies the COCs for remediation.

2.1.1 Statement of Remedial Action Objectives

Site-specific RAOs specify COCs, media of interest, exposure pathways, and cleanup goals or acceptable contaminant concentrations. RAOs may be developed to permit consideration of a range of treatment and containment alternatives. This FS addresses groundwater contamination at OU 10, Site 25. To protect the public from potential current and future health risks, as well as to protect the environment, the following RAO has been developed:

- Prevent ingestion of groundwater with alpha- and beta-BHC concentrations greater than the FDEP GCTLs of 0.006 µg/L and 0.02 µg/L, respectively.

2.1.2 Applicable or Relevant and Appropriate Requirements and To Be Considered Criteria

ARARs consist of the following:

- Any standard, requirement, criterion, or limitation under Federal environmental law.

- Any promulgated standard, requirement, criteria, or limitation under a state environmental or facility-siting law that is more stringent than the associated Federal standard, requirement, criterion, or limitation.

TBCs are nonpromulgated, nonenforceable guidelines or criteria that may be useful for developing a remedial action or are necessary for determining what is protective to human health and/or the environment. Examples of TBCs include United States Environmental Protection Agency (USEPA) Drinking Water Health Advisories, Reference Doses (RfDs) and Cancer Slope Factors (CSFs).

One of the primary concerns during the development of remedial action alternatives for hazardous waste sites under CERCLA is the degree of human health and environmental protection offered by a given remedy. Section 121 of CERCLA requires that primary consideration be given to remedial alternatives that attain or exceed ARARs. The purpose of this requirement is to make CERCLA response actions consistent with other pertinent Federal and state environmental requirements.

2.1.2.1 Definitions

The definitions of ARARs are given below:

- Applicable Requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.

- Relevant and Appropriate Requirements are cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or state law, while not "applicable" to a hazardous substance, pollutant, contaminant, or remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

- TBCs are a category created by the USEPA that includes non-promulgated criteria, advisories, and guidance issued by Federal or state government that are not legally binding and do not have the status of potential ARARs. However, pertinent TBCs will be considered along with the ARARs in determining the necessary level of cleanup or technology requirements.

Under CERCLA Section 121(d)(4), the USEPA may waive compliance with an ARAR if one of the following conditions can be demonstrated:

- The remedial action selected is only part of a total remedial action that will attain the ARAR level or standard of control upon completion;

- Compliance with the requirement will result in greater risk to human health and the environment than other alternatives;

- Compliance with the requirement is technically impracticable from an engineering perspective;

- The remedial action selected will attain a standard of performance that is equivalent to that required by the ARAR through the use of another method or approach;

- With respect to a state requirement, the state has not consistently applied the ARAR in similar circumstances at other remedial actions within the state; or

- Compliance with the ARAR will not provide a balance between protecting public health, welfare, and the environment at the facility with the availability of Superfund money for response at other facilities (fund-balancing). This condition only applies to Superfund-financed actions.

The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) has identified three categories of ARARs [40 Code of Federal Regulations (CFR) Section 300.400 (g)]:

- Chemical-Specific: Health/risk-based numerical values or methodologies that establish concentration or discharge limits for particular contaminants. Examples include Maximum Contaminant Levels (MCLs) and Clean Water Act (CWA) Ambient Water Quality Criteria (AWQC).

- Location-Specific: Restrict actions or contaminant concentrations in certain environmentally sensitive areas. Examples of these areas regulated under various Federal laws include floodplains, wetlands, and locations where endangered species or historically significant cultural resources are present.

- Action-Specific: Technology- or activity-based requirements, limitations on actions, or conditions involving special substances. Examples of action-specific ARARs include wastewater discharge standards.

The following section discusses contaminant- and location-specific ARARs and TBCs. Action-specific ARARs and TBCs are presented in Section 2.3 along with the discussion of GRAs.

2.1.2.2 Chemical-Specific ARARs and TBCs

This section presents a summary of Federal and state chemical-specific ARARs and TBCs. These ARARs and TBCs provide some medium-specific guidance on “acceptable” or “permissible” concentrations of contaminants. Tables 2-1 and 2-2 present a list of Federal and State of Florida chemical-specific ARARs and TBCs for this FS.

2.1.2.3 Location-Specific ARARs and TBCs

This section presents a summary of Federal and state location-specific ARARs and TBCs. These ARARs and TBCs place restrictions on concentrations of contaminants or the conduct of activities based upon the site’s particular characteristics or location. Tables 2-3 and 2-4 present a list of Federal and State of Florida location-specific ARARs and TBCs for this FS.

2.1.3 Medium of Concern

Based upon the discussion in Section 1.0 involving toxicity and risk assessment for both human and ecological receptors, the only remaining medium of concern at Site 25 was determined to be groundwater.

2.1.4 Chemicals of Concern for Remediation

The RI human health risk assessment did identify chemicals in the groundwater as a concern to human receptors. Analytical groundwater data for the site were compared to the USEPA’s current drinking water standards (USEPA, 1998), the FDEP drinking water criteria (FDEP, 1999b), the FDEP GCTLs (FDEP, 1999a), and the NAS Cecil Field site-specific IBDS screening criteria (HLA, 1998).

Two chemicals, alpha- and beta-BHC, were detected in the groundwater above their FDEP GCTLs and were retained as COCs in the RI.

2.2 PRELIMINARY REMEDIATION GOAL

A PRG is the target concentration to which a COC must be reduced within a particular medium of concern to achieve one or more of the established RAOs. PRGs are developed to make sure that contaminant concentration levels left on site are protective of human and ecological receptors.

TABLE 2-1

FEDERAL CHEMICAL-SPECIFIC ARARs
SITE 25 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Safe Drinking Water Act (SDWA) Regulations, Maximum Contaminant Levels (MCLs)	40 Code of Federal Regulation (CFR) Part 141	Relevant and Appropriate	Establishes enforceable standards for potable water for specific contaminants that have been determined to adversely affect human health.	Would be used as protective levels for groundwater or surface waters that are current or potential drinking water sources.
SDWA Regulations, National Secondary Drinking Water Standards (SMCLs)	40 CFR Part 143	To Be Considered	Establishes welfare-based standards for public water systems for specific contaminants or water characteristics that may affect the aesthetic qualities of drinking water.	Would be used as protective levels for groundwater or surface waters that are current or potential drinking water sources.
USEPA Office of Drinking Water, Health Advisories		Potential To Be Considered	Health advisories are estimates of non-carcinogenic risk due to consumption of contaminated drinking water.	These advisories would be considered for contaminants in surface water and groundwater that is or could be used as a potable water source.
Cancer Slope Factors (CSFs)		To Be Considered	CSFs are guidance value used to evaluate the potential carcinogenic hazard caused by exposure to contaminants.	CSFs would be considered for development of human health protection preliminary remedial goals (PRGs) for soil and groundwater at this site.
Reference Doses (RfDs)		To Be Considered	RfDs are guidance values used to evaluate the potential noncarcinogenic hazard caused by exposure to contaminants.	RfDs would be considered for development of human health protection PRGs for soil and groundwater at this site.

TABLE 2-2

STATE CHEMICAL-SPECIFIC ARARs
SITE 25 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Surface Water Quality Standards	Florida Administrative Code (FAC) Chapter 62-302	Potentially Applicable	This rule distinguishes surface water into five classes based on designated uses and establishes ambient water quality standards (called Florida Water Quality Standards) for listed pollutants.	Because these standards are specifically tailored to Florida waters, they should be used to establish cleanup levels rather than the Federal Ambient Water Quality Criteria (AWQC).
Groundwater Classes, Standards and Exemptions	FAC Chapter 62-520	Applicable	This rule designates the groundwater of the state into five classes and establishes minimum "free from" criteria. This rule also specifies that Classes I & II must meet the primary and secondary drinking water standards listed in Chapter 62-550.	This rule would be used to establish PRGs for groundwater that is a potential source of drinking water.
Drinking Water Criteria	FAC Chapter 62-550	TBC	This rule provides primary and secondary drinking water quality criteria.	This rule would be considered for the establishment of PRGs
Contaminant Cleanup Target Levels Rule	FAC Chapter 62-777	TBC	This rule provides guidance for soil, groundwater, and surface water cleanup levels that can be developed on a site-by-site basis.	This rule would be considered for the establishment of PRGs.

TABLE 2-3

FEDERAL LOCATION-SPECIFIC ARARs
SITE 25 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Endangered Species Act Regulations	50 CFR Parts 81, 225, 402	Potentially Applicable	This act requires Federal agencies to act to avoid jeopardizing the continued existence of federally listed endangered or threatened species.	If a site investigation or remediation could potentially affect an endangered species, these regulations would apply.
Historic Sites Act Regulations	36 CFR Part 62	Potentially Applicable	Requires Federal agencies to consider to existence and location of landmarks on the National Registry of Natural Landmarks to avoid undesirable impacts on such landmarks.	The existence of Natural Landmarks would be identified prior to remedial activities onsite including remedial investigations
Fish and Wildlife Coordination Act Regulations	33 CFR Subsection 320.3	Potentially Applicable	Requires that the United States Fish and Wildlife Service (USFWS), National Marine Fisheries Service, and related state agencies be consulted prior to structural modification of any body of water, including wetlands. If modifications must be conducted, the regulation requires that adequate protection be provided for fish and wildlife resources.	If a remedial alternative involves the alteration of a stream or wetland, these agencies would be consulted.
National Environmental Policy Act (NEPA) Regulations, Wetlands, Floodplains, etc.	40 CFR Subsection 6.302 [a]	Potentially Applicable	These regulations contain the procedures for complying with Executive Order 11990 on wetlands protection. Appendix A states that no remedial alternative adversely affect a wetland if another practicable alternative is available. If no alternative is available, impacts from implementing the chosen alternative must be mitigated.	If remedial action affects a wetland, these regulations would apply.

TABLE 2-3

FEDERAL LOCATION-SPECIFIC ARARs
SITE 25 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
NEPA Regulations, Floodplain Management, Executive Order 11988	40 CFR Part 6, Appendix A	Potentially Applicable	Appendix A describes the policy for carrying out the Executive Order regarding floodplains. If no practicable alternative exists to performing cleanup in a floodplain, potential harm must be mitigated and actions taken to preserve the beneficial value of the floodplain.	If removal actions take place in a floodplain, alternatives would be considered that would reduce the risk of flood loss and restore and preserve the floodplain.
Fish and Wildlife Conservation Act	40 CFR Section 6.302	Potentially Applicable	Requires action to be taken to protect fish and wildlife from projects affecting streams or rivers.	USFWS officials would be consulted on how to minimize impacts of any remedial activities on any wildlife.

TABLE 2-4

STATE LOCATION-SPECIFIC ARARs
SITE 25 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken

There are no State Location-Specific ARARs

For Site 25, groundwater PRGs were determined for alpha- and beta-BHC based on the following criteria:

- Protection of human health from exposure to contaminants in groundwater
- Compliance with ARARs and TBCs to the extent practicable

Accordingly the alpha- and beta-BHC PRGs for groundwater at Site 25 are 0.006 µg/L and 0.02 µg/L, respectively, which are the FDEP GCTLs for these chemicals.

2.3 GENERAL RESPONSE ACTIONS (GRAs) AND ACTION-SPECIFIC ARARs

GRAs are broadly defined remedial approaches that may be used (by themselves or in combination with one or more of the others) to attain the RAO. Action-specific ARARs and TBCs are those regulations, criteria, and guidances that must be complied with or taken into consideration during remedial activities on site.

2.3.1 General Response Actions

GRAs describe categories of actions that could be implemented to satisfy or address a component of the RAOs for the site. Remedial action alternatives will then be composed using general response actions singly or in combination to meet the RAOs. The remedial action alternatives, composed of GRAs, will be capable of achieving the RAOs for each contaminated medium at the site.

The following GRAs will be considered for groundwater at Site 25:

- No Action,
- Limited Action (Natural Attenuation, Institutional Controls, Monitoring),
- Containment,
- Removal,
- In-Situ Treatment,
- Ex-Situ (On-Site) Treatment, and
- Disposal

2.3.2 Action-Specific ARARs

Action-specific ARARs and TBCs are technology- or activity-based regulatory requirements or guidance that would control or restrict remedial action. Tables 2-5 and 2-6 present a list of Federal and state action-specific ARARs and TBCs for this FS.

TABLE 2-5

FEDERAL ACTION-SPECIFIC ARARs
SITE 25 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Clean Water Act (CWA), National Pollution Discharge Elimination System (NPDES)	40 CFR Parts 122 through 125, and 131	Potentially Relevant and Appropriate	NPDES (National Pollution Discharge Elimination System) permits are required for any discharges to navigable waters. If remedial activities include such a discharge, the NPDES standards would be ARARs.	Any alternative which would discharge into any navigable water would require compliance with these regulations including treatment, if necessary.
Occupational Safety and Health Act (OSHA) Regulations, General Industry Standards	29 CFR Part 1910	Applicable	Requires establishment of programs to assure worker health and safety at hazardous waste sites, including employee training requirements.	These regulations would apply to all response activities.
OSHA Regulations, Occupational Health and Safety Regulations	29 CFR Part 1910, Subpart Z	Potentially Applicable	Establishes permissible exposure limits for workplace exposure to a specific listing of chemicals.	Standards are applicable for worker exposure to OSHA hazardous chemicals during remedial activities.
OSHA Regulations, Recordkeeping, Reporting, and Related Regulations	29 CFR Part 1904	Potentially Applicable	Provides recordkeeping and reporting requirements applicable to remedial activities.	These requirements apply to all site contractors and subcontractors and must be followed during all site work.
OSHA Regulations, Health and Safety Standards	29 CFR Part 1926	Potentially Applicable	Specifies the type of safety training, equipment, and procedures to be used during the site investigation and remediation.	All phases of the remedial response project would be executed in compliance with this regulation.

TABLE 2-5

FEDERAL ACTION-SPECIFIC ARARs
SITE 25 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Resource Conservation and Recovery Act (RCRA) Regulations, Contingency Plan and Emergency Procedures	40 CFR 264, Subpart D	Potentially Relevant and Appropriate	Outlines requirements for emergency procedures to be followed in case of an emergency.	The administrative requirements established in this rule would be met for remedial actions involving the management of hazardous waste.
CWA Regulations, National Pretreatment Standards	40 CFR Part 403	Potentially Relevant and Appropriate	Sets pretreatment standards through the National Categorical Standards of the General Pretreatment Regulations for the introduction of pollutants from non-domestic sources into publicly owned treatment works (POTWs) in order to control pollutants that pass through, cause interference, or are otherwise incompatible with treatment processes at a POTW.	If groundwater is discharged to a POTW, the discharge must meet local limits imposed by the POTW. A discharge from a CERCLA site must meet the POTW's pretreatment standards in the effluent of the POTW. Discharge to a POTW is considered an offsite activity and is, therefore subject to both the substantive requirements of this rule.
RCRA Regulations, General Facility Standards	40 CFR Subpart B, 264.10-264.18	Potentially Relevant and Appropriate	Sets the general facility requirements including general waste analysis, security measures, inspections, and training requirements. Section 264.18 establishes that a facility located in a 100-year floodplain must be designed, constructed, and maintained to prevent washout of any hazardous wastes by a 100-year flood.	If the remedial action involves construction of an onsite treatment facility, such as a groundwater treatment facility, the substantive requirements of this rule would be applicable requirements. A permitted treatment facility must be selected for offsite treatment. These regulations do not apply to the aboveground treatment or storage of hazardous waster before it is injected into underground. However, this rule may be an applicable requirement for alternatives that do not involve groundwater reinjection.

TABLE 2-5

FEDERAL ACTION-SPECIFIC ARARs
SITE 25 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
RCRA Regulations, Miscellaneous Units	40 CFR Part 264, Subpart X	Potentially Relevant and Appropriate	These standards are applicable to miscellaneous units not previously defined under existing RCRA regulations. Subpart X outlines performance requirements that miscellaneous units be designed, constructed, operated, and maintained to prevent releases to the subsurface, groundwater, and wetland that may have adverse effects on human health and the environment.	The design of proposed treatment alternatives, not specifically regulated under other subparts of RCRA, must prevent the release of hazardous constituents and future impacts on the environment. This subpart would apply to onsite construction of any treatment facility that is not previously defined under the RCRA regulation.
RCRA Regulations, Preparedness and Prevention	40 CFR Part 264, Subpart C	Potentially Relevant and Appropriate	Outlines requirements for safety equipment and spill control for hazardous waste facilities. Facilities must be designed, maintained, constructed, and operated to minimize the possibility of an unplanned release that could threaten human health or the environment.	Safety and communication equipment would be incorporated into all aspects of the remedial process and local authorities would be familiarized with site operations.
RCRA Regulations, Releases from Solid Waste Management Units (SWMUs)	40 CFR Part 264, Subpart F	Potentially Relevant and Appropriate	Establishes the requirements for SWMUs at RCRA regulated treatment, storage, and disposal (TSD) facilities. The scope of the regulation encompasses groundwater protection standards, point of compliance, compliance period, and requirements for groundwater monitoring.	These regulations would be followed for the treatment of hazardous waste.

TABLE 2-5

FEDERAL ACTION-SPECIFIC ARARs
SITE 25 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
RCRA Regulations, Standards for Owners and Operators of Hazardous Waste TSD Facilities	40 CFR Part 264	Potentially Relevant and Appropriate	Establishes minimum national standards defining the acceptable management of hazardous wastes for owners and operators of facilities that treat, store, or dispose of hazardous wastes.	If remedial actions involving management of RCRA wastes at an off-site TSD Facility or if RCRA wastes are managed onsite, the requirements of this rule would be followed.
RCRA Regulations, Use and Management of Containers	40 CFR Part 264, Subpart I	Potentially Relevant and Appropriate	Sets standards for the storage of containers of hazardous waste.	This requirement would apply if a remedial alternative involves the storage of a hazardous waste (i.e. contaminated groundwater) in containers, prior to treatment.
SWDA Regulations, Underground Injection Control Regulations	40 CFR Parts 144, 146, 147, and 1000	Potentially Relevant and Appropriate	Establishes minimum program and performance standards for underground injection programs. Technical criteria and standards for siting, operation, maintenance, reporting, and recordkeeping are included in Part 146. Also requires protection of underground sources of drinking water.	Discharge of treated groundwater, by well injection, would be in accordance with all criteria and standards in these regulations, as well as meet all State Underground Injection Control Program requirements. Treated groundwater would meet all SDWA standards for reinjection prior to well injection.

TABLE 2-6

STATE ACTION-SPECIFIC ARARs
SITE 25 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Florida Hazardous Waste Rules – October 1993	FAC Chapter 62-730	Potentially Applicable	Adopts by reference sections of the Federal hazardous waste regulations and establishes minor additions to these regulations concerning the generation, storage, treatment, transportation and disposal of hazardous wastes.	These regulations would apply if waste onsite were deemed hazardous and needed to be stored, transported, or disposed of properly.
Florida Drinking Water Standards	FAC Chapter 62-550	Potentially Applicable	This rule adopts Federal primary and secondary drinking water standards	These regulations would apply to remedial activities that involve discharges to potential sources of drinking water.
Florida Wetland Application Regulations – November 1989	FAC Chapter 62-611	Potentially Applicable	Sets requirements for discharge of domestic wastewater to wetland. Addresses the discharge of domestic wastewater to wetlands. Limits are set for biochemical oxygen demand (BOD), total suspended solids (TSS), nitrogen, and phosphorus.	This rule would be considered for remedial alternatives that would result in discharges to wetlands where these limits may be approached.
Florida Wastewater Facility Permits	FAC Chapter 62-620	Potentially Applicable	This rule establishes requirements for wastewater permits. It was published in November 1994; however, it is not effective until Florida is recognized as a “delegated” state.	Upon delegation, facilities in Florida requiring a wastewater permit will meet the permitting requirements under this rule. Upon Florida becoming a “delegated” state, facilities will be allowed to have a single permit to meet both Federal and State discharge requirements.
Florida Regulation of Stormwater Discharge –May 1993	FAC Chapter 62-25	Potentially Relevant and Appropriate	Establishes requirements for discharges of untreated stormwater to ensure protection of the surface water of the state.	Remedial actions would consider the impact of the discharge of untreated stormwater.

TABLE 2-6

STATE ACTION-SPECIFIC ARARs
SITE 25 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Florida Underground Injection Control Regulations – April 1989	FAC Chapter 62-28	Potentially Applicable	Establishes a State Underground Injection Control Program consistent with federal requirements and appropriate to the hydrogeology of Florida.	These regulations would be considered if remedial actions involve underground injection.
Florida Groundwater Permitting and Monitoring Requirements – April 1994	FAC Chapter 62-522	Potentially Applicable	Establishes permitting and monitoring requirements for installations discharging to groundwater.	The substantive requirements of this rule would be met when discharge to groundwater is a possible remedial action. If these requirements are met under another permit, a separate discharge permit may not be required.
Florida Water Well Permitting and Construction Requirements – March 1992	FAC Chapter 62-532	Applicable	Establishes minimum standards for the location, construction, repair, and abandonment of water wells. Permitting requirements and procedures are established.	The substantive requirements for permitting would be met if remedial actions involve the construction, repair, or abandonment of monitoring, extraction, or injection wells.
Florida Rules on Hazardous Waste Warning Signs – July 1991	FAC Chapter 62-736	Applicable	Requires warning signs at NPL and FDEP identified hazardous waste sites to inform the public of the presence of potentially harmful conditions.	This requirement will be met.
Florida Rules on Permits – November 1994	FAC Chapter 62-4	Potentially Applicable	Establishes procedures for obtaining permits for sources of pollution. This rule also establishes a “mixing zone” rule for facilities that discharge wastewater into the surface waters of the state.	These substantive requirements would be met during remediation. Through dilution, applying the “mixing zone” rule allows wastewater with higher concentrations of pollutants to be discharged into surface water, while still maintaining the Florida water quality standards.

2.4 ESTIMATED VOLUME OF CONTAMINATED GROUNDWATER

For remedial action purposes, a preliminary volume of contaminated groundwater was estimated based on the location of samples where alpha- and beta-BHC were detected in excess of their PRGs.

Based on the analytical results of the RI, it was conservatively assumed that the groundwater contaminant plume where alpha- and beta-BHC concentrations exceeds 0.006 µg/L and 0.02 µg/L, respectively, extends over a circular area approximately 100 ft in diameter centered on monitoring well CEF-P25-01S. Areal extent of the contaminant plume is estimated at approximately 7,854 square feet (ft^2). Plume depth is assumed to extend to 15 ft bgs. Based on a water table depth of 5 ft bgs and porosity of 0.25 that are typical at NAS Cecil Field, the total BHC plume volume is estimated at approximately 19,635 cubic feet (ft^3), or 147,000 gallons. Computations of contaminated groundwater volume are presented in Appendix A.

3.0 SCREENING OF REMEDIATION TECHNOLOGIES AND PROCESS OPTIONS

This section identifies, screens, and evaluates the potential remediation technologies and process options that may be applicable to assemble groundwater remedial alternatives for Site 25 at the former NAS Cecil Field. The primary objective of this phase of the FS is to develop an appropriate range of remedial technologies and process options that will be used for developing remedial alternatives.

The basis for remediation technology identification and screening began in Section 2.0 with a series of discussions that included the following:

- Identification of ARARs
- Development of RAOs
- Identification of GRAs
- Identification of volumes or areas of media of concern

Remediation technology screening is performed in this section with the completion of the following analytical steps:

- Identification and screening of remediation technologies and process options
- Evaluation and selection of representative process options

In this section a variety of remediation technologies and process options is first identified for each of the GRAs listed in Section 2.3.1 and then screened. The selection of remediation technologies and process options for initial screening is based on the “Guidance for Conducting Remedial Investigations/Feasibility Studies under CERCLA” (USEPA, 1988). The screening is first conducted at a preliminary level to focus on relevant remediation technologies and process options. Then the screening is conducted at a more detailed level based on certain evaluation criteria. Finally, process options are selected to represent the remediation technologies that have passed the detailed evaluation and screening.

The evaluation criteria for detailed screening of remediation technologies and process options that have been retained after the preliminary screening are effectiveness, implementability, and cost. The following are descriptions of these evaluation criteria:

- Effectiveness
  - Protection of human health and environment; reduction in toxicity, mobility, or volume; and permanence of solution.
  - Ability of the technology to address the estimated areas or volumes of contaminated medium.
  - Ability of the technology to attain the PRGs required to meet the RAOs.
  - Technical reliability (innovative versus well-proven) with respect to contaminants and site conditions.

- Implementability
  - Overall technical feasibility at the site.
  - Availability of vendors, mobile units, storage and disposal services, etc.
  - Administrative feasibility.
  - Special long-term considerations (e.g., maintenance and operation requirements).

- Cost (Qualitative)
  - Capital cost.
  - Operation and maintenance (O&M) costs.

3.1 PRELIMINARY SCREENING OF GROUNDWATER REMEDIATION TECHNOLOGIES AND PROCESS OPTIONS

This Section identifies and screens remediation technologies and process options for groundwater at a preliminary stage based on implementation with respect to site conditions and contaminants of concern. Table 3-1 summarizes the preliminary screening of remediation technologies and process options applicable to groundwater. This table presents the GRAs, identifies the remediation technologies and process options, and provides a brief description of each process option followed by a screening comment.

The following are the groundwater remediation technologies and process options remaining for detailed screening:

TABLE 3-1

PRELIMINARY SCREENING OF GROUNDWATER REMEDIATION TECHNOLOGIES AND PROCESS OPTIONS
SITE 25 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

General Response Action	Technology	Process Options	Description	Screening Comment
No Action	None	Not Applicable	No activities conducted at site to address contamination.	Required by NCP. Retain for baseline comparison to other technologies.
Limited Action	Monitoring	Sampling and Analysis	Periodic sampling and analysis of groundwater and other media to track the spread of contamination.	Retain to assess natural attenuation and/or migration of contaminants from site and evaluate remedial actions.
	Institutional Controls	Passive Controls: Deed Restrictions	Administrative action using property deeds to restrict current and future use of groundwater.	Retain to limit human exposure to contaminated groundwater.
	Natural Attenuation	Naturally-Occurring Biodegradation, Dilution, and Dispersion	Monitoring of groundwater quality to assess effectiveness of naturally-occurring attenuation processes (biodegradation, dilution, dispersion).	Retain
Containment	Vertical Barriers	Slurry Wall	Low-permeability wall formed in a perimeter trench to restrict horizontal migration of groundwater.	Eliminate – existing structures would severely restrict constructibility and the depth of the nearest impervious layer makes this technology impractical.
		Grout Curtain	Pressure injection of grout to form a low-permeability perimeter wall to restrict horizontal migration of groundwater.	Eliminate – existing structures would severely restrict constructibility and the depth of the nearest impervious layer makes this technology impractical.
		Sheet Piling	Metal sheet piling driven into the ground to restrict horizontal migration of groundwater.	Eliminate – existing structures would severely restrict constructibility and the depth of the nearest impervious layer makes this technology impractical.

TABLE 3-1

PRELIMINARY SCREENING OF GROUNDWATER REMEDIATION TECHNOLOGIES AND PROCESS OPTIONS
SITE 25 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

General Response Action	Technology	Process Options	Description	Screening Comment
Containment (Continued)	Vertical Barriers (Continued)	Hydraulic Barrier	Use of extraction wells and/or collection trenches to restrict horizontal migration of groundwater.	Eliminate – no suitable area exists reasonably close to Site 25 for reinjection.
	Horizontal Barriers	Physical Barrier	Injection of bottom sealing slurry beneath source to minimize vertical migration of groundwater.	Eliminate – existing structures would severely restrict constructibility of such a barrier.
Removal	Groundwater Extraction	Extraction Wells	Series of conventional pumping wells used to remove contaminated groundwater.	Retain to remove contaminated groundwater.
		Collection Trench	A permeable trench used to intercept and collect groundwater.	Retain to remove contaminated groundwater.
In-situ Treatment	Biological	Enhanced In-Situ Biodegradation	Enhancement of natural biodegradation processes by addition of bacterial cultures and/or chemical additives.	Retain for the in-situ removal of BHC.
		In-Situ Air Sparging	Enhancement of biodegradation by supply of air and extraction of vapors.	Retain for the in-situ removal of BHC.
	Physical/ Chemical	Permeable Reactive Barrier (PRB)	Use of a permeable barrier that allows the passage of groundwater and reacts with the contaminants.	Eliminate because lack of mobility and questionable reactivity of BHC.
		Enhanced Oxidation	Chemical treatment of contaminants through oxidation using ferrous iron and hydrogen peroxide (Fenton's Reagent) of potassium permanganate.	Eliminate – testing of Fenton's Reagent and permanganate was unsuccessful and is inappropriate for the removal of low concentrations of organic compounds.
Ex-situ Treatment	Biological	Aerobic/Anaerobic	Natural degradation of organic contaminants via microorganisms in an aerobic (oxygen) environment.	Retain for the ex-situ removal of BHC.

TABLE 3-1

PRELIMINARY SCREENING OF GROUNDWATER REMEDIATION TECHNOLOGIES AND PROCESS OPTIONS
SITE 25 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

General Response Action	Technology	Process Options	Description	Screening Comment
Ex-situ Treatment (Continued)	Physical	Filtration	Separation of suspended solids from water via entrapment in a bed of granular media or membrane.	Retain as a pretreatment step prior to potential treatment processes.
		Air Stripping	Contact of water with air to remove volatile compounds.	Eliminate – BHC is not particularly amenable to volatilization.
		Granular Activated Carbon (GAC) Adsorption	Separation of dissolved contaminants from water via adsorption onto GAC.	Retain for the ex-situ removal of BHC.
		Solvent Extraction	Separation of contaminants from a solution by contact with an non-miscible liquid with a higher affinity for the contaminants of concern.	Eliminate - not effective for the removal of low concentrations of organic compounds.
		Sedimentation	Separation of solids from water via gravity settling.	Retain as a pretreatment step prior to potential treatment processes.
	Chemical	Enhanced Oxidation	Use of oxidizers such as air, ozone, hydrogen peroxide, chlorine, Fenton's Reagent, or permanganate, or use of high pressure/temperature to chemically increase the oxidation state of organic and inorganic compounds.	Eliminate – testing of Fenton's reagent and permanganate was unsuccessful. Unproven for the treatment of pesticides and generally not effective for the removal of low concentrations of organic compounds.
		Reduction	Use of reducers such as sulfur dioxide, sulfite compounds, or ferrous iron compounds to decrease the oxidation state of organic and inorganic compounds.	Eliminate – not applicable to the removal of pesticides.

TABLE 3-1

PRELIMINARY SCREENING OF GROUNDWATER REMEDIATION TECHNOLOGIES AND PROCESS OPTIONS
SITE 25 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

General Response Action	Technology	Process Options	Description	Screening Comment
Ex-situ Treatment (Continued)	Chemical (Continued)	Chemical Precipitation	Use of reagents to convert soluble constituents into insoluble constituents.	Eliminate – not applicable for the removal of pesticides.
		Coagulation/ Flocculation	Use of chemicals to neutralize surface charges and promote attraction of colloidal particles to facilitate settling.	Retain as a pretreatment step prior to potential treatment processes.
		Neutralization/pH Adjustment	Use of acids or bases to counteract excess pHs.	Retain as a possible pretreatment step or final step prior to discharge.
Discharge/ Disposal	Surface Discharge	Direct Discharge to surface water	Discharge of treated water.	Retain for discharge of treated groundwater.
		Indirect Discharge to industrial wastewater / sewage treatment plant (IWTP/STP)	Discharge of collected/treated water to the former NAS Cecil Field STP or regional POTW once the Base is connected.	Retain for discharge of treated groundwater.
		Off-Site Treatment Facility	Treatment and disposal of water at an off-site treatment works.	Eliminate – impractical due to large volume of treated groundwater.
	Subsurface Discharge	Reinjection	Use of injection wells, spray irrigation, or infiltration to discharge collected/treated groundwater underground.	Eliminate – groundwater is too shallow for effective discharge to surficial aquifer. No suitable area is located reasonably close to Site 45 for deep well injection.

General Response Action	RemediatonTechnology	Process Options
No Action	None	Not Applicable
Limited Action	Monitoring	Sampling and Analysis
	Institutional Controls	Groundwater Use Restrictions
	Natural Attenuation	Naturally-Occurring Biodegradation, Dispersion and Dilution
Removal	Groundwater Extraction	Extraction Wells or Trenches
In-situ Treatment	BIOLOGICAL	Chemically- Enhanced In-Situ Biodegradation
		In-Situ Air Sparging
Ex-situ Treatment	Biological	Aerobic/Anaerobic Biodegradation
	Physical	Sedimentation
		Filtration
		Granular Activated Carbon (GAC) Adsorption
	Chemical	Neutralization/pH Adjustment
		Coagulation/Flocculation
Discharge/Disposal	Onsite Surface Discharge	Direct Discharge (NPDES)
		Indirect Discharge (IWTP/STP)

3.2 DETAILED SCREENING OF GROUNDWATER REMEDIATION TECHNOLOGIES AND PROCESS OPTIONS

3.2.1 No Action

No action consists of maintaining status quo at the site. As required under CERCLA regulations, the No Action alternative is carried through the FS to provide a baseline for comparison of alternative and their effectiveness in mitigating risks posed by site contaminants. Since no remedial actions are conducted under this alternative, there are no costs associated with “walking away from” the site. Neither is there a reduction in risk through exposure control or treatment.

Effectiveness

No Action would not be effective in meeting the RAOs for the site. No Action would not be effective in evaluating either potential contaminant reduction through natural attenuation or potential contaminant migration off-site since no monitoring would be performed.

Implementability

There would be no implementability concerns since no actions would be implemented.

Cost

There would be no costs associated with No Action.

Conclusion

No Action is retained for comparison to other options.

3.2.2 Limited Action

3.2.2.1 Institutional Controls

Institutional controls would consist of limiting access to groundwater. Deed restrictions would be prepared and implemented to restrict the use of the surficial aquifer groundwater. A formal notification would be issued to the St. John's Water Authority not to issue permits for installation of wells at Site 25 that would draw water from the surficial aquifer.

Effectiveness

Groundwater use restrictions would be effective, depending on the administration of controls. These controls would minimize potential human health risks associated with exposure to contaminated groundwater.

Implementability

Institutional controls would be readily implementable. As part of change of the sites from military to private ownership, provisions were incorporated in property transfer documents to make sure the continued implementation of institutional controls. Resources are readily available for the preparation of deed restrictions.

Cost

Costs of institutional controls would be low.

Conclusion

Institutional controls are retained in combination with other process options for the development of remedial alternatives.

3.2.2.2 Monitoring

Sampling and analysis of groundwater within and downgradient of the contaminant plume could be used to evaluate migration of contaminants and the potential for contamination of onsite drinking water supply and nearby residential, municipal, and commercial wells. Monitoring could also be used to monitor the progress of natural attenuation or active groundwater remediation.

Effectiveness

Monitoring would not of itself reduce the toxicity, mobility, or volume of contaminants in the groundwater but it would allow the evaluation of potential off-site migration of contaminants and the potential reduction in contaminant concentrations through natural attenuation. By serving as a warning mechanism, periodic groundwater monitoring would enable the evaluation of active remedial actions if a threat of contamination arose in the area. Monitoring would also be helpful in measuring and evaluating the effectiveness of groundwater remediation technologies.

Implementability

A groundwater monitoring program could be readily implemented at Site 25. Local and state permits would be required for monitoring well installation.

Cost

Capital and O&M costs of monitoring would be low.

Conclusion

Monitoring is retained in combination with other process options for the development of remedial alternatives.

3.2.2.3 Natural Attenuation

Natural attenuation would consist of monitoring groundwater quality to determine the extent to which, if any, contaminant concentrations would be reduced over time through naturally-occurring processes, such as biodegradation, dispersion, dilution, or adsorption.

Effectiveness

The observed decrease in BHC and aluminum concentrations between the pre-RI and RI samplings provides some evidence that natural attenuation is occurring at Site 25 (see Tables 1-1 and 1-2). The

small size of the BHC plume and relatively low detected concentrations of BHC further support the likeliness of such natural attenuation. Because the area of groundwater contamination is quite small even moderate groundwater movements could result in significant dilution and dispersion. Also, even though detected concentrations of BHC are greater than GCTLs they are below the acute toxicity threshold that would prevent in-situ biodegradation by naturally-occurring microorganisms.

Implementability

Natural attenuation would be easy to implement. Monitoring of groundwater quality, groundwater use restrictions, and periodic site reviews could readily be performed and the necessary resources are available to provide these services.

Cost

Capital and O&M costs for natural attenuation would be low.

Conclusion

Natural attenuation is retained in combination with other process options for the development of remedial alternatives.

3.2.3 Removal

The only technology considered under this GRA is groundwater extraction. Two methods for groundwater extraction were retained from the preliminary screening, extraction wells and collection trenches.

3.2.3.1 Extraction Wells

Wells are drilled into the aquifer and screened below the water table to access the groundwater. Pumping is used to extract the water as it collects in the wells and bring it to the surface. The process of extraction creates a hydraulic gradient, that induces further flow of groundwater into the well. Extraction wells that are placed in the path of migration of a contaminant plume can also be used to intercept and contain the plume. Extraction wells that are placed within the contaminated plume can be used to clean the aquifer by removing the contaminated groundwater and flushing the saturated zone. The flushing action occurs when the fresh water from upgradient (clean) areas replaces the extracted contaminated groundwater and causes more contaminants to desorb from the saturated zone soils. Thus, theoretically, the saturated zone soils progressively lose contaminants until the concentrations in the groundwater are

at acceptable levels. The selection of the appropriate well system depends upon the depth of contamination and the hydrologic and geologic characteristics of the aquifer.

Extraction pumps are typically submersible, electrically operated centrifugal pumps or pneumatically operated ejector pumps. For shallow groundwater extraction (depths up to 10 ft), surface pumps may be used. Centrifugal pumps are not practical for use at low extraction rates less than 1 gpm, and, in such cases, pneumatic ejector pumps are preferred.

Effectiveness

Extraction wells can be effective for intercepting and containing the migration of a contaminant plume. The location and screening depth of the wells are important criteria that must be taken into consideration in achieving adequate capture of the contaminant plume. Extraction wells are a well-established and well-proven technology for the removal of contaminated groundwater and the containment of groundwater contaminant plumes. While the initial effectiveness of this technology for contaminant capture is high, it has often been shown to decrease over time. This decrease is generally due to one or more of several factors, including the presence of preferential flow pathways due to aquifer heterogeneity, contaminant adsorption onto aquifer materials, diffusion of contaminants into the pore spaces of low-permeability materials, and creation of stagnation zones due to pumping operations. It should be noted, however, that no such decrease over time is observed in the effectiveness of this technology for containment of contaminant plumes. The effectiveness of an extraction well system depends largely on the extent of contamination and site-specific geology and hydrogeology. The use of wells to extract groundwater should reduce contaminant concentration and may attain the PRGs over the long term. This technology is reliable and minimal effects on human health and the environment would be expected during implementation.

Implementability

Extraction wells are relatively easily installed and pumps are widely available for a variety of flow rates and aquifer conditions. Implementation of this technology would require long-term O&M. Well screens require regular inspection and well flushing to remove fine-grained material that may clog the wells. Pumps also require regular preventive maintenance. Pneumatic pumps have an additional requirement of a source of compressed air and regular inspection of the pump mechanism as well as the air supply lines. Local and state permits may be required for installation of extraction wells. Extracted groundwater would require treatment prior to disposal/discharge.

Site 25 lies within a relatively congested area that will remain active. Existing structures may limit placement of wells and optimal placement may not be possible.

Cost

Capital and O&M costs of extraction wells are low.

Conclusion

Extraction wells are retained in combination with other process options for the development of remedial alternatives.

3.2.3.2 Collection Trenches

Collection trenches are used to convey and collect aqueous discharges by gravity flow. They essentially function like a line of extraction wells by creating a continuous zone of influence. Groundwater within this zone flows toward the collection points. However, trenches cannot create as steep a hydraulic gradient as extraction wells and, consequently, are less effective at depressing the water table. Since collection trenches function like a line of extraction wells, they can perform many of the same functions. They offer the advantage of being able to collect contaminated water in situations where the groundwater recharge rate is insufficient to sustain extraction well pumping.

A collection trench is formed by excavating a ditch a few feet wide to a depth where an impermeable base is encountered or to the depth of contamination. A backhoe or clamshell is common equipment used for the excavation. This excavated trench is then backfilled with permeable material, such as gravel or crushed rock. Collection pipes and pumps are then placed in the trench for water removal.

Effectiveness

Collection trenches can be effective for capturing and containing a contaminant plume. Collection trenches do not generate hydraulic gradients as steep as those created by wells. Therefore, remediation of the aquifer may take more time, since the flushing action will not be as powerful. Collection trenches are also best-suited for the extraction of shallow groundwater and, although current depth of contamination does not extend beyond approximately 15 ft bgs, no confining layer is reached until approximately 90 ft bgs, and this technology could therefore be ineffective to prevent potential downward contaminant migration.

Implementability

Collection trenches would be relatively easy to install. However, in a congested area such as Site 25, proper placement of these trenches would be even more restricted than that of extraction wells. Soil excavated to install the trenches would have to be disposed appropriately.

Cost

Costs depend primarily on the depth of excavation, stability of soils, and groundwater flow rates. Capital costs are generally low to moderate and O&M costs are low.

Conclusion

Collection trenches are eliminated from further consideration because extraction wells would be more effective and easier to implement.

3.2.4 In-Situ Treatment

3.2.4.1 Enhanced In-Situ Biodegradation

In-situ biodegradation involves the use of naturally-occurring microorganisms, primarily bacteria and fungi, to breakdown hazardous organic compounds into nontoxic or less toxic forms. Enhanced in-situ biodegradation would consist in accelerating this process by stimulating biological activity through the injection of chemical additives and/or custom microorganism cultures into the contaminant plume.

One of the most likely process option for this technology would consist of using an hydrogen release compound (HRC®), such as lactic acid, to enhance the anaerobic degradation of BHC. This would possibly be supplemented by the injection of an oxygen release compound (ORC®), such as hydrogen or magnesium peroxide, to complete the biodegradation of BHC metabolites in an aerobic environment. These compounds would be injected into the contaminant plume using direct push technology (DPT). Treatment would consist of an initial injection followed, as required, by maintenance dosages either through DPT injection points or existing monitoring wells. Groundwater samples would be regularly collected and analyzed to evaluate the progress of remediation.

Effectiveness

The effectiveness of HRC®/ORC® injection is well documented for the in-situ biodegradation of chlorinated and non-chlorinated volatile and low molecular weight organic compounds. However, the effectiveness of this or other similar process option for the in-situ biodegradation of pesticides such as

BHC is not as of yet as well established. A treatability study would be needed in order to fully evaluate the process.

Implementability

Enhanced in-situ biodegradation would be relatively easy to implement at Site 25. The DPT application of HRC® and/or ORC® would be relatively unobtrusive with respect to existing structure although these structures might restrict the optimal placement of some DPT injection points. Several qualified contractors would be available for the implementation of this technology.

Cost

Capital and O&M costs for enhanced in-situ biodegradation would be low to moderate, depending on the extent of the area treated.

Conclusion

Enhanced in-situ biodegradation is retained in combination with other processes options for the development of remedial alternatives.

3.2.4.2 Air Sparging

Air sparging consists of injecting compressed air in the groundwater contaminant plume. This induces an air current through the groundwater and soil that promotes short-term stripping of VOCs and long-term biodegradation of SVOCs in both groundwater and soil. Compressed air is injected through one or more vertical wells screened within the contaminant plume. Groundwater and soil samples are regularly collected and analyzed to monitor the progress of the remedial action.

Effectiveness

Air sparging effectively removes organic contaminants from groundwater through volatilization and/or enhanced aerobic degradation. Since pesticides in general and BHC in particular are not particularly volatile, the effectiveness of air sparging for the in-situ remediation of the Site 25 groundwater would be tied to its ability to significantly enhance the aerobic biodegradation of BHC. While such a capability has been well demonstrated with a wide-range of non-chlorinated organic compounds, including many polynuclear aromatic hydrocarbons (PAHs), it is much less so for more toxic compounds such as pesticides. A treatability study would have to be performed to determine the potential effectiveness of air sparging.

Implementability

Air sparging would be relatively easy to implement at Site 25. Due to the small size of the plume, a limited number of air sparging wells would be required and their installation would be relatively unobtrusive with respect to existing structures although these structures might restrict the optimal placement of some air sparging wells. Several qualified contractors would be available for the implementation of this technology.

Cost

Capital and O&M cost for air sparging would be low to moderate.

Conclusion

Air sparging is eliminated from further consideration because of effectiveness concerns and because enhanced in-situ biodegradation with HRC® and/or ORC® would constitute a better in-situ treatment approach.

3.2.5 Ex-situ Biological Treatment

Biological treatment involves the use of microorganisms, primarily bacteria and fungi to breakdown hazardous organic compounds into nontoxic or less toxic forms.

Ex-situ aerobic or anaerobic biological treatment consists of contacting the contaminated groundwater with a concentrated culture of such microorganisms under controlled operating conditions, including mixing, presence or absence of oxygen, pH, temperature, and addition of nutrients.

Ex-situ aerobic/anaerobic biological treatment of groundwater may require pre-treatment of groundwater, including neutralization/pH adjustment and/or the removal of excess suspended solids by coagulation/flocculation and sedimentation or filtration. Ex-situ aerobic/anaerobic biological treatment may also generate fugitive emissions that have to be controlled and solid or liquid residues, such as waste activated sludge, that require further treatment and disposal.

Effectiveness

Ex-situ aerobic biological treatment is a well-proven technology for the removal of a wide range of non-chlorinated organic compounds. Ex-situ anaerobic dechlorination followed by aerobic biological treatment has been proven effective for the removal of certain chlorinated organic compounds, such as trichloroethene (TCE). Certain fungi cultures (i.e., white rot fungus) have also shown success for the

removal of such pesticides such as DDT, but in a solid matrix rather than groundwater. The effectiveness of ex-situ aerobic and/or anaerobic biological treatment for the removal of BHC in groundwater would have to be demonstrated through a treatability study.

Implementability

Ex-situ aerobic/anaerobic biological treatment would be implementable. Numerous qualified vendors and contractors offer equipment and services for this technology. However, availability of proven technology and know-how for ex-situ aerobic/anaerobic biological treatment of pesticides is limited.

Implementation of ex-situ aerobic/anaerobic biological treatment for the Site 25 groundwater would require treatment and disposal of the residues generated by these processes.

Cost

Capital and O&M costs for ex-situ aerobic/anaerobic biological treatment would be low to moderate.

Conclusion

Ex-situ aerobic/anaerobic biological treatment is eliminated from further consideration because of effectiveness concerns and because liquid-phase GAC adsorption constitute a better ex-situ treatment approach.

3.2.6 Ex-Situ Physical Treatment

3.2.6.1 Sedimentation

Sedimentation is a process that removes the suspended solids from a liquid by producing quiescent hydraulic conditions. This allows gravity to settle out the unstable solids from suspension. This technology may be used in conjunction with precipitation. Two slightly different sedimentation options are used including clarification (to typically produce a 2 to 8 percent sludge) and thickening (to typically further concentrate clarification sludges to 8 to 15 percent).

Effectiveness

Sedimentation would not of itself be effective for the removal of COCs from groundwater at Site 25. However, this technology would be effective for the removal of excessive concentrations of suspended solids that would otherwise undermine the efficiency of certain ex-situ treatment technologies such as

liquid-phase GAC adsorption. However, based on previous characterization of the groundwater at Site 25, it is unlikely that such pretreatment would be required.

Implementability

Sedimentation would be readily implementable. Numerous qualified equipment vendors and contractors offer this type of equipment and services.

Cost

Capital and O&M costs for sedimentation would be low.

Conclusion

Sedimentation is eliminated because no high concentrations of suspended solids are anticipated in the extracted groundwater.

3.2.7.2 Filtration

Filtration is a process using a porous medium to remove solid particles from a liquid or gas. This technology is generally used as a groundwater pre-treatment to remove suspended solids before other treatment processes and/or for the final cleaning or polishing of treated effluent.

Liquid filtration may be accomplished by numerous methods including screens, fibrous fabrics (paper or cloth), or beds of granular material, such as sand. Flow through a filter can be encouraged by pressure on the inlet side or by drawing a vacuum on the filter outlet.

Most type of liquid filters, except those utilizing disposable filter elements (such as cartridge filters) require periodic cleaning to remove the suspended solids accumulated in the filter medium and restore filtration efficiency. This cleaning is typically performed with a countercurrent of water, or backwash, which carries away the solids retained on the filter medium.

Effectiveness

Filtration would not be expected to be effective of itself for the removal of vanadium from groundwater at Site 25. However, this technology would effectively reduce excessive concentrations of solids particles suspended in the groundwater and that might otherwise undermine the efficiency of downstream treatment technologies such as liquid-phase GAC adsorption. Filtration would also effectively remove whatever contaminants may be adsorbed on the solid particles suspended in the groundwater. Based on

previous characterization of the groundwater at Site 25, it is likely that such pretreatment would be required.

Implementability

Filtration would be readily implementable. Filtration systems are commercially available from a wide variety of manufacturers and can be readily ordered to almost any specification. Liquid or solid residues resulting from the periodic cleaning or replacement of the filter medium would have to be properly disposed of.

Cost

Capital and O&M costs for filtration would be low.

Conclusion

Filtration is retained in combination with other process options for the development of remedial alternatives.

3.2.7.3 Granular Activated Carbon (GAC) Adsorption

GAC adsorption is a frequently applied technology for the removal of contaminants from air or water. GAC adsorption is principally targeted towards the removal of organic compounds and is more effective for the less polar and less soluble compounds. The fundamental principle behind GAC adsorption involves the physical attraction of organic solute molecules to exchange sites on the internal pore surface areas of the specially treated (activated) carbon grains. As the contaminated liquid or vapor passes through one or more vessels containing GAC, the contaminants are captured on the active sites of the carbon grains and eventually occupy all of these sites. The exhausted GAC must then either be regenerated or disposed of.

Typical GAC adsorption treatment systems include atmospheric or pressurized columns operating in series and/or parallel configuration. Liquid-phase GAC columns are typically designed with backwashing capability to minimize solids fouling that would increase GAC replacement frequency. Factors such as pH and temperature of the influent, empty bed contact time (EBCT), surface area/volume ratio of the activated carbon, and solubility of the organic compound will affect the carbon adsorption process.

Effectiveness

Liquid- and vapor-phase GAC adsorption is a well-proven, reliable technology that would be effective for removing of many organic compounds, such as the BHC contained in the Site 25 groundwater. Adsorption of such high molecular weight, highly-substitutized compounds is generally very effective in terms of the ratio of contaminant removed to GAC used. However, it should be noted that since the BHC constitutes a very small proportion of the organic compounds dissolved in the Site 25 groundwater far more GAC will be used for the treatment of that groundwater than would be required for the removal of BHC alone.

Implementability

GAC adsorption would be readily implementable. There are a sufficient number of qualified vendors that provide GAC adsorption units. Pretreatment would be required to prevent premature carbon fouling if the groundwater to be treated has a suspended solids concentration greater than 50 mg/L, or an oil and grease concentrations greater than 10 mg/L, or calcium or magnesium concentrations greater than 500 mg/L. At Site 25, a filtration pretreatment step is likely to be required as a safeguard to ensure maximum GAC life. Spent GAC containing the concentrated contaminants would have to be regenerated, incinerated, or disposed of in a hazardous waste landfill. Thermal, steam, and solvent treatments are the most common types of GAC regeneration technologies that are typically conducted off site. Special handling of the periodically generated backwash liquids must also be taken into account.

Cost

Capital cost for GAC adsorption would be low while O&M costs would be moderate, based upon expected GAC consumption.

Conclusion

GAC adsorption is retained in combination with other process options for the development of remedial alternatives.

3.2.8 Ex-Situ Chemical Treatment

3.2.8.1 Neutralization/pH Adjustment

Neutralization/pH adjustment is a process for achieving appropriate pH levels for removal of contaminants. This is generally accomplished by adding acidic compounds to balance alkaline solutions or vice-versa.

Effectiveness

Neutralization/pH adjustment is generally effective for the removal of certain contaminants, mostly inorganics, by bringing them out of solution. For Site 25, neutralization/pH adjustment would not of itself be effective for the removal of BHC in groundwater. However, this technology would enhance the effectiveness of such pretreatment technologies as coagulation/flocculation and sedimentation and may be required prior to discharge of treated groundwater.

Implementability

Neutralization/pH adjustment would be readily implementable. This technology is widely used and numerous qualified equipment vendors and contractors offer this type of equipment and services.

Cost

Capital and O&M costs for neutralization/pH adjustment would be low.

Conclusion

Neutralization/pH adjustment is eliminated because the pH of the extracted groundwater is anticipated to be acceptable for discharge and pH adjustment would not be required for removing contaminants out of solution.

3.2.8.2 Coagulation/Flocculation

Coagulation/flocculation is a process that consists of adding certain chemical reagents that result in the agglomeration of small suspended solids particles into larger ones, thus increasing significantly the effectiveness of sedimentation.

Effectiveness

Coagulation/flocculation would not of itself be effective for the removal of BHC from groundwater at Site 25. However, this technology would be effective to optimize the removal of excessive concentrations of suspended solids that would otherwise undermine the efficiency of removal technologies such as liquid-phase GAC adsorption. Based on previous characterization of the groundwater at Site 25, it is unlikely that such pretreatment would be required.

Implementability

Coagulation/flocculation would be readily implementable. Numerous qualified equipment vendors and contractors offer equipment and services to implement this technology.

Cost

Capital and O&M costs for coagulation/flocculation would be low.

Conclusion

Coagulation/flocculation is eliminated because no high concentrations of suspended solids are anticipated in the extracted groundwater.

3.2.9 Disposal

3.2.9.1 Direct Discharge

This technology would consist of discharging the treated (or untreated) groundwater to the NAS Cecil Field storm sewer and drainage ditch system. This system eventually discharges into Sal Taylor Creek that flows to the St. John River.

Effectiveness

Direct discharge to the storm sewer and drainage ditch system would be an effective means of disposal for groundwater at Site 25. However, the groundwater would have to undergo adequate treatment for this option to be environmentally acceptable.

Implementability

Direct discharge to the storm sewer and drainage ditch system would be implementable. Prior to discharge, groundwater would have to be treated to comply with Florida Water Quality Standards. In addition, although an actual permit would not be required, the substantive requirements of a National Pollutant Discharge Elimination System (NPDES) permit would have to be met. Monitoring of discharged water would be required to ensure that downstream areas are not adversely effected. These requirements would be implementable and the resources necessary to satisfy them are available.

Cost

Capital and O&M costs of direct discharge would be low.

Conclusion

Direct discharge is retained in combination with other process options for the development of remedial alternatives.

3.2.9.2 Indirect Discharge

This technology would consist of discharging the untreated (or treated) groundwater to the local sewage treatment plant (STP) where it would undergo either the full or incremental treatment required for discharge to Sal Taylor Creek.

Effectiveness

Indirect discharge of untreated groundwater to the local STP would probably not be an effective mean for the disposal of the Site 25 groundwater. It is uncertain if the local STP could provide the necessary BHC removal for ultimate discharge to surface water. Indirect discharge of treated groundwater to the local STP would be effective but unnecessary since on-site treatment would already have achieved the water quality required for surface discharge.

Implementability

Indirect discharge to the local STP would be implementable. Connection to the local sanitary sewer network should not be a problem and the relatively low flow of extracted groundwater could probably be accommodated by the STP. However, discharge of untreated groundwater would require a thorough evaluation of impacts to the STP and a modification of its NPDES permit.

Cost

Capital and O&M costs for indirect discharge to a local STP would be moderate to high, depending on the distance to the STP and whether upgrading of the STP would be necessary.

Conclusion

Indirect discharge is eliminated from further consideration due to effectiveness and implementability concerns.

3.3 SELECTION OF GROUNDWATER REMEDIATION TECHNOLOGIES AND PROCESS OPTIONS

The following remediation technologies and process options are retained to develop groundwater remedial alternatives for Site 25:

- No Action
- Institutional Controls
- Monitoring
- Natural Attenuation
- Groundwater Extraction
- Enhanced In-Situ Biodegradation
- Filtration
- Liquid-Phase GAC Adsorption
- Direct Discharge

4.0 ASSEMBLY AND DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

4.1 INTRODUCTION

This section presents an evaluation of each remedial alternative with respect to the criteria of the NCP of 40 CFR Part 300, as revised in 1990. The criteria as required by the NCP and the relative importance of these criteria are described in the following subsections.

4.1.1 Evaluation Criteria

In accordance to the NCP (40 CFR 300.430), the following nine criteria are used for the evaluation of remedial alternatives:

- Overall Protection of Human Health and the Environment,
- Compliance with ARARs,
- Long-term Effectiveness and Permanence,
- Reduction of Toxicity, Mobility, and Volume through Treatment,
- Short-term Effectiveness,
- Implementability,
- Cost,
- State Acceptance, and
- Community Acceptance

4.1.1.1 Overall Protection of Human Health and the Environment

Alternatives must be assessed for adequate protection of human health and environment in both short- and long-term, from unacceptable risks posed by hazardous substances, or contaminants present at the site by eliminating, reducing, or controlling exposure to levels exceeding remediation goals. Overall protection draws on the assessments of other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

4.1.1.2 Compliance with ARARs

Alternatives must be assessed to determine whether they attain ARARs under Federal environmental laws and state environmental or facility siting laws. If one or more regulations that are applicable cannot be complied with, then a waiver must be invoked. Grounds for invoking a waiver would depend on the following circumstances.

- The alternative is an interim measure and will become part of a total remedial action that will attain the ARAR.

- Compliance will result in greater risk to human health and the environment.

- Compliance is technically impracticable from an engineering perspective.

- The alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method or approach.

- A state requirement has not been consistently applied, or the state has not demonstrated the intention to consistently apply the promulgated requirement in similar circumstances at other remedial actions within the state.

- For Fund-financed response actions only, an alternative that attains the ARAR will not provide a balance between the need for protection of human health and the environment at the site and the availability of Fund monies to respond to other sites that may present a threat to human health and the environment.

4.1.1.3 Long-term Effectiveness and Permanence

Alternatives must be assessed for the long-term effectiveness and permanence they offer, along with the degree of certainty that the alternative will prove successful. Factors that shall be considered as appropriate include the following:

Magnitude of Residual Risk:

Risk posed by untreated waste or treatment residuals at the conclusion of remedial activities. The characteristics of residuals should be considered to the degree that they remain hazardous, taking into account their volume, toxicity, mobility, and propensity to bioaccumulate.

Adequacy and reliability of controls:

Controls such as containment systems and institutional controls that are necessary to manage treatment residuals and untreated waste must be shown reliable. In particular, the uncertainties associated with land disposal for providing long-term protection from residuals; the assessment for the potential need to replace technical components of the alternative such as a cap, a slurry wall, or a treatment system; and the potential exposure pathways and risks posed should the remedial action need replacement.

4.1.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

The degree to which the alternative employs recycling or treatment that reduces the toxicity, mobility, or volume shall be assessed, including how treatment is used to address the principal threats posed by the site. Factors that shall be considered, as appropriate, include the following:

- The treatment or recycling processes the alternative employs and the materials that they will treat.
- The amount of hazardous substances, pollutants, or contaminants that will be destroyed, treated, or recycled.
- The degree of expected reduction in toxicity, mobility, or volume of waste due to treatment or recycling and the specification of which reduction(s) are occurring.
- The degree to which the treatment is irreversible.
- The type and quantity of residuals that will remain following treatment considering the presistence, toxicity, mobility, and propensity to bioaccumulate of such hazardous substances and their constituents.
- The degree to which treatment reduces the inherent hazards posed by principal threats at the site.

4.1.1.5 Short-Term Effectiveness

The short-term impacts of the alternative shall be assessed considering the following:

- Short-term risks that might be posed to the community during implementation.
- Potential impacts on workers during remedial action and the effectiveness and reliability of protective measures.
- Potential environmental impacts of the remedial action and the effectiveness and reliability of mitigative measures during implementation.
- Time until protection is achieved.

4.1.1.6 Implementability

The ease or difficulty of implementing the alternatives shall be assessed by considering the following types of factors, as appropriate:

- Technical feasibility, including technical difficulties and unknowns associated with the construction and operation of a technology, the reliability of the technology, ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the remedy.

- Administrative feasibility, including activities needed to coordinate with other offices and agencies, and the ability and time required obtaining any necessary approvals and permits from other agencies (for off-site actions).

- Availability of services and materials, including the availability of adequate off-site treatment, storage capacity, and disposal capacity and services; the availability of necessary equipment and specialists, and provisions to ensure necessary additional resources; the availability of services and materials; and availability of prospective technologies.

4.1.1.7 Cost

Capital costs shall include both direct and indirect costs. Annual O&M costs shall be provided. A net present worth (NPW) of the capital and O&M costs shall also be provided. Typically, the cost estimate accuracy range is plus 50 percent to minus 30 percent.

4.1.1.8 State Acceptance

The state's concerns that must be assessed include the following:

- The state's position and key concerns related to the preferred alternative and other alternatives
- State comments on ARARs or the proposed use of waivers

These concerns cannot be evaluated at this time in the FS until the state has reviewed and commented on the FS. These concerns will be discussed, to the extent possible, in the proposed plan to be issued to for public comment.

4.1.1.9 Community Acceptance

This assessment consists of responses of the community to the proposed plan. This assessment includes determining which components of the alternatives interested persons in the community support, have reservations about, or oppose. This assessment can be done after comments on the proposed plan are received from the public.

4.1.2 Relative Importance of Criteria

Among the nine criteria, the threshold criteria are considered to be:

Overall Protection of Human Health and the Environment
Compliance with ARARs (excluding those that may be waived)

The threshold criteria must be satisfied in order for an alternative to be eligible for selection.

Among the remaining criteria, the following five criteria are considered to be the primary balancing criteria.

- Long-term Effectiveness and Permanence
- Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment
- Short-Term Effectiveness
- Implementability
- Cost

The balancing criteria are used to weigh the relative merits of alternatives.

The remaining two of the nine criteria, namely: State Acceptance and Community Acceptance are considered to be modifying criteria that must be considered during remedy selection. These last two criteria can be evaluated after the document has been reviewed by the State of Florida and the proposed plan has been discussed in a public meeting. Therefore, this document addresses only seven out of the nine criteria.

4.1.3 Selection of Remedy

The selection of a remedy is a two-step process. The first step consists of identification of a preferred alternative and presentation of the alternative in a proposed plan to the community for review and comment. The preferred alternative must meet the following criteria.

- Protection of human health and the environment.
- Compliance with ARARs unless a waiver is justified.
- Cost effectiveness in protecting human health and environment and in complying with ARARs.
- Utilization of permanent solutions and alternate treatment technologies or resource recovery technologies to the maximum extent practicable.

The second step consists of the review of the comments and determination of whether or not the preferred alternative continues to be the most appropriate remedial action for the site, in consultation with the State of Florida.

4.2 ASSEMBLY OF GROUNDWATER REMEDIAL ALTERNATIVES

Based on the technology screening presented in Section 3.2, the following four remedial alternatives were developed.

- Alternative 1: No Action
- Alternative 2: Natural Attenuation, Institutional Controls, and Monitoring
- Alternative 3: In-Situ Enhanced Biodegradation, Institutional Controls, and Monitoring
- Alternative 4: Extraction, On-Site Treatment, Surface Discharge, Institutional Controls, and Monitoring

Alternative 1 was developed and analyzed to serve as a baseline for other alternatives, as required by CERCLA and the NCP. Alternative 2 was formulated and analyzed to evaluate the adequacy of minimal action. Alternatives 3 and 4 were formulated and analyzed to evaluate active remediation of the contaminant plume. A description and detailed analysis of these alternatives are presented in the following sections.

4.2.1 <u>Alternative 1: No Action</u>

4.2.1.1 Description

The No Action alternative maintains the site as is. This alternative does not address the groundwater contamination and is retained to provide a baseline for comparison to other alternatives. There would be no reduction in toxicity, mobility, or volume of the contaminants other than what would result from natural dispersion, dilution, biodegradation, and other attenuating factors. Existing monitoring programs and institutional controls would be discontinued, and the site would be available for unrestricted use.

4.2.1.2 Detailed Analysis

Overall Protection of Human Health and the Environment

Alternative 1 would not provide protection of human health and the environment. Under the current industrial land use, the potential for unacceptable risks to human health from exposure to contaminated groundwater would remain. BHC contamination in the groundwater might migrate and, although this migration would not have an immediate negative impact since Site 25 is located far from any surface water body, such a negative impact could eventually develop. Since no monitoring would be performed, potential BHC migration would not be detected.

Compliance with ARARs and TBCs

Alternative 1 would not comply with chemical-specific ARARs or TBCs (Safe Drinking Water Act, CSF, RfDs, and Contaminant Cleanup Target Levels) since no action would be taken to reduce contaminant concentrations. Compliance with location-specific ARARs or TBCs would be purely incidental. Action-specific ARARs or TBCs are not applicable.

Long-term Effectiveness and Permanence

Alternative 1 would have no long-term effectiveness and permanence because contaminated groundwater would remain on site. As there would be no institutional controls to restrict the use of the surficial aquifer groundwater, the potential would exist for unacceptable risk to develop for human receptors. Since there would be no groundwater monitoring, potential contaminant migration would not be detected. Although contaminant concentrations might eventually decrease to acceptable levels through natural attenuation, no monitoring would verify this.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 1 would not reduce toxicity, mobility, or volume of contaminants through treatment since no treatment would occur. Some reduction of contaminant toxicity or volume might occur through natural dispersion, dilution, or other attenuation process but no monitoring would be performed to verify this.

Short-term Effectiveness

Since no action would occur, implementation of Alternative 1 would not pose any risks to onsite workers or result in short-term adverse impact to the local community and the environment. Alternative 1 would never achieve the RAO and, although the BHC PRGs might eventually be achieved through natural attenuation, it would never be known when.

Implementability

Since no action would occur, Alternative 1 would be readily implementable. The technical feasibility criteria, including constructability, operability, and reliability, are not applicable. Implementability of administrative measures is not applicable since no such measures would be taken.

Cost

There would be no costs associated with the no-action alternative.

4.2.2 Alternative 2: Natural Attenuation, Institutional Controls, and Monitoring

4.2.2.1 Description

Alternative 2 is illustrated on Figure 4-1 and would consist of three major components: (1) natural attenuation, (2) institutional controls, and (3) monitoring.

Component 1: Natural Attenuation

Natural attenuation would rely on naturally occurring processes within the aquifer to reduce the concentration of BHC. Dispersion and dilution through aquifer movement, adsorption on soil particles, and biodegradation would mainly be responsible for this. Aquifer conditions would be continually monitored to make sure that concentrations are being adequately reduced through natural processes.

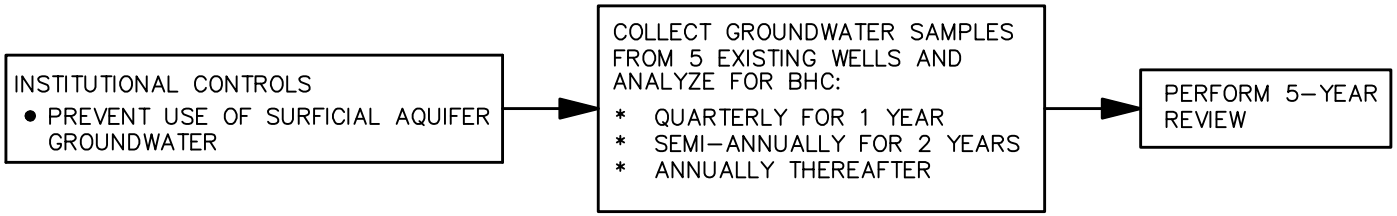
Component 2: Institutional Controls

Institutional controls would consist of prohibiting usage of the surficial aquifer. These controls would eliminate or reduce pathways of exposure to contaminated groundwater. Use of groundwater would be controlled through deed restrictions and formal notice would be issued to the St. John's Water Authority not to issue permits for installation at of wells Site 25 that would draw water from the surficial aquifer.

Component 3: Monitoring

Monitoring would consist of regularly collecting and analyzing groundwater samples both from within the contaminant plume to assess natural attenuation and downgradient of the leading edge of the plume to evaluate contaminant migration.

NATURAL ATTENUATION, INSTITUTIONAL CONTROLS, AND MONITORING



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Monitoring would consist of collecting samples from five existing monitoring wells and analyzing them for BHC. Monitoring would be performed for a period of 5 years. Sampling frequency would be quarterly for the first year, semi-annual for the next 2 years, and annual thereafter.

Site conditions would be reviewed at the end of 5 years. If natural attenuation proves to be insufficient, another remedial approach would be evaluated and implemented.

4.2.2.2 Detailed Analysis

Overall Protection of Human Health and the Environment

Alternative 2 would be protective of human health and the environment.

Although the contaminant plume might expand, natural attenuation would eventually reduce alpha- and beta-BHC concentrations to below their PRGs. If the results of the monitoring conducted as part of this alternative indicate otherwise and that contaminant plume expansion could have a negative environmental impact, contingency remedies would be implemented to prevent such an occurrence.

Institutional controls would be protective of human health and the environment. Prohibiting the use of surficial aquifer groundwater would be protective of human health by preventing unacceptable risks from exposure to contaminated groundwater.

Monitoring would be protective of the environment by evaluating the progress of remediation and detecting potential migration of contaminated groundwater so that appropriate contingency measures can be taken, if required.

Some short-term risks could be incurred by workers from exposure to contamination during implementation of this alternative. However, the potential for such exposure would be minimized by the wearing of appropriate personal protective equipment (PPE) and compliance with site-specific health and safety procedures.

No adverse short-term or cross-media effects are anticipated as a result of implementing this alternative.

Compliance with ARARs and TBCs

Alternative 2 would comply with location-, and action-specific ARARs and TBCs. In the short-term, this alternative would not comply with chemical-specific ARARs, such as the FDEP GCTLs but, eventually, compliance would be achieved as natural processes within the aquifer reduce BHC concentration.

Long-term Effectiveness and Permanence

Alternative 2 would provide long-term effectiveness and permanence. Although no removal of contaminated groundwater would occur and the contaminant plume might expand, risks to human health and the environment would be monitored.

Naturally-occurring processes, such as dispersion, dilution, adsorption, and biodegradation would reduce alpha- and beta-BHC concentrations in the aquifer over the long term to levels that comply with their FDEP GCTLs. However, it would be some time before these processes achieve the PRGs and risk from exposure to contaminated groundwater would be addressed through institutional controls.

Groundwater use restrictions would effectively prevent the use of the surficial aquifer until the PRGs have been achieved.

Long-term monitoring would be an effective means to evaluate the progress of natural attenuation and detect the potential migration of contaminated groundwater.

Reduction of Toxicity, Mobility, or Volume through Treatment

Although no active treatment is included in this alternative, contaminant volume and toxicity would be reduced over time through natural degradation processes. This alternative would not provide an immediate reduction in contaminant mobility since no groundwater containment or extraction is proposed. This alternative would not increase the rate of natural transformation processes that reduce the toxicity, mobility, or volume of BHC in groundwater. Human health toxicity posed by ingestion of BHC in groundwater would remain until its concentration has been sufficiently reduced by natural processes. No treatment residuals would be produced if this alternative were implemented.

Short-term Effectiveness

Alternative 2 would have minimal short-term effectiveness concerns. Exposure of workers to contamination during the maintenance and sampling of monitoring wells would be minimized by wearing of appropriate PPE and complying with site-specific health and safety procedures. Alternative 2 would also not adversely impact the surrounding community or the environment.

The RAO would be achieved immediately upon implementation of institutional controls and monitoring. Based upon the results of the preliminary modeling presented in Appendix B, it is estimated that Alternative 2 would meet the groundwater PRGs for alpha- and beta-BHC through natural attenuation within 16 (β-BHC) to 32 months (α-BHC). As additional site-specific data becomes available the modeling can be further refined and the range of remedial duration narrowed.

Implementability

Alternative 2 would be readily implementable.

Maintenance of existing monitoring wells, sampling and analysis of groundwater, and performance of a 5-year review could readily be accomplished. The resources, equipment, and materials required to implement these activities are readily available.

The administrative aspects of Alternative 2 would be relatively simple to implement. No construction permits would be required for this alternative. As part of the change of the site from military to private ownership, appropriate provisions will be incorporated into the property transfer documents to ensure continued implementation of aquifer use restrictions and monitoring.

Cost

The estimated costs for Alternative 2 are:

- Capital Cost: $5,000
- NPW of O&M Costs: $84,000
- NPW: $89,000

The above figures have been rounded to the nearest $1,000 to reflect the preliminary nature of these estimates. A detailed breakdown of the cost estimate for this alternative is provided in Appendix C.

4.2.3 Alternative 3: In-Situ Enhanced Biodegradation, Institutional Controls, and Monitoring

4.2.3.1 Description

Alternative 3 is illustrated on Figure 4-2 and would consist of three major components: (1) In-situ enhanced biodegradation, (2) institutional controls. and (3) monitoring.

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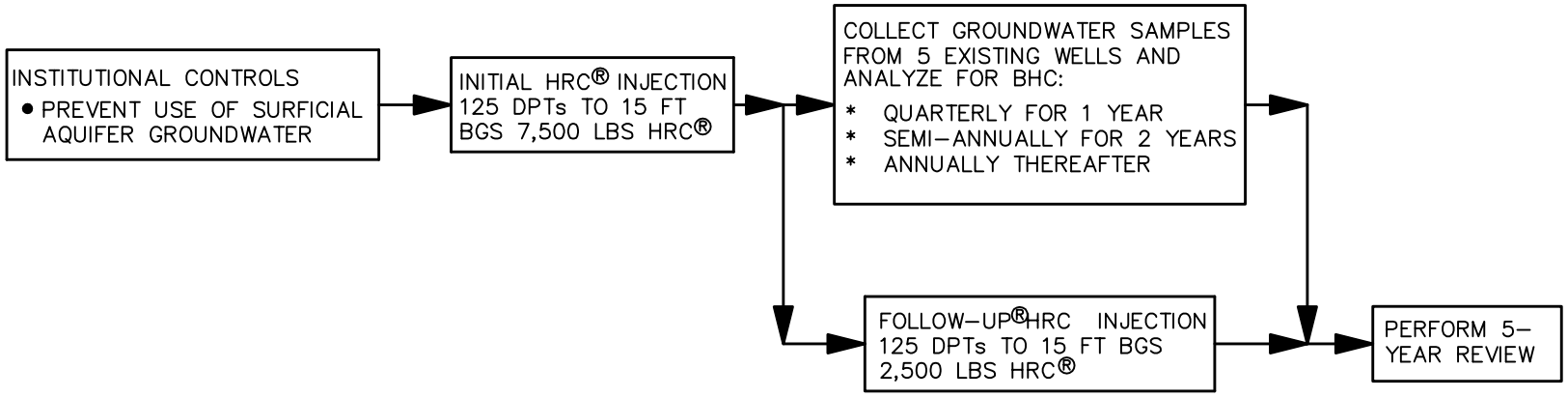
IN-SITU ENHANCED BIODEGRADATION, INSTITUTIONAL CONTROLS, AND MONITORING



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Component 1: In-situ Enhanced Biodegradation (HRC®/ORC®)

In-situ enhanced biodegradation would consist of using an HRC®, such as lactic acid, to enhance the growth of naturally-occurring microorganisms for the anaerobic degradation of BHC in the contaminant plume. A treatability study would be performed to verify the effectiveness of HRC® and to determine if an ORC®, such as magnesium peroxide, would also have to be applied to complete the remedial process by enhancing the aerobic biodegradation of BHC metabolites. For the purpose of this FS, it was assumed that results of the treatability study would indicate that no ORC® injection is required. HRC® would be injected in selected portions of the contaminant plume using DPT. As part of this component, groundwater samples would be regularly collected from the existing monitoring well located within the BHC plume (CEF-P25-01S). These samples would be analyzed for BHC and natural attenuation parameters to evaluate the progress of remediation.

Based upon the information received from a qualified remediation contractor specializing with this technology (REGENESIS, see Appendix A), the following HRC® treatment scheme is assumed:

- Initial application of HRC® with an injection system consisting of one hundred and twenty-five 15 ft deep DPTs in which HRC® would be injected at the rate of six pounds per foot of depth in the 5 to 15 ft bgs interval for a total application of 7,500 pounds.

- Follow-up application of HRC® approximately one year after the initial application. The DPT injection system would be identical (i.e., 125 locations) but with HRC® injected at the rate of two pounds per foot of depth, for a total application of 2,500 pounds.

Conceptual design calculations are included in Appendix A.

Component 2: Institutional Controls

This component would be identical to Component 2 of Alternative 2.

Component 3: Monitoring

This component would be identical to Component 3 of Alternative 2.

4.2.3.2 Detailed Analysis

Overall Protection of Human Health and the Environment

Alternative 3 would be protective of human health and the environment.

In-situ enhanced biodegradation would significantly reduce risk from exposure to BHC in the contaminated groundwater and provide protection to future human receptors who may use this aquifer as a potable water source.

Institutional controls would be protective of human health and the environment during the remedial period until the BHC PRGs are met. Preventing the use of the surficial aquifer groundwater would be protective of human health and the environment by avoiding unacceptable risks of exposure to contaminated groundwater.

Monitoring would be protective by evaluating the effectiveness of in-situ treatment and detecting potential migration of groundwater contaminants.

Some short-term risks could be incurred by workers from exposure to contamination during the implementation of this alternative. However, the potential for this exposure would be minimized by the wearing of appropriate PPE and compliance with site-specific health and safety procedures.

No adverse short-term or cross-media effects are anticipated as a result of implementing this alternative.

Compliance with ARARs and TBCs

Alternative 3 would eventually comply with chemical-specific ARARs and TBCs through in-situ groundwater treatment. Alternative 3 would also comply with location- and action-specific ARARs and TBCs.

Long-term Effectiveness and Permanence

Alternative 3 would provide long-term effectiveness and permanence.

In-situ enhanced biodegradation with the use of HRC® should effectively reduce concentrations of alpha- and beta-BHC in the contaminant plume to below their PRGs. However, a treatability study would be necessary to verify the effectiveness of the treatment process and determine if application of ORC® might be required as well.

Groundwater use restrictions would effectively prevent the use of the surficial aquifer groundwater until the BHC PRGs are met.

Long-term monitoring would be an effective means to evaluate the progress of remediation and verify that no contaminant migration is occurring.

The controls proposed in this alternative are considered reliable.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 3 would reduce the toxicity, mobility and volume of the contaminated groundwater. The in-situ enhanced biodegradation scheme provided under this alternative is designed to remove approximately 0.0006 pounds of BHC. The reduction in contaminant toxicity and volume would be completely irreversible.

Short-term Effectiveness

Alternative 3 would reduce human health risks in the short term because groundwater use restrictions would be implemented. Exposure of workers to contamination during installation of DPTs, injection of HRC®, and groundwater sampling would be minimized by compliance with the requirements of the Occupational Safety and Health Act (OSHA), including wearing of appropriate PPE and adherence to site-specific health and safety procedures. Implementation of institutional controls and monitoring would not adversely impact the surrounding community or the environment.

The RAO would be achieved immediately upon implementation of institutional controls and monitoring.

Based upon the results of similar application of HRC®, it is estimated that the in-situ enhanced biodegradation of this alternative would reduce the concentrations of alpha- and beta-BHC in the contaminant plume down to their PRGs within approximately 36 months.

Implementability

Alternative 3 would be readily implementable.

HRC® could readily be applied to the groundwater contaminant plume without unduly restricting the ability of Site 25 to function as an active airport support area. However, existing structures might interfere with the optimum placement of certain DPT injection points. A treatability study would have to be performed to

verify the effectiveness of HRC® application for the removal of BHC and to determine if ORC® application would be required. Qualified contractors are available to perform this work. Sampling and maintenance of existing monitoring wells and performance of a 5-year review could readily be accomplished. The resources, equipment, and materials required for these activities are readily available. There would be no treatment residuals associated with implementation of this alternative.

The administrative aspects of Alternative 3 would be relatively simple to implement. Construction permits would be required for this alternative. As part of the change of the site from military to private ownership, appropriate provisions will be incorporated into the property transfer documents to ensure continued implementation of land and aquifer use restrictions and monitoring.

Cost

The estimated costs for Alternative 3 are:

- Capital Cost: $485,000
- NPW of O&M Cost: $93,000
- NPW: $578,000

A detailed breakdown of the cost estimate for this alternative is provided in Appendix C.

4.2.4 Alternative 4: Extraction, On-Site Treatment, Surface Discharge, Institutional Controls, and Monitoring

4.2.4.1 Description

Alternative 4 is illustrated on Figure 4-3 and would consist of five major components: (1) groundwater extraction, (2) on-site treatment, (3) discharge to surface water, (4) institutional controls, and (5) monitoring. A typical process flow diagram (PFD) for components (1) and (2) is shown on Figure 4-4.

Component 1: Groundwater Extraction

This component would consist of installing a groundwater extraction well system and operating that system for a period of 5 years. Preliminary design calculations for this component are provided in Appendix A.

Based upon analysis of the known hydrogeological characteristics of Site 25, the groundwater extraction system would consist of two wells (EW-1, EW-2) located near the center of the BHC plume as shown on

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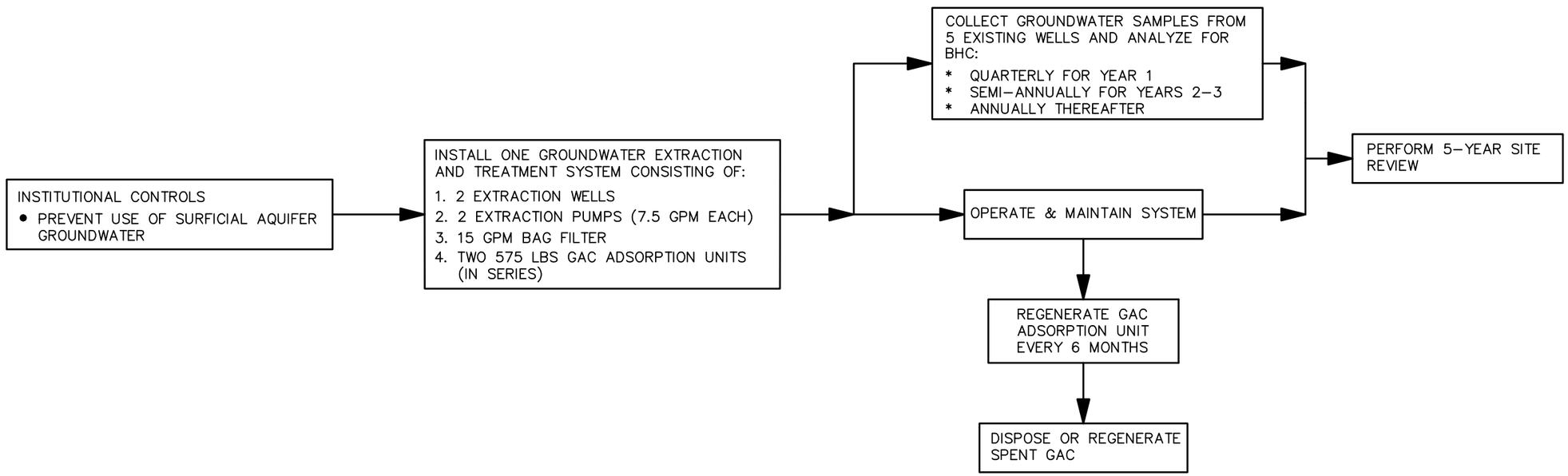
EXTRACTION, ON-SITE TREATMENT, SURFACE DISCHARGE INSTITUTIONAL CONTROLS, AND MONITORING



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BLOCK FLOW DIAGRAM
ALTERNATIVE 4
SITE 25 FS
NAS CECIL FIELD
JACKSONVILLE, FLORIDA

CONTRACT NO. 0039
APPROVED BY DATE
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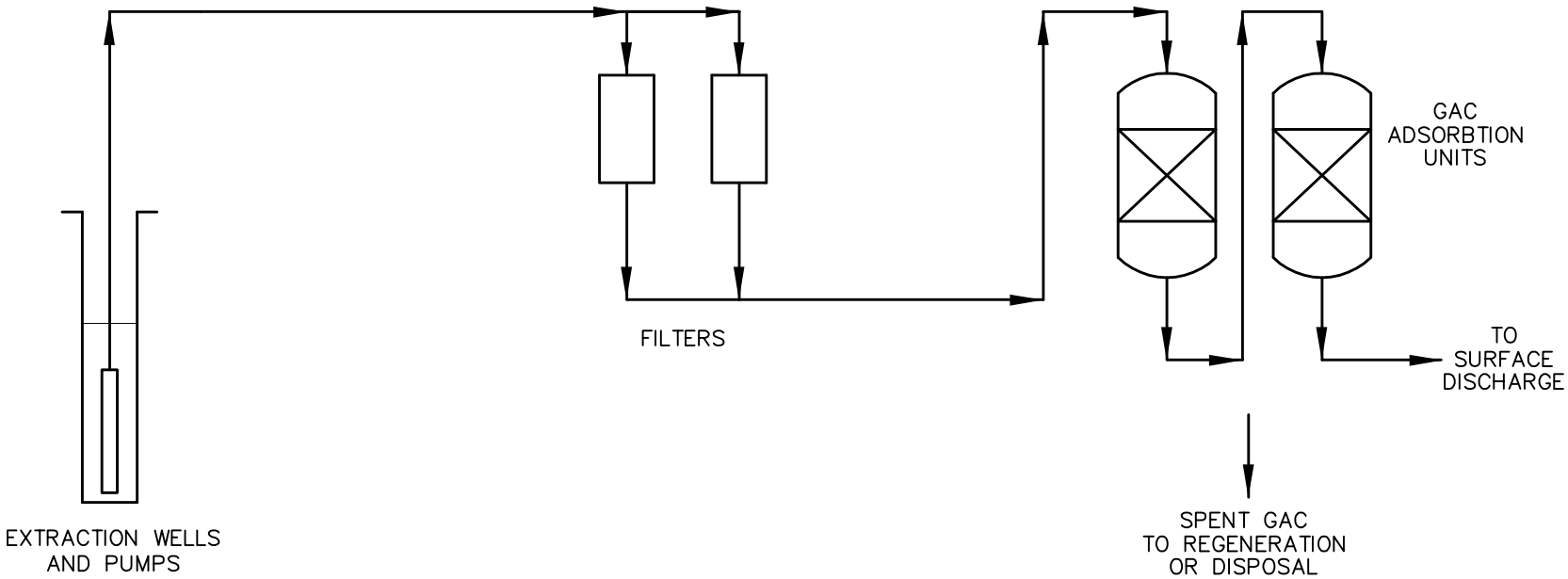

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PROCESS FLOW DIAGRAM
TYPICAL GROUNDWATER EXTRACTION & TREATMENT SYSTEM
ALTERNATIVE 4 – SITE 25 FS
NAS CECIL FIELD
JACKSONVILLE, FLORIDA

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Figure 4-5. This extraction wells would be screened from approximately 5 to 17 ft bgs and would each pump at the rate of 7.5 gallons per minute (gpm), for a total extraction rate of 15 gpm. A submersible centrifugal pump equipped with level controls would be installed in each groundwater extraction well. That pump would be connected to a pipeline network that would convey the extracted groundwater to an on-site treatment system.

Component 2: On-Site Treatment

This component would consist of installing an on-site treatment system and operating this system for a period of 10 years. The groundwater treatment system would be housed in a 200-square-foot pre-engineered and pre-fabricated building and would consist of the following sequence of unit processes:

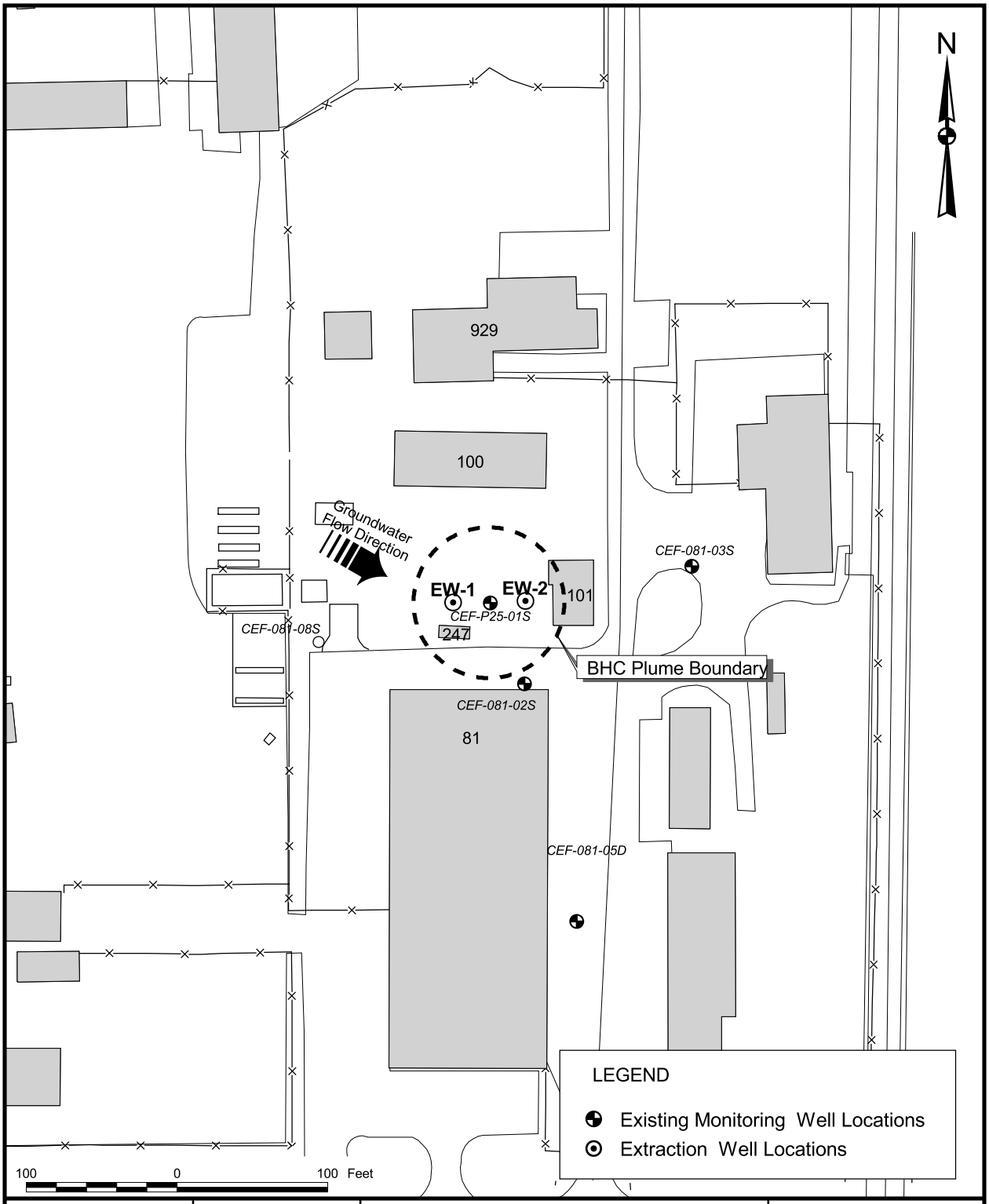
- Filtration
- Liquid-Phase GAC Adsorption

The design flow of the treatment system would be 15 gpm. Conceptual design calculations for the groundwater treatment system are provided in Appendix A.

The extracted groundwater would enter the treatment system through a filter unit. The purpose of this filter unit would be to remove most of the suspended solids that might be present in the groundwater at Site 25 and if not removed, could result in premature fouling of the downstream GAC adsorption unit. The filter unit would be of the pressurized type and would be equipped with multiple disposable filter elements installed in parallel to allow for continued service during the periodic replacement of a clogged element. Clogged filter elements would be disposed off site and replaced with fresh ones.

The filtered groundwater, still under pressure, would then flow to a liquid-phase GAC adsorption unit. This unit would consist of two canisters, each holding 575 pounds of GAC and operating in series. The low concentrations of BHC in the filtered groundwater would be completely removed by the lead GAC adsorption canister and the lag canister would only be provided for contingency purposes. It is anticipated that the lead GAC adsorption unit will have to be replaced approximately every 5 months during the 10 years of operation of the treatment system. Both the lead and lag adsorption unit would feature backwash capabilities to deal with potential long-term accumulation of suspended solids in the GAC beds.

The treated groundwater effluent would be conveyed under residual pressure to its discharge point.



DRAWN BY MJJ	DATE 31Jan01	LOCATION OF GROUNDWATER EXTRACTION WELLS ALTERNATIVE 4 SITE 25 FEASIBILITY STUDY REPORT NAVAL AIR STATION CECIL FIELD JACKSONVILLE, FLORIDA	CONTRACT NUMBER 0039
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Performance of the treatment system would be monitored. Performance monitoring would consist of collecting monthly water samples from the inlet and outlet of the treatment system and analyzing these samples for BHC and general water-quality parameters.

Component 3: Discharge to Surface Water

Treated groundwater would be discharged to the nearest storm drainage ditch. Sampling of treated groundwater would be required to satisfy the substantive requirements of an NPDES permit, as administered by the State of Florida. Sampling and analysis would be as described for treatment system performance monitoring under Component 2.

Component 4: Institutional Controls

This component would be identical to Component 2 of Alternative 2.

Component 5: Monitoring

This component would be identical to Component 3 of Alternative 2.

4.2.4.2 Detailed Analysis

Overall Protection of Human Health and the Environment

Alternative 4 would be protective of human health and the environment.

The extraction of contaminated groundwater and its treatment by use of liquid-phase GAC adsorption followed by discharge of the treated water would significantly reduce risk from exposure to BHC in the contaminated groundwater and provide protection to future human receptors who may use this aquifer as a potable water source.

Institutional controls would be protective of human health and the environment during the remedial period until the BHC PRGs are met. Preventing the use of the surficial aquifer groundwater would be protective of human health and the environment by avoiding unacceptable risks of exposure to contaminated groundwater.

Monitoring would be protective by evaluating the effectiveness of groundwater extraction and treatment and detecting potential migration of groundwater contaminants.

Some short-term risks could be incurred by workers from exposure to contamination during the implementation of this alternative. However, the potential for this exposure would be minimized by the wearing of appropriate PPE and compliance with site-specific health and safety procedures.

No adverse short-term or cross-media effects are anticipated as a result of implementing this alternative.

Compliance with ARARs and TBCs

Alternative 4 would eventually comply with chemical-specific ARARs and TBCs through a combination of groundwater extraction and treatment. Alternative 4 would also comply with location- and action-specific ARARs and TBCs.

Long-term Effectiveness and Permanence

Alternative 4 would provide long-term effectiveness and permanence.

Extraction and on-site treatment of the groundwater from the contaminant plume would effectively remove BHC from groundwater. Extraction is a well-established technology for the control and remediation of groundwater contaminant plumes. Liquid-phase GAC adsorption is a well-proven technology for the removal of pesticides such as BHC from contaminated groundwater.

Groundwater use restrictions would effectively prevent the use of the surficial aquifer groundwater until the BHC PRGs are met.

Long-term monitoring would be an effective means to evaluate the progress of remediation and verify that no contaminant migration is occurring.

The controls proposed in this alternative are considered reliable.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 4 would reduce the toxicity, mobility, and volume of the contaminated groundwater. The groundwater extraction and treatment system provided under this alternative is designed to remove and treat approximately 0.0006 pounds of BHC over its operating life. Regeneration and/or disposal of the spent GAC would ensure that the reduction in contaminant toxicity and volume is completely irreversible.

Short-term Effectiveness

Alternative 4 would reduce human health risks in the short term because groundwater use restrictions would be implemented. Exposure of workers to contamination during installation of groundwater extraction wells, construction and operation of the groundwater treatment system, and groundwater sampling would be minimized by compliance with OSHA requirements, including wearing of appropriate PPE and adherence to site-specific health and safety procedures. Implementation of institutional controls and monitoring would not adversely impact the surrounding community or the environment.

The RAO would be achieved immediately upon implementation of institutional controls and monitoring.

Based upon the results of the preliminary groundwater modeling presented in Appendix A, it is estimated that the groundwater extraction and treatment system of Alternative 4 would reduce the concentrations of BHC in the contaminant plume down to their PRGs within approximately 25 months.

Implementability

Alternative 4 would be readily implementable.

A groundwater extraction and treatment system could readily be constructed and operated without unduly restricting the ability of Site 25 to function as an active airport support area. Qualified personnel would be needed to operate and to maintain this system, but such personnel are available. Sampling and maintenance of existing monitoring wells and performance of a 5-year review could readily be accomplished. The resources, equipment, and materials required for these activities are readily available.

The surface discharge of the treated water would also be implementable. Storm sewers are located in the vicinity of Site 25 and would be available for such discharge. In order to discharge treated water to the storm sewer system, the substantive requirement of an NPDES permit would have to be met.

Treatment residuals would be produced during treatment including clogged filter elements and spent GAC but disposal and/or regeneration of these would be readily implementable.

The administrative aspects of Alternative 4 would be relatively simple to implement. Construction permits would be required for this alternative. As part of the change of the site from military to private ownership, appropriate provisions will be incorporated into the property transfer documents to ensure continued implementation of land and aquifer use restrictions and monitoring.

Cost

The estimated costs for Alternative 4 are:

- Capital Cost: $423,000
- NPW of O&M Cost: $279,000
- NPW: $702,000

A detailed breakdown of the cost estimate for this alternative is provided in Appendix C.

5.0 COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

This section compares the analyses that were presented for each of the remedial alternatives in Section 4.0 of this FS. The criteria for comparison are identical to those used for the detailed analysis of individual alternatives.

5.1 COMPARISON OF REMEDIAL ALTERNATIVES BY CRITERIA

The following remedial alternatives for groundwater are being compared in this section:

- Alternative 1: No Action
- Alternative 2: Natural Attenuation, Institutional Controls, and Monitoring
- Alternative 3: In-Situ Enhanced Biodegradation, Institutional Controls, and Monitoring
- Alternative 4: Extraction, On-Site Treatment, Surface Discharge, Institutional Controls, and Monitoring

5.1.1 Overall Protection of Human Health and the Environment

Alternative 1 would not provide protection of human health and the environment because contaminants would remain in groundwater and potential use of surficial aquifer groundwater could result in unacceptable risk to human and ecological receptors. Also, under this alternative, no warning would be provided of the potential for migration of BHC in groundwater since no monitoring would occur.

Alternatives 2, 3, and 4 would be protective of human health and the environment.

The institutional controls component of these alternatives would be protective of human health and the environment as they would reduce exposure to contaminated groundwater by preventing use of the surficial aquifer groundwater at Site 25.

The monitoring component of these alternatives would be protective of human health and the environment by evaluating the progress of remediation and detecting potential migration of contaminated groundwater so that appropriate contingency measures can be taken.

Although Alternative 2 would allow the contaminated plume to continue expanding, it would be protective of human health and the environment since natural attenuation would eventually reduce the concentrations of alpha- and beta-BHC down to their PRGs over time.

Alternatives 3 and 4 would be more protective than Alternative 2 as they would significantly accelerate the natural attenuation of BHC through either in-situ enhanced biodegradation or extraction and on-site treatment of contaminated groundwater.

5.1.2 Compliance with ARARs and TBCs

Alternative 1 would not comply with chemical- and location-specific ARARs. Action-specific ARARs or TBCs would not apply.

In the short-term, Alternatives 2, 3, or 4 would not comply with chemical-specific ARARs and TBCs but all three would eventually achieve compliance as they attain the BHC PRGs through natural attenuation or active remediation. The alternative to achieve compliance first would be Alternative 3.

5.1.3 Long-term Effectiveness and Permanence

Alternative 1 would have very limited long-term effectiveness and permanence because no contaminant removal or reduction would occur through treatment although, over time, some contaminant reduction might occur through natural attenuation. As there would be no institutional controls to limit the use of the surficial aquifer groundwater, the potential would also exist for unacceptable risk to develop due to exposure to contaminated and groundwater. Since there would be no monitoring, potential migration of contaminants would remain undetected.

Alternatives 2, 3, and 4 would provide long-term effectiveness and permanence.

The institutional controls component of these alternatives would effectively prevent the use of the surficial aquifer groundwater until the BHC PRGs are met.

The long-term monitoring component of these alternatives would provide an effective means of evaluating the progress of remediation and verifying that no contaminant migration is occurring.

Alternative 2 would provide long-term effectiveness and permanence since natural attenuation would eventually reduce concentrations of alpha- and beta-BHC in groundwater down to their PRGs.

Alternatives 3 and 4 would be more long-term effective and permanent than Alternative 2 since they would both accelerate the remediation process and irreversibly remove BHC from the contaminant plume through either in-situ biodegradation or extraction and on-site treatment. However, the effectiveness of the HRC® application proposed for Alternative 3 would have to be verified through a treatability study.

5.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives 1 and 2 would not achieve any reduction of toxicity, mobility, or volume of contaminants through treatment. Both alternatives would achieve reduction of contaminant toxicity and volume through natural attenuation, however, under Alternative 1, this reduction would neither be verified nor quantified.

Alternatives 3 and 4 would remove an estimated 0.0006 pounds of BHC from the contaminant plume through either in-situ enhanced biodegradation or extraction and on-site treatment. In either case, contaminant removal would be completely irreversible.

5.1.5 Short-term Effectiveness

Implementation of Alternative 1 would not result in risks to site workers or adversely impact the surrounding community or environment since no remedial activities would be performed. Alternative 1 would never achieve the RAO and although the BHC PRGs might eventually be attained through natural processes, this would not be verified.

Implementation of Alternative 2 would result in a slight possibility of exposing site workers to contaminated groundwater during the sampling and maintenance of existing monitoring wells. However, these risks of exposure would be effectively controlled by wearing appropriate PPE and compliance with proper site-specific health and safety procedures. Implementation of Alternative 2 would not adversely impact the surrounding community or environment. Alternative 2 would achieve the RAO immediately upon implementation of institutional controls and monitoring. The BHC PRGs would be attained within an estimated 16 (β-BHC) to 32 months (α-BHC).

Implementation of Alternatives 3 and 4 would result in a possibility of exposing construction workers to contaminated groundwater during the installation of DPT injection points or a groundwater extraction and on-site treatment system. Implementation of Alternative 4 would also result in the possibility of exposing O&M personnel to contaminated groundwater during the operation of the on-site treatment system and the monitoring of groundwater. However, these risks of exposure would be effectively controlled by the implementation of engineering controls (e.g., dust suppression, offgas treatment), by the wearing of appropriate PPE, and by compliance with applicable OSHA regulations and proper site-specific health and safety procedures. Implementation of Alternatives 3 and 4 would not adversely impact the surrounding community and environment. Alternatives 3 and 4 would achieve RAO immediately upon implementation of institutional controls and monitoring. The BHC PRGs would be met within an estimated 36 months for Alternative 3 and 25 months for Alternative 4.

5.1.6 Implementability

Alternative 1 would be very simple to implement since no action would occur.

Alternatives 2, 3, and 4 would be technically implementable.

The technical implementability of Alternative 2 would be simpler than that of Alternatives 3 or 4, since it would only require implementation of the institutional controls and monitoring.

The technical implementability of Alternative 3 would be slightly more difficult than that of Alternative 2 since, in addition to institutional controls and monitoring, this alternative would require the installation of DPT injection points and the periodic application of HRC®. Alternative 3 would also require the performance of a treatability study to verify the effectiveness of HRC® application and determine if ORC® application would be required as well. Qualified contractors are readily available to perform all of these tasks. No treatment residues would be associated with this alternative.

The technical implementability of Alternative 4 would be slightly more difficult than that of Alternative 3 since this alternative would require the installation and O&M of a relatively small groundwater extraction and treatment system. Although qualified personnel would be required over the long-term for the O&M of these systems, such personnel would be readily available. Discharge of the treated groundwater to surface water would also be technically simple to implement, as storm sewers are present in the immediate vicinity of Site 25, which could be used for this purpose. Alternative 4 would generate treatment residues, including clogged filter elements and spent GAC, but disposal and/or regeneration of these materials would be reasonably easy to accomplish.

Administrative implementability of Alternative 2 would be very simple. Performance of a 5-year review and notification to the St. John's Water Authority could readily be accomplished. Administrative implementability of Alternatives 3 and 4 would be slightly more complex than that of Alternative 2 because these alternatives would also require permits for the construction of the in-situ or on-site groundwater treatment systems. However, these permits could readily be secured.

5.1.7 Cost

The capital and O&M costs and NPW of the groundwater alternatives are as follows.

Alternative	Capital ($)	NPW of O&M ($)	NPW ($)
1	0	0	0
2	5,000	84,000	89,000
3	485,000	93,000	578,000
4	423,000	209,000	702,000

Detailed cost estimates are provided in Appendix C.

5.2 SUMMARY OF COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

Table 5-1 summarizes the comparative analysis of the four groundwater remedial alternatives.

TABLE 5-1

SUMMARY OF COMPARATIVE EVALUATION OF ALTERNATIVES
SITE 25 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

Evaluation Criteria	Alternative 1: No Action	Alternative 2: Natural Attenuation, Institutional Controls, and Monitoring	Alternative 3: In-Situ Enhanced Biodegradation, Institutional Controls, and Monitoring	Alternative 3: Extraction, On-Site Treatment, Surface Discharge, Institutional Controls, and Monitoring
Overall Protection of Human Health and Environment	Would not be protective because there would be a continued risk from human exposure to contaminated groundwater. Also, potential contaminant migration would remain unchecked.	Would be protective by preventing risk from exposure to contaminated groundwater through institutional controls and monitoring.	Would be more protective than Alternative 2 by providing the same protective components plus elimination of risk from exposure to contaminated groundwater through active biodegradation of BHC.	Would be as protective as Alternative 3. by eliminating risk from exposure to contaminated groundwater through extraction and treatment.
Compliance with ARARs and TBCs:				
Chemical-Specific	Would not comply	Would eventually comply	Would eventually comply	Would eventually comply
Location-Specific	Would not comply	Would comply	Would comply	Would comply
Action-Specific	Not applicable	Would comply	Would comply	Would comply
Long-Term Effectiveness and Permanence	Would not be long-term effective and permanent since contaminants would remain on-site. Any long-term effectiveness would not be known since monitoring would not occur.	Would be long-term effective and permanent. Land and groundwater use restrictions and monitoring would effectively prevent unacceptable risk from exposure to contaminated groundwater.	Would be more long-term effective and permanent than Alternative 2 since it would actively cleanup contaminated groundwater in addition to institutional controls and monitoring. A treatability study would be required to verify effectiveness of HRC® application.	Would be slightly more long-term effective and permanent as Alternative 3 since it would also actively cleanup contaminated groundwater but with use of a well-proven technology which does not require demonstration.
Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment	Would not achieve reduction of toxicity, mobility, or volume of contaminants through treatment but might achieve some reduction through natural processes.	Would not achieve reduction of toxicity, mobility, or volume of contaminants through treatment but would achieve some reduction through natural processes.	Would achieve reduction of contaminant toxicity, mobility, and volume through treatment.	Would achieve reduction of contaminant toxicity, mobility, and volume through treatment.
Short-Term Effectiveness	Would not result in short-term risks to site workers or adversely impact the surrounding community but would also not achieve RAO through treatment.	Would result in slight risk of exposure to site workers during sampling of groundwater. This risk would be reduced through the wearing of appropriate PPE and the compliance with site-specific health and safety procedures. RAO would be achieved immediately upon implementation. PRGs would be attained within an estimated 16 (β-BHC) to 32 months (α-BHC).	Would result in slight risk of exposure to site workers during the installation of DPTs, application of HRC®, and the sampling of groundwater. This risk would be reduced through the wearing of appropriate PPE and the compliance with site-specific health and safety procedures. RAO would be achieved immediately upon implementation. PRGs would be attained within 36 months.	Would result in slight risk of exposure to site workers during the installation and operation of the groundwater extraction and treatment system and the sampling of groundwater. This risk would be reduced through the wearing of appropriate PPE and the compliance with site-specific health and safety procedures. RAO would be achieved immediately upon implementation. PRGs would be attained within 25 months.
Implementability	Would be simple to implement since no action would occur.	Would be easy to implement. Resources, materials, and equipment are readily available. Provisions will be incorporated into the property transfer documents to ensure the continuation of the institutional controls and monitoring when ownership of the site are transferred to the private sector. A construction permit would be required.	Would be slightly more difficult to implement than Alternative 2 since, in addition to institutional controls and monitoring, DPTs would have to be installed and HRC® periodically applied. Also, a treatability study would have to be performed. Provisions will be incorporated into the property transfer documents to ensure the continuation of the institutional controls and monitoring when ownership of the site are transferred to the private sector. A construction permit would be required. No treatment residues would be generated.	Would be slightly more difficult to implement than Alternative 3 since a groundwater extraction and treatment system would have to be installed, operated, and maintained. Provisions will be incorporated into the property transfer documents to ensure the continuation of the institutional controls and monitoring when ownership of the site are transferred to the private sector. A construction permit would be required. Clogged filter elements and spent GAC would have to be periodically disposed and/or regenerated.
Costs:				
Capital	$0	$5,000	$485,000	$423,000
NPW of O&M	$0	$24,000	$93,000	$279,000
NPW	$0	$89,000	$578,000	$702,000

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APPENDIX A

CONCEPTUAL DESIGN CALCULATIONS

A.1 HRC® Injection System Design
A.2 Groundwater Extraction System Design
A.3 Groundwater Treatment System Design

A.1

HRC® INJECTION SYSTEM DESIGN

Tetra Tech NUS			STANDARD CALCULATION SHEET
CLIENT: USN SouthDiv CLEAN	FILE No: 0039DS011E220	BY: JLG	PAGE: 1 OF 1
SUBJECT: NAS Cecil Field, Site 25 FS Alternative 3: In-Situ Enhanced Biodegradation		CHECKED BY:	DATE: 01/31/01

1.0 DESIGN ASSUMPTIONS

The following design assumptions are made based upon the results of the RI and previous investigations:

- The only COCs are α-BHC and β-BHC.
- The contaminant plume where α-BHC and β-BHC concentrations exceed PRGs (0.06 and 0.2 μg/L) extends in a circular area 100 ft in diameter and centered on well CEF-P25-01S
- The depth to which α-BHC and β-BHC concentrations exceed PRGs extends to 15 ft bgs.
- Average total BHC (α-, β-, γ-) concentration within the contaminant plume is approximately 0.48 μg/L, which is the mathematical average of the concentrations detected at well CEF-P25-01S. Maximum total BHC concentration is 0.67 μg/L.

2.0 CONTAMINANT PLUME AREA AND VOLUME

Contaminant plume area, as shown on Figure 4-5: $\pi \times (100)^2 \div 4 = 7{,}854\ ft^2$.

Based upon a typical groundwater table depth of 5 ft bgs and on the above assumption for depth of BHC contamination, the average thickness of the contaminant plume is approximately 10 ft (5 to 15 ft bgs).

Based on a porosity of 0.25, that is typical at NAS Cecil Field, the design volume of the contaminant plume is:

$7{,}854\ ft^2 \times 10\ ft \times 0.25 = 19{,}635\ ft^3$ or 147,000 gallons.

3.0 TREATMENT SCHEME

The treatment scheme would consist of enhancing naturally-occurring biodegradation processes by injecting an hydrogen release compound (HRC®) for BHC remediation. This compound would be injected in the contaminant plume groundwater using direct-push technology (DPT).

Remedial action duration for enhanced bioremediation is hard to predict and highly variable, ranging from as short as 1 to 2 years to as long as 20 years or more. It is assumed that remedial action duration would be approximately 5 years.

4.0 DPT INJECTION SYSTEM

As per attached REGENESIS HRC® pilot-scale treatability study recommendation and additional input from 01/31/01 phone conversation with Craig Sandefur, the conceptual design of the full-scale HRC® injection system is based upon the following assumptions:

- Nominal spacing between each DPT injection point: 8 ft

- Initial application of HRC® at the rate of 6 pounds per foot of depth with one follow-up application at the rate of 2 pounds per foot

Number of DPT injection points:

$7{,}854\ ft^2 \div 64\ ft^2/DPT = 122.7$, say 125 DPTs installed to 15 ft bgs

Initial HRC® application: 125 DPTs x 6 lbs/ft x (15-5) ft = 7,500 lbs HRC®

Follow-up HRC® application: 125 DPTs x 2 lbs/ft x (15-5) ft = 2,500 lbs HRC®

REGENESIS

March 23, 2000

Shawn Scaff
Tetra Tech NUS, Inc.
661 Anderson Drive
Pittsburgh, Pennsylvania 15220-2745
Fax: 412-921-7276

Subject: A Pilot Test Approach for Accelerated Bioremediation of Pesticides at the Naval Air Station Cecil Field, Jacksonville FL Site

Dear Shawn:

We have reviewed the information that you provided for the above referenced site. In the following sections, we provide design and cost information for a pilot scale remedial approach. This proposal includes a number of technical assumptions that should be addressed prior to full-scale application

Use of HRC to Accelerate Bioremediation

Hydrogen Release Compound (HRC) is typically used to enhance in situ biodegradation rates for chlorinated hydrocarbons (CHs) by fueling anaerobic reductive dechlorination processes. Reductive dechlorination is recognized as one of the primary attenuation mechanisms by which chlorinated solvent groundwater plumes can be contained and/or remediated. By extension, use of HRC for the reductive dechlorination of pesticides is an appropriate and reasonable approach.

Anaerobic degradation of chlorinated pesticides such as lindane has been documented in the literature. The following is a brief list of work focused on the anaerobic degradation of pesticides: Bachmann (1988), Camacho (1999), Haider (1975), Jagnow (1977), Langenhoff (1999), Middlethorp (1996) and Van Eekert (1998). In conjunction with planned field activites at the Rocky Mountain Arsenal, Regenesis recently completed a laboratory test of the biodegradation of dieldrin using HRC. Results of the test demonstrated rapid degradation of dieldrin (within a 7 day period). A copy of this report is attached.

Review of the literature indicates that some anaerobic degradation intermediates of pesticides may be more rapidly degraded under aerobic conditions. Therefore, it may be appropriate to set up a sequential anaerobic/aerobic treatment approach at some future date, depending on the results of the groundwater monitoring program. If it is determined that intermediates are an issue at Sites 11, 21 or 25 we suggest application of Oxygen Release Compound (ORC®) to improve biodegradation rates.

Of the contaminants of concern for Sites 11, 21 and 25, it is not clear, nor is there a direct basis upon which to judge which contaminant will be more difficult to degrade/remove. This is a result of a lack of information and experience with these contaminants within the scientific and industrial communities.

HRC is a proprietary polylactate ester that, upon being deposited into the subsurface, slowly releases lactate. Lactate is metabolized by naturally occurring microorganisms, resulting in the creation of anaerobic aquifer conditions and the production of hydrogen. Naturally occurring microorganisms capable of reductive dechlorination then use the hydrogen to progressively remove chlorine atoms from chlorinated contaminants.

HRC is manufactured as a viscous gel that can be injected into the saturated zone in a grid configuration for localized area-based treatment approaches or in a barrier configuration for plume containment-based remediation designs. The use of HRC for groundwater remediation offers a comparatively simple and cost effective remediation alternative for sites that would otherwise require unacceptably long periods of time for natural attenuation or the high levels of capital investment and operating expense associated with active remediation technologies.

Design Basis/Assumptions

Using the information you provided, we have made the following assumptions to estimate pilot test design variables and dose amounts.

- Three separate application Sites (11, 21 and 25): dimension of 40 x 40 feet
- Representative contaminant concentration range for each application area:
  - Site 11: 1,2-Dibromo-3-chloropropane 1-34 ug/L
  - Site 21: Chlordane 3 ug/L
  - Site 25: a-BHC 12ug/L; b-BHC 0.12ug/L; g-BHC 0.42ug/L
- Contaminated saturated zone thickness requiring treatment: 10 feet (5 to 15 feet bgs).
- Estimated groundwater velocity: up to 27 feet/year.
- A 50% reapplication dose of the pilot study area is assumed to be needed to maintain the activity of the reductive dechlorination processes.
- Aquifer geochemistry and electron acceptor concentrations: oxygen <2 ppm, nitrate <2 ppm, manganese reduction demand <5 ppm, ferric iron reduction potential <20 ppm, and sulfate reduction demand <40 ppm. Higher CEA-based electron donor demand may require increased amounts of HRC to achieve remedial goals.

Pilot-Scale Field Design

Design parameters for the field test are described below:

Site 11 – 1,2 Dibromo-3-chloropropane

Field Test Design Feature	Specification
Contaminated saturated thickness	10 feet
Number of delivery locations	25 locations (5 rows of 5 injection points)
Application rate	4 lbs/vertical foot
Initial HRC material application and Cost at $6/lb for 30 lb buckets	(25 pts.) x (10 feet) x (4 lbs/ft) = 1,000 lbs $6,000 + shipping
Second application	(25 pts.) x (10 feet) x (2 lbs/ft) = 500 lbs $3,000 + shipping

Site 21 - Chlordane

Field Test Design Feature	Specification
Contaminated saturated thickness	10 feet
Number of delivery locations	25 locations (5 rows of 5 injection points)
Application rate	4 lbs/vertical foot
Initial HRC material application and Cost at $6/lb for 30 lb buckets	(25 pts.) x (10 feet) x (4 lbs/ft) = 1,000 lbs $6,000 + shipping
Second application	(25 pts.) x (10 feet) x (2 lbs/ft) = 500 lbs $3,000 + shipping

Increased to 6 lbs/ft per conversation of 01/31/01 with Craig Sandefur

Site 25 - Lindane

Field Test Design Feature	Specification
Contaminated saturated thickness	10 feet
Number of delivery locations	25 locations (5 rows of 5 injection points)
Application rate	4 lbs/vertical foot
Initial HRC material application and Cost at $6/lb for 30 lb buckets	(25 pts.) x (10 feet) x (4 lbs/ft) = 1,000 lbs $6,000 + shipping
Second application	(25 pts.) x (10 feet) x (2 lbs/ft) = 500 lbs $3,000 + shipping

A.2

GROUNDWATER EXTRACTION SYSTEM DESIGN

Project:	Cecil Field	Project No.:	0039 DSO 11E220
Subject:	Site 25 Groundwater Extraction System FS Design		
By:	JPO	Date:	3/28/2001
Checked:	RM	Date:	

Project/Design Objective:

Design a groundwater extraction system for cleanup of alpha-BHC and beta-BHC contamination. Project cleanup rates/times assuming that the source has been removed or is otherwise isolated from the groundwater. The final design should be capable of remediating groundwater within a reasonable time frame (< 30 years), and should offer significant advantages over natural processes in terms of cleanup rate and/or protection of receptors. This design should be considered a conceptual design only - additional field data, i.e., aquifer characteristics, contaminant distributions are needed for a final design.

Basis of Design Data:

Groundwater Plume Information

Plume Width (W):	100	ft.
Plume Thickness:	10	ft.
Plume Area:	7854	ft^2
Plume Volume:	19635	ft^3

Aquifer Characteristics

Thickness (B):	95	ft.
Hydraulic Conductivity (K):	7.65	ft/day
Transmissivity (T):	726.75	ft^2/day
Porosity (n):	0.25	
Storativity (S):	0.25	
Fractional organic carbon content (foc):	0.0075	
Flow Gradient (i):	0.0009	

Contaminant Characteristics

Contaminant A representative gw conc.:	alpha-BHC	0.06	ug/L
Contaminant B representative gw conc.:	beta-BHC	0.074	ug/L
Koc, Contaminant A:		1,790	
Koc, Contaminant B:		2140	
Kd, Contaminant A:		13.425	
Kd, Contaminant B:		16.05	
Half-life, Contaminant A:		0.74	years
Half-life, Contaminant B:		0.68	years
Target Cleanup Level, Contaminant A:		0.005	ug/L
Target Cleanup Level, Contaminant B:		0.02	ug/L

Remedial System Information

Extraction Well Radius, (r) :	0.25	ft.
Time to Reach Steady-State Drawdown (t):	30	days
Allowable Drawdown, Single Well, (s):	3	ft.

Technical Approach:

Using aquifer characteristics, plume volume (use 2x plume volume to factor in plume thickness << aquifer thickness), Kd, half-life, and representative groundwater concentration data, calculate the number of pore volumes and times required to reach the target groundwater concentration (performed using the attached spreadsheets). Use standard equations to calculate the minimum required pumping rate for plume containment, per-well achievable pumping rates, and well spacings. Develop a preliminary extraction system design based on the calculations, adjusting the design as appropriate based on data limitation considerations and best scientific judgement.

Minimum Required Total Pumping Rate (Qt)

Qt = TiW x 2 (2x the natural groundwater flow-through rate)

Qt = 65.41 ft^3/day x 2, or 0.34 gpm x 2

Qt = 130.82 ft^3/day, or 0.68 gpm

Maximum Achievable Pumping Rate in a Single Well (Qa)

Qa = $[4\pi Ts/2.3] / \log [2.25Tt/r^2S]$

Qa = 1833.52 ft^3/day, or 9.52 gpm

Minimum Number of Extraction Wells Required

= Qt/Qa

= 0.07 wells

Plume Cleanup Rate Projections (From Spreadsheet Program or Other Source)

Contaminant A:				
	At	5.00	gpm,	2.4 years
	At	10.00	gpm,	2.25 years
	At	15.00	gpm,	2.1 years
	At		gpm,	years
At natural GW flow rate:		0.34	gpm,	2.6 years

Plume Cleanup Rate Projections (From Spreadsheet Program or Other Source)

Contaminant B:				
	At	5.00	gpm,	1.2 years
	At	10.00	gpm,	1.1 years
	At	15.00	gpm,	1.1 years
	At		gpm,	years
At natural GW flow rate:		0.34	gpm,	1.3 years

Based on the limiting conditions calculated above, projections regarding cleanup times at various pumping rates (see accompanying spreadsheets), a suitable safety factor based on the degree of confidence in the design data, and best scientific judgement, the following are the number of extraction wells and pumping rates selected:

Number of Wells:	2		
Per-well Pumping Rate (Qw):	7.5	gpm, or	1443.83 ft^3/day
Total System Pumping Rate (Qes):	15	gpm, or	2887.65 ft^3/day

Extraction Well Spacings, (WSp), ft Perpendicular to Groundwater Flow Direction

WSp = $Qw/\pi Ti$, for a 2-well extraction system

WSp = 702.65 ft

or

WSp = $1.26(Qw)/\pi Ti$, for a 3-well extraction system

WSp = 885.33 ft

or

WSp = $1.2(Qw)/\pi Ti$, for an extraction system with 4+ wells

WSp = 843.17 ft

Downgradient Stagnation Point (SPd) Approximation

SPd = $Qes/2\pi Ti$, Qes = total extraction system pumping rate, ft^3/day

SPd = 702.65 ft

Alternate Layout of Extraction Well System (i.e., parallel to GW flow direction): Install two extraction wells within the plume interior, positioned within the hot spot areas to maximize the flushing efficiency of the extraction wells in terms of contaminant removal. The system extraction rate is sufficient to contain the entire plume w/out precise positioning, thus the well siting focus can be on maximizing contaminant removal efficiency.
Final Configuration, Groundwater Extraction System: Two 6-inch diameter extraction wells, screened from 8 to 15 feet below ground, installed within the plume interior at hot spot locations. Each well will pump at an approximate rate of 7.5 gpm, for a total extraction system pumping rate of 15 gpm and projected cleanup time of approximately 2.1 years.

Pore Volume Contaminant Concentration Calculations

Project:	Cecil Field Site 25	Proj. No.:	0039.DSO.11E220
Chemical :	alpha-BHC	Koc (Kd*) :	1790
Concentration units, water & soil (pick 1):	mg/L & mg/Kg:	ug/L & ug/Kg:	X

NOTE: Input cells are shaded - all other cells are fixed or are automatically calculated.

All groundwater/soil contaminant concentrations are in consistent units, i.e., mg/L & mg/Kg, or ug/L & ug/Kg.

Heterogeneous Aquifer Flushing Rate, With or Without Contaminant Decay

This spreadsheet calculates pore volume flushing rates and cleanup times for a groundwater flow system that consists of up to 3 identified groundwater "flow units". Flow units are defined as discrete portions of the aquifer that have unique properties, i.e., a higher or lower average hydraulic conductivity, porosity, or specific gravity relative to other portions of the aquifer, higher or lower average contaminant concentrations, and/or different organic carbon contents. The spreadsheet allows for factoring in different flushing rates for discrete portions of the aquifer based on the differences in the physical/chemical characteristics of the flow units. First-order contaminant decay/degradation processes can also be factored into the cleanup rate prediction, through the optional use of contaminant half-life data. For simple,homogeneous aquifer flushing time simulations, the input parameters for all three flow units can be set at the same values.

Groundwater Flow Unit Physical/Chemical Data

Flow Unit 1 (U1)		Flow Unit 2 (U2)		Flow Unit 3 (U3)	
Cw_{0U1}	0.060	Cw_{0U2}	0.060	Cw_{0U3}	0.060
n	0.250	n	0.250	n	0.250
SG	2.650	SG	2.650	SG	2.650
foc*	0.0075	foc*	0.0075	foc*	0.0075
Kd	13.425	Kd	13.425	Kd	13.425
Mw	0.015	Mw	0.015	Mw	0.015
Cs	0.806	Cs	0.806	Cs	0.806
Ms	1.601	Ms	1.601	Ms	1.601
Mt	1.616	Mt	1.616	Mt	1.616
Ms/Mt	0.9907	Ms/Mt	0.9907	Ms/Mt	0.9907

Cw_{0Un} = initial contaminant concentration in groundwater flow unit n

Groundwater Flow Unit Hydrogeologic Characteristics

Avg. K, ft/day listed highest to lowest	Relative average K, K_{Un}	Fraction of aquifer volume, FV_{Un}	Fraction of total flow, FQ_{Un}	Flow unit designation, Un
1	1	0.333	0.333	U1
1	1	0.333	0.333	U2
1	1	0.333	0.333	U3

Contaminant Partitioning Formulas :

Mw = Cw x n
Cs = Koc x foc x Cw, or, Kd x Cw
Kd = Koc x foc, or, Cs/Cw
Ms = SG x (1-n) x Cs
Mt = Mw + Ms
$Cw_{n+1} = [Cw_n](Ms_n/Mt_n)$

where:
Cw = contaminant concentration in groundwater
n = aquifer porosity
SG = specific gravity of aquifer solids (default value = 2.65)
Mw = mass of contaminants per unit volume of aquifer water
Cs = contaminant concentration on aquifer solids
Ms = mass of contaminants per unit volume of aquifer solids
Mt = total mass of contaminants per unit volume of aquifer
Koc = organic carbon partition coefficient
foc = fractional organic carbon content of solids
Kd = soil/water distribution coefficient

*** for contaminants that partition between soil and water thru mechanisms other than adsoption onto organic carbon, i.e., metals, the compound's Kd is input directly into the Koc entry cell, with foc then set to 1.**

Fraction of total flow, flow unit n (FQ_{Un}) = $K_{Un} \times FV_{Un}^{2/3} / (K_{U1} \times FV_{U1}^{2/3} + K_{U2} \times FV_{U2}^{2/3} + K_{U3} \times FV_{U3}^{2/3})$

where K_{U1}, K_{U2}, K_{U3} = the relative average hydraulic conductivities of 3 flow units or zones within the aquifer; FV_{U1}, FV_{U2}, FV_{U3} = fractional volume of the aquifer represented by each flow unit or flow zone

Pore Volumes and Pore Volume Removal Rates

Discharge rate, gpm	Discharge rate, ft^3/day, Q_t	Groundwater plume vol., ft^3, PV_t	Volume, U1 discharged, ft^3/day, Q_{U1}	Volume, U2 discharged, ft^3/day, Q_{U2}	Volume, U3 discharged, ft^3/day, Q_{U3}	Plume pore volume, U1, ft^3, PV_{U1}	Plume pore volume, U2, ft^3, PV_{U2}	Plume pore volume, U3, ft^3, PV_{U3}	Time for 1 PV flush, Unit 1, days, U1T	Time for 1 PV flush, Unit 2, days, U2T	Time for 1 PV flush, Unit 3, days, U3T
0.34	65.45	39,270	21.82	21.82	21.82	13076.91	13076.91	13076.91	599.36	599.36	599.36

Groundwater discharged per day from flow unit n (Q_{Un}) = Q_t x FQ_{Un}

Time required for 1 pore volume flush, flow unit n (UnT) = PV_{Un} / Q_{Un}

One plume pore volume, flow unit n (PV_{Un}) = PV_t x FV_{Un}

Contaminant Half-Life Data

Does contaminant have a decay half-life (yes/no):	yes	If yes, give half-life (days):	270	1st order decay coef. (k):	0.002567

1st order decay coefficient = 0.693/half-life

Average Pumped/Discharged and Residual Plume Concentrations Over Time

Time period	Time span, days, T	Avg pumped concentration	Avg residual GW conc.	Time span, years
1	599.36	0.013	0.013	1.64
2	1198.72	0.003	0.003	3.28
3	1798.08	0.001	0.001	4.92
5	2996.79	0.000	0.000	8.20
7	4195.51	0.000	0.000	11.49
9	5394.23	0.000	0.000	14.77
12	7192.30	0.000	0.000	19.69
15	8990.38	0.000	0.000	24.61
20	11987.17	0.000	0.000	32.82
25	14983.96	0.000	0.000	41.02
30	17980.75	0.000	0.000	49.23
40	23974.34	0.000	0.000	65.64
50	29967.92	0.000	0.000	82.05
70	41955.09	0.000	0.000	114.87
90	53942.25	0.000	0.000	147.69
120	71923.01	0.000	0.000	196.91
150	89903.76	0.000	0.000	246.14
180	107884.51	0.000	0.000	295.37
210	125865.26	0.000	0.000	344.60
250	149839.59	0.000	0.000	410.24
1.2	719.23	0.009	0.009	1.97
1.4	839.10	0.007	0.007	2.30
1.5	899.04	0.006	0.006	2.46
1.6	958.97	0.005	0.005	2.63
1.7	1018.91	0.004	0.004	2.79

Residual groundwater concentration @ time T = $[Cw_{0U1} \times (Ms/Mt)^{T/U1T} \times 2.718^{-kT} \times FV_{U1}] + [Cw_{0U2} \times (Ms/Mt)^{T/U2T} \times 2.718^{-kT} \times FV_{U2}] + [Cw_{0U3} \times (Ms/Mt)^{T/U3T} \times 2.718^{-kT} \times FV_{U3}]$

where U1T, U2T,U3T = times required to remove 1 pore volume from the U1, U2, and U3 portions of the aquifer; Cw_{0U1}, Cw_{0U2}, Cw_{0U3} = initial groundwater concentrations for the U1, U2, U3 flow units, $2.718^{-kT} = e^{-kT}$ = the 1st order decay term (= 1 if there is no decay half-life for the contaminant)

Average pumped (discharged) conc. @ time T = $[Cw_{0U1} \times (Ms/Mt)^{T/U1T} \times 2.718^{-kT} \times FQ_{U1}] + [Cw_{0U2} \times (Ms/Mt)^{T/U2T} \times 2.718^{-kT} \times FQ_{U2}] + [Cw_{0U3} \times (Ms/Mt)^{T/U3T} \times 2.718^{-kT} \times FQ_{U3}]$

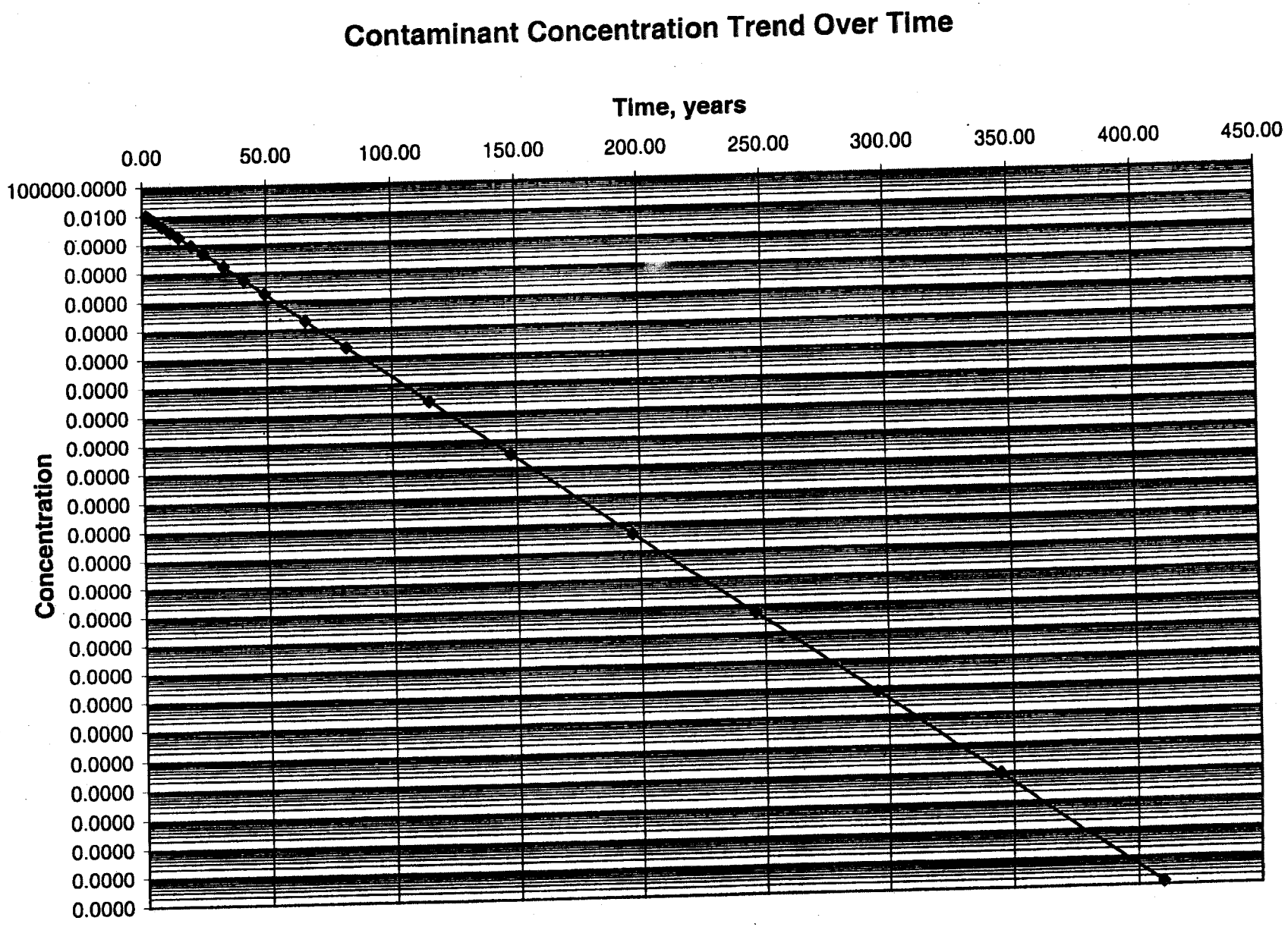
where FQ_{Un} = Fraction of total flow per day, Un unit (volume Un pumped/total volume pumped per day, or volume Un discharged/total volume discharged per day, under natural flushing conditions)

Number of pore volumes (PVs) required to reach target gw concentration Cw_x:

PVs = log (Cw_x/Cw_0) / log (Ms/Mt), for each groundwater flow unit

The last 5 time periods can be modified to evaluate contaminants w/ long cleanup times or more precisely determine the time required to meet a specific residual concentration.

Spreadsheet developed by J. P. Orient, 2/2001


Contaminant Concentration Trend Over Time
Time, years
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
Concentration
100000.0000
0.0100
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
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0.0000
0.0000
0.0000
0.0000
0.0000
0.0000

Pore Volume Contaminant Concentration Calculations

Project:	Cecil Field Site 25	Proj. No.:	0039.DSO.11E220
Chemical :	alpha-BHC	Koc (Kd*) :	1790
Concentration units, water & soil (pick 1):	mg/L & mg/Kg:	ug/L & ug/Kg:	X

Heterogeneous Aquifer Flushing Rate, With or Without Contaminant Decay

This spreadsheet calculates pore volume flushing rates and cleanup times for a groundwater flow system that consists of up to 3 identified groundwater "flow units". Flow units are defined as discrete portions of the aquifer that have unique properties, i.e., a higher or lower average hydraulic conductivity, porosity, or specific gravity relative to other portions of the aquifer, higher or lower average contaminant concentrations, and/or different organic carbon contents. The spreadsheet allows for factoring in different flushing rates for discrete portions of the aquifer based on the differences in the physical/chemical characteristics of the flow units. First-order contaminant decay/degradation processes can also be factored into the cleanup rate prediction, through the optional use of contaminant half-life data. For simple,homogeneous aquifer flushing time simulations, the input parameters for all three flow units can be set at the same values.

Groundwater Flow Unit Physical/Chemical Data

Flow Unit 1 (U1)		Flow Unit 2 (U2)		Flow Unit 3 (U3)	
Cw_{0U1}	0.060	Cw_{0U2}	0.060	Cw_{0U3}	0.060
n	0.250	n	0.250	n	0.250
SG	2.650	SG	2.650	SG	2.650
foc*	0.0075	foc*	0.0075	foc*	0.0075
Kd	13.425	Kd	13.425	Kd	13.425
Mw	0.015	Mw	0.015	Mw	0.015
Cs	0.806	Cs	0.806	Cs	0.806
Ms	1.601	Ms	1.601	Ms	1.601
Mt	1.616	Mt	1.616	Mt	1.616
Ms/Mt	0.9907	Ms/Mt	0.9907	Ms/Mt	0.9907

Cw_{0Un} = initial contaminant concentration in groundwater flow unit n

Groundwater Flow Unit Hydrogeologic Characteristics

Avg. K, ft/day listed highest to lowest	Relative average K, K_{Un}	Fraction of aquifer volume, FV_{Un}	Fraction of total flow, FQ_{Un}	Flow unit designation, Un
1	1	0.333	0.333	U1
1	1	0.333	0.333	U2
1	1	0.333	0.333	U3

NOTE: Input cells are shaded - all other cells are fixed or are automatically calculated.

All groundwater/soil contaminant concentrations are in consistent units, i.e., mg/L & mg/Kg, or ug/L & ug/Kg.

Contaminant Partitioning Formulas :

Mw = Cw x n
Cs = Koc x foc x Cw, or, Kd x Cw
Kd = Koc x foc, or, Cs/Cw
Ms = SG x (1-n) x Cs
Mt = Mw + Ms
$Cw_{n+1} = [Cw_n](Ms_n/Mt_n)$

where:
Cw = contaminant concentration in groundwater
n = aquifer porosity
SG = specific gravity of aquifer solids (default value = 2.65)
Mw = mass of contaminants per unit volume of aquifer water
Cs = contaminant concentration on aquifer solids
Ms = mass of contaminants per unit volume of aquifer solids
Mt = total mass of contaminants per unit volume of aquifer
Koc = organic carbon partition coefficient
foc = fractional organic carbon content of solids
Kd = soil/water distribution coefficient

*** for contaminants that partition between soil and water thru mechanisms other than adsoption onto organic carbon, i.e., metals, the compound's Kd is input directly into the Koc entry cell, with foc then set to 1.**

Fraction of total flow, flow unit n (FQ_{Un}) = $K_{Un} \times FV_{Un}^{2/3}/(K_{U1} \times FV_{U1}^{2/3} + K_{U2} \times FV_{U2}^{2/3} + K_{U3} \times FV_{U3}^{2/3})$

where K_{U1}, K_{U2}, K_{U3} = the relative average hydraulic conductivities of 3 flow units or zones within the aquifer; FV_{U1}, FV_{U2}, FV_{U3} = fractional volume of the aquifer represented by each flow unit or flow zone

Pore Volumes and Pore Volume Removal Rates

Discharge rate, gpm	Discharge rate, ft^3/day, Q_t	Groundwater plume vol., ft^3, PV_t	Volume, U1 discharged, ft^3/day, Q_{U1}	Volume, U2 discharged, ft^3/day, Q_{U2}	Volume, U3 discharged, ft^3/day, Q_{U3}	Plume pore volume, U1, ft^3, PV_{U1}	Plume pore volume, U2, ft^3, PV_{U2}	Plume pore volume, U3, ft^3, PV_{U3}	Time for 1 PV flush, Unit 1, days, U1T	Time for 1 PV flush, Unit 2, days, U2T	Time for 1 PV flush, Unit 3, days, U3T
5	962.57	39,270	320.86	320.86	320.86	13076.91	13076.91	13076.91	40.76	40.76	40.76

Groundwater discharged per day from flow unit n (Q_{Un}) = Q_t x FQ_{Un}

Time required for 1 pore volume flush, flow unit n (UnT) = PV_{Un} / Q_{Un}

One plume pore volume, flow unit n (PV_{Un}) = PV_t x FV_{Un}

Contaminant Half-Life Data

Does contaminant have a decay half-life (yes/no):	yes	If yes, give half-life (days):	270	1st order decay coef. (k):	0.002567

1st order decay coefficient = 0.693/half-life

Average Pumped/Discharged and Residual Plume Concentrations Over Time

Time period	Time span, days, T	Avg pumped concentration	Avg residual GW conc.	Time span, years
1	40.76	0.054	0.053	0.11
2	81.51	0.048	0.048	0.22
3	122.27	0.043	0.043	0.33
5	203.78	0.034	0.034	0.56
7	285.29	0.027	0.027	0.78
9	366.81	0.022	0.021	1.00
12	489.08	0.015	0.015	1.34
15	611.35	0.011	0.011	1.67
20	815.13	0.006	0.006	2.23
25	1018.91	0.003	0.003	2.79
30	1222.69	0.002	0.002	3.35
40	1630.25	0.001	0.001	4.46
50	2037.82	0.000	0.000	5.58
70	2852.95	0.000	0.000	7.81
90	3668.07	0.000	0.000	10.04
120	4890.76	0.000	0.000	13.39
150	6113.46	0.000	0.000	16.74
180	7336.15	0.000	0.000	20.09
210	8558.84	0.000	0.000	23.43
250	10189.09	0.000	0.000	27.90
22	896.64	0.005	0.005	2.45
21	855.88	0.005	0.005	2.34
23	937.40	0.004	0.004	2.57
17	692.86	0.009	0.009	1.90
19	774.37	0.007	0.007	2.12

Residual groundwater concentration @ time T = $[Cw_{0U1} \times (Ms/Mt)^{T/U1T} \times 2.718^{-kT} \times FV_{U1}] + [Cw_{0U2} \times (Ms/Mt)^{T/U2T} \times 2.718^{-kT} \times FV_{U2}] + [Cw_{0U3} \times (Ms/Mt)^{T/U3T} \times 2.718^{-kT} \times FV_{U3}]$

where U1T, U2T,U3T = times required to remove 1 pore volume from the U1, U2, and U3 portions of the aquifer; Cw_{0U1}, Cw_{0U2}, Cw_{0U3} = initial groundwater concentrations for the U1, U2, U3 flow units, $2.718^{-kT} = e^{-kT}$ = the 1st order decay term (= 1 if there is no decay half-life for the contaminant)

Average pumped (discharged) conc. @ time T = $[Cw_{0U1} \times (Ms/Mt)^{T/U1T} \times 2.718^{-kT} \times FQ_{U1}] + [Cw_{0U2} \times (Ms/Mt)^{T/U2T} \times 2.718^{-kT} \times FQ_{U2}] + [Cw_{0U3} \times (Ms/Mt)^{T/U3T} \times 2.718^{-kT} \times FQ_{U3}]$

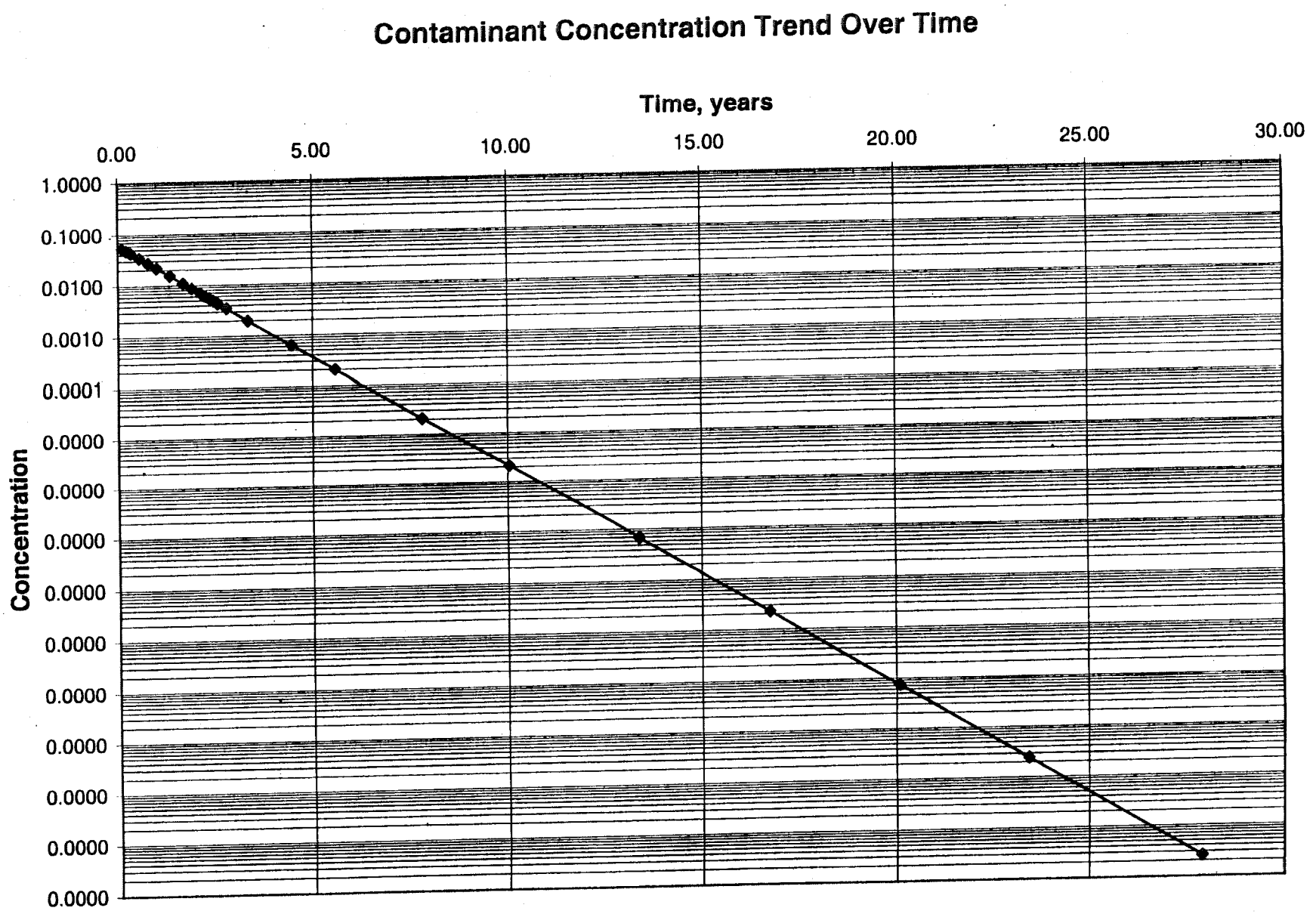
where FQ_{Un} = Fraction of total flow per day, Un unit (volume Un pumped/total volume pumped per day, or volume Un discharged/total volume discharged per day, under natural flushing conditions)

Number of pore volumes (PVs) required to reach target gw concentration Cw_x:

PVs = log (Cw_x/Cw_0) / log (Ms/Mt), for each groundwater flow unit

The last 5 time periods can be modified to evaluate contaminants w/ long cleanup times or more precisely determine the time required to meet a specific residual concentration.

Spreadsheet developed by J. P. Orient, 2/2001


Contaminant Concentration Trend Over Time
Time, years
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Concentration
1.0000
0.1000
0.0100
0.0010
0.0001
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000

Pore Volume Contaminant Concentration Calculations

Project:	Cecil Field Site 25	Proj. No.:	0039.DSO.11E220
Chemical :	alpha-BHC	Koc (Kd*) :	1790
Concentration units, water & soil (pick 1):	mg/L & mg/Kg:	ug/L & ug/Kg:	X

Heterogeneous Aquifer Flushing Rate, With or Without Contaminant Decay

This spreadsheet calculates pore volume flushing rates and cleanup times for a groundwater flow system that consists of up to 3 identified groundwater "flow units". Flow units are defined as discrete portions of the aquifer that have unique properties, i.e., a higher or lower average hydraulic conductivity, porosity, or specific gravity relative to other portions of the aquifer, higher or lower average contaminant concentrations, and/or different organic carbon contents. The spreadsheet allows for factoring in different flushing rates for discrete portions of the aquifer based on the differences in the physical/chemical characteristics of the flow units. First-order contaminant decay/degradation processes can also be factored into the cleanup rate prediction, through the optional use of contaminant half-life data. For simple,homogeneous aquifer flushing time simulations, the input parameters for all three flow units can be set at the same values.

Groundwater Flow Unit Physical/Chemical Data

Flow Unit 1 (U1)		Flow Unit 2 (U2)		Flow Unit 3 (U3)	
Cw_{0U1}	0.060	Cw_{0U2}	0.060	Cw_{0U3}	0.060
n	0.250	n	0.250	n	0.250
SG	2.650	SG	2.650	SG	2.650
foc*	0.0075	foc*	0.0075	foc*	0.0075
Kd	13.425	Kd	13.425	Kd	13.425
Mw	0.015	Mw	0.015	Mw	0.015
Cs	0.806	Cs	0.806	Cs	0.806
Ms	1.601	Ms	1.601	Ms	1.601
Mt	1.616	Mt	1.616	Mt	1.616
Ms/Mt	0.9907	Ms/Mt	0.9907	Ms/Mt	0.9907

Cw_{0Un} = initial contaminant concentration in groundwater flow unit n

Groundwater Flow Unit Hydrogeologic Characteristics

Avg. K, ft/day listed highest to lowest	Relative average K, K_{Un}	Fraction of aquifer volume, FV_{Un}	Fraction of total flow, FQ_{Un}	Flow unit designation, Un
1	1	0.333	0.333	U1
1	1	0.333	0.333	U2
1	1	0.333	0.333	U3

NOTE: Input cells are shaded - all other cells are fixed or are automatically calculated.

All groundwater/soil contaminant concentrations are in consistent units, i.e., mg/L & mg/Kg, or ug/L & ug/Kg.

Contaminant Partitioning Formulas :

Mw = Cw x n
Cs = Koc x foc x Cw, or, Kd x Cw
Kd = Koc x foc, or, Cs/Cw
Ms = SG x (1-n) x Cs
Mt = Mw + Ms
$Cw_{n+1} = [Cw_n](Ms_n/Mt_n)$

where:
Cw = contaminant concentration in groundwater
n = aquifer porosity
SG = specific gravity of aquifer solids (default value = 2.65)
Mw = mass of contaminants per unit volume of aquifer water
Cs = contaminant concentration on aquifer solids
Ms = mass of contaminants per unit volume of aquifer solids
Mt = total mass of contaminants per unit volume of aquifer
Koc = organic carbon partition coefficient
foc = fractional organic carbon content of solids
Kd = soil/water distribution coefficient

*** for contaminants that partition between soil and water thru mechanisms other than adsoption onto organic carbon, i.e., metals, the compound's Kd is input directly into the Koc entry cell, with foc then set to 1.**

Fraction of total flow, flow unit n (FQ_{Un}) = $K_{Un} \times FV_{Un}^{2/3} / (K_{U1} \times FV_{U1}^{2/3} + K_{U2} \times FV_{U2}^{2/3} + K_{U3} \times FV_{U3}^{2/3})$

where K_{U1}, K_{U2}, K_{U3} = the relative average hydraulic conductivities of 3 flow units or zones within the aquifer; FV_{U1}, FV_{U2}, FV_{U3} = fractional volume of the aquifer represented by each flow unit or flow zone

Pore Volumes and Pore Volume Removal Rates

Discharge rate, gpm	Discharge rate, ft^3/day, Q_t	Groundwater plume vol., ft^3, PV_t	Volume, U1 discharged, ft^3/day, Q_{U1}	Volume, U2 discharged, ft^3/day, Q_{U2}	Volume, U3 discharged, ft^3/day, Q_{U3}	Plume pore volume, U1, ft^3, PV_{U1}	Plume pore volume, U2, ft^3, PV_{U2}	Plume pore volume, U3, ft^3, PV_{U3}	Time for 1 PV flush, Unit 1, days, U1T	Time for 1 PV flush, Unit 2, days, U2T	Time for 1 PV flush, Unit 3, days, U3T
10	1925.13	39,270	641.71	641.71	641.71	13076.91	13076.91	13076.91	20.38	20.38	20.38

Groundwater discharged per day from flow unit n (Q_{Un}) = Q_t x FQ_{Un}

Time required for 1 pore volume flush, flow unit n (UnT) = PV_{Un} / Q_{Un}

One plume pore volume, flow unit n (PV_{Un}) = PV_t x FV_{Un}

Contaminant Half-Life Data

Does contaminant have a decay half-life (yes/no):	yes	If yes, give half-life (days):	270	1st order decay coef. (k):	0.002567

Ist order decay coefficient = 0.693/half-life

Average Pumped/Discharged and Residual Plume Concentrations Over Time

Time period	Time span, days, T	Avg pumped concentration	Avg residual GW conc.	Time span, years
1	20.38	0.056	0.056	0.06
2	40.76	0.053	0.053	0.11
3	61.13	0.050	0.050	0.17
5	101.89	0.044	0.044	0.28
7	142.65	0.039	0.039	0.39
9	183.40	0.034	0.034	0.50
12	244.54	0.029	0.029	0.67
15	305.67	0.024	0.024	0.84
20	407.56	0.017	0.017	1.12
25	509.45	0.013	0.013	1.39
30	611.35	0.009	0.009	1.67
40	815.13	0.005	0.005	2.23
50	1018.91	0.003	0.003	2.79
70	1426.47	0.001	0.001	3.91
90	1834.04	0.000	0.000	5.02
120	2445.38	0.000	0.000	6.70
150	3056.73	0.000	0.000	8.37
180	3668.07	0.000	0.000	10.04
210	4279.42	0.000	0.000	11.72
250	5094.55	0.000	0.000	13.95
38	774.37	0.006	0.006	2.12
39	794.75	0.005	0.005	2.18
41	835.51	0.005	0.005	2.29
42	855.88	0.005	0.005	2.34
45	917.02	0.004	0.004	2.51

Residual groundwater concentration @ time T = $[Cw_{0U1} \times (Ms/Mt)^{T/U1T} \times 2.718^{-kT} \times FV_{U1}] + [Cw_{0U2} \times (Ms/Mt)^{T/U2T} \times 2.718^{-kT} \times FV_{U2}] + [Cw_{0U3} \times (Ms/Mt)^{T/U3T} \times 2.718^{-kT} \times FV_{U3}]$

where U1T, U2T,U3T = times required to remove 1 pore volume from the U1, U2, and U3 portions of the aquifer; Cw_{0U1}, Cw_{0U2}, Cw_{0U3} = initial groundwater concentrations for the U1, U2, U3 flow units, $2.718^{-kT} = e^{-kT}$ = the 1st order decay term (= 1 if there is no decay half-life for the contaminant)

Average pumped (discharged) conc. @ time T = $[Cw_{0U1} \times (Ms/Mt)^{T/U1T} \times 2.718^{-kT} \times FQ_{U1}] + [Cw_{0U2} \times (Ms/Mt)^{T/U2T} \times 2.718^{-kT} \times FQ_{U2}] + [Cw_{0U3} \times (Ms/Mt)^{T/U3T} \times 2.718^{-kT} \times FQ_{U3}]$

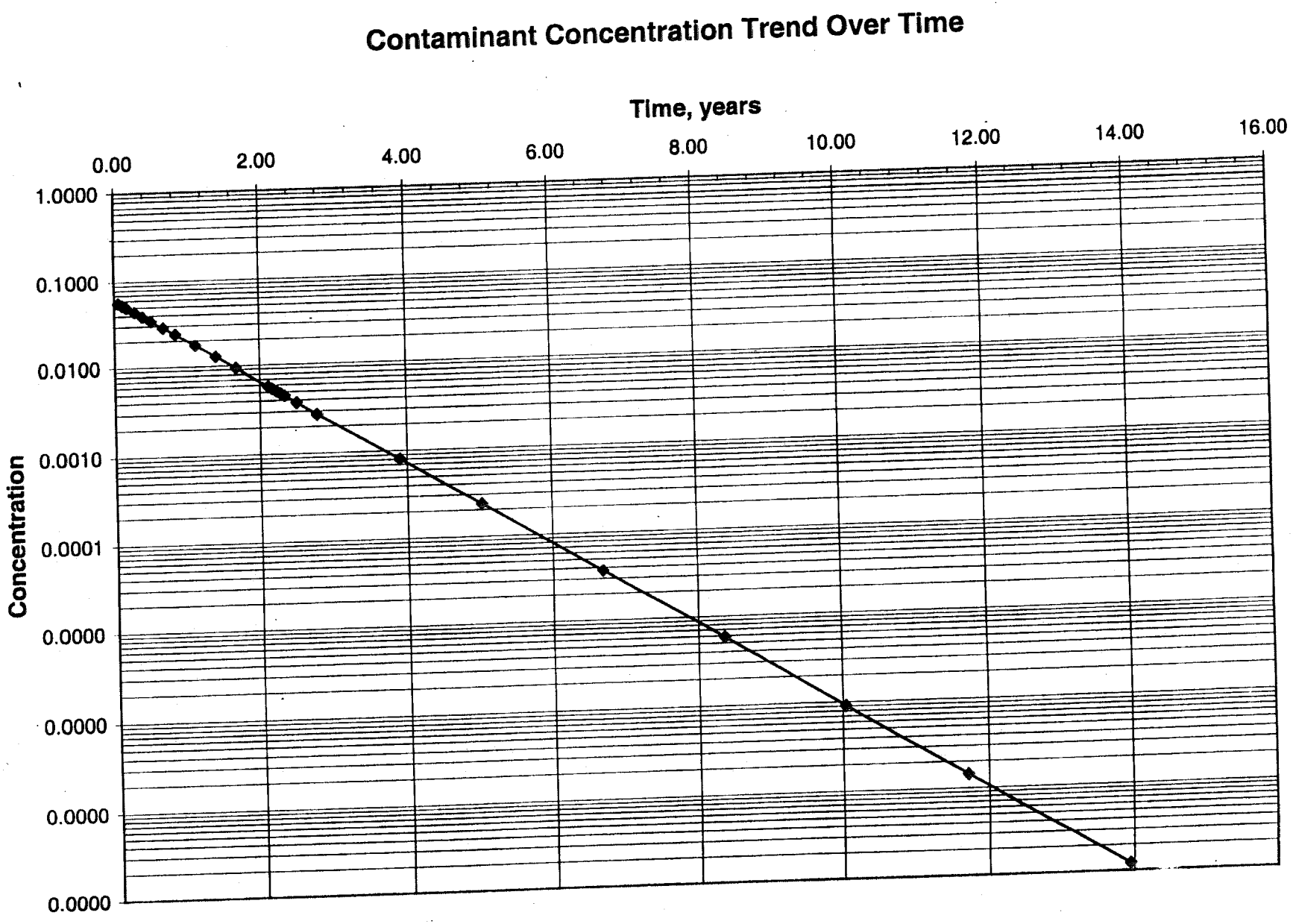
where FQ_{Un} = Fraction of total flow per day, Un unit (volume Un pumped/total volume pumped per day, or volume Un discharged/total volume discharged per day, under natural flushing conditions)

Number of pore volumes (PVs) required to reach target gw concentration Cw_x:

PVs = log (Cw_x/Cw_0) / log (Ms/Mt), for each groundwater flow unit

The last 5 time periods can be modified to evaluate contaminants w/ long cleanup times or more precisely determine the time required to meet a specific residual concentration.

Spreadsheet developed by J. P. Orient, 2/2001


Contaminant Concentration Trend Over Time
Time, years
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Concentration
1.0000
0.1000
0.0100
0.0010
0.0001
0.0000
0.0000
0.0000
0.0000

Pore Volume Contaminant Concentration Calculations

Project:	Cecil Field Site 25	Proj. No.:	0039.DSO.11E220
Chemical :	alpha-BHC	Koc (Kd*) :	1790
Concentration units, water & soil (pick 1):	mg/L & mg/Kg:	ug/L & ug/Kg:	X

Heterogeneous Aquifer Flushing Rate, With or Without Contaminant Decay

This spreadsheet calculates pore volume flushing rates and cleanup times for a groundwater flow system that consists of up to 3 identified groundwater "flow units". Flow units are defined as discrete portions of the aquifer that have unique properties, i.e., a higher or lower average hydraulic conductivity, porosity, or specific gravity relative to other portions of the aquifer, higher or lower average contaminant concentrations, and/or different organic carbon contents. The spreadsheet allows for factoring in different flushing rates for discrete portions of the aquifer based on the differences in the physical/chemical characteristics of the flow units. First-order contaminant decay/degradation processes can also be factored into the cleanup rate prediction, through the optional use of contaminant half-life data. For simple,homogeneous aquifer flushing time simulations, the input parameters for all three flow units can be set at the same values.

Groundwater Flow Unit Physical/Chemical Data

Flow Unit 1 (U1)		Flow Unit 2 (U2)		Flow Unit 3 (U3)	
Cw_{0U1}	0.060	Cw_{0U2}	0.060	Cw_{0U3}	0.060
n	0.250	n	0.250	n	0.250
SG	2.650	SG	2.650	SG	2.650
foc*	0.0075	foc*	0.0075	foc*	0.0075
Kd	13.425	Kd	13.425	Kd	13.425
Mw	0.015	Mw	0.015	Mw	0.015
Cs	0.806	Cs	0.806	Cs	0.806
Ms	1.601	Ms	1.601	Ms	1.601
Mt	1.616	Mt	1.616	Mt	1.616
Ms/Mt	0.9907	Ms/Mt	0.9907	Ms/Mt	0.9907

Cw_{0Un} = initial contaminant concentration in groundwater flow unit n

Groundwater Flow Unit Hydrogeologic Characteristics

Avg. K, ft/day listed highest to lowest	Relative average K, K_{Un}	Fraction of aquifer volume, FV_{Un}	Fraction of total flow, FQ_{Un}	Flow unit designation, Un
1	1	0.333	0.333	U1
1	1	0.333	0.333	U2
1	1	0.333	0.333	U3

NOTE: Input cells are shaded - all other cells are fixed or are automatically calculated.

All groundwater/soil contaminant concentrations are in consistent units, i.e., mg/L & mg/Kg, or ug/L & ug/Kg.

Contaminant Partitioning Formulas :

Mw = Cw x n
Cs = Koc x foc x Cw, or, Kd x Cw
Kd = Koc x foc, or, Cs/Cw
Ms = SG x (1-n) x Cs
Mt = Mw + Ms
$Cw_{n+1} = [Cw_n](Ms_n/Mt_n)$

where:
Cw = contaminant concentration in groundwater
n = aquifer porosity
SG = specific gravity of aquifer solids (default value = 2.65)
Mw = mass of contaminants per unit volume of aquifer water
Cs = contaminant concentration on aquifer solids
Ms = mass of contaminants per unit volume of aquifer solids
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foc = fractional organic carbon content of solids
Kd = soil/water distribution coefficient

*** for contaminants that partition between soil and water thru mechanisms other than adsoption onto organic carbon, i.e., metals, the compound's Kd is input directly into the Koc entry cell, with foc then set to 1.**

Fraction of total flow, flow unit n (FQ_{Un}) $= K_{Un} \times FV_{Un}^{2/3}/(K_{U1} \times FV_{U1}^{2/3} + K_{U2} \times FV_{U2}^{2/3} + K_{U3} \times FV_{U3}^{2/3})$

where K_{U1}, K_{U2}, K_{U3} = the relative average hydraulic conductivities of 3 flow units or zones within the aquifer; FV_{U1}, FV_{U2}, FV_{U3} = fractional volume of the aquifer represented by each flow unit or flow zone

Pore Volumes and Pore Volume Removal Rates

Discharge rate, gpm	Discharge rate, ft^3/day, Q_t	Groundwater plume vol., ft^3, PV_t	Volume, U1 discharged, ft^3/day, Q_{U1}	Volume, U2 discharged, ft^3/day, Q_{U2}	Volume, U3 discharged, ft^3/day, Q_{U3}	Plume pore volume, U1, ft^3, PV_{U1}	Plume pore volume, U2, ft^3, PV_{U2}	Plume pore volume, U3, ft^3, PV_{U3}	Time for 1 PV flush, Unit 1, days, U1T	Time for 1 PV flush, Unit 2, days, U2T	Time for 1 PV flush, Unit 3, days, U3T
15	2887.70	39,270	962.57	962.57	962.57	13076.91	13076.91	13076.91	13.59	13.59	13.59

Groundwater discharged per day from flow unit n (Q_{Un}) = Q_t x FQ_{Un}

Time required for 1 pore volume flush, flow unit n (UnT) = PV_{Un} / Q_{Un}

One plume pore volume, flow unit n (PV_{Un}) = PV_t x FV_{Un}

Contaminant Half-Life Data

Does contaminant have a decay half-life (yes/no):	yes	If yes, give half-life (days):	270	1st order decay coef. (k):	0.002567

1st order decay coefficient = 0.693/half-life

Average Pumped/Discharged and Residual Plume Concentrations Over Time

Time period	Time span, days, T	Avg pumped concentration	Avg residual GW conc.	Time span, years
1	13.59	0.057	0.057	0.04
2	27.17	0.055	0.055	0.07
3	40.76	0.053	0.052	0.11
5	67.93	0.048	0.048	0.19
7	95.10	0.044	0.044	0.26
9	122.27	0.040	0.040	0.33
12	163.03	0.035	0.035	0.45
15	203.78	0.031	0.031	0.56
20	271.71	0.025	0.025	0.74
25	339.64	0.020	0.020	0.93
30	407.56	0.016	0.016	1.12
40	543.42	0.010	0.010	1.49
50	679.27	0.007	0.007	1.86
70	950.98	0.003	0.003	2.60
90	1222.69	0.001	0.001	3.35
120	1630.25	0.000	0.000	4.46
150	2037.82	0.000	0.000	5.58
180	2445.38	0.000	0.000	6.70
210	2852.95	0.000	0.000	7.81
250	3396.36	0.000	0.000	9.30
60	815.13	0.004	0.004	2.23
55	747.20	0.005	0.005	2.05
57	774.37	0.005	0.005	2.12
53	720.03	0.006	0.006	1.97
56	760.79	0.005	0.005	2.08

Residual groundwater concentration @ time T = $[Cw_{0U1} \times (Ms/Mt)^{T/U1T} \times 2.718^{-kT} \times FV_{U1}] + [Cw_{0U2} \times (Ms/Mt)^{T/U2T} \times 2.718^{-kT} \times FV_{U2}] + [Cw_{0U3} \times (Ms/Mt)^{T/U3T} \times 2.718^{-kT} \times FV_{U3}]$

where U1T, U2T,U3T = times required to remove 1 pore volume from the U1, U2, and U3 portions of the aquifer; Cw_{0U1}, Cw_{0U2}, Cw_{0U3} = initial groundwater concentrations for the U1, U2, U3 flow units, $2.718^{-kT} = e^{-kT}$ = the 1st order decay term (= 1 if there is no decay half-life for the contaminant)

Average pumped (discharged) conc. @ time T = $[Cw_{0U1} \times (Ms/Mt)^{T/U1T} \times 2.718^{-kT} \times FQ_{U1}] + [Cw_{0U2} \times (Ms/Mt)^{T/U2T} \times 2.718^{-kT} \times FQ_{U2}] + [Cw_{0U3} \times (Ms/Mt)^{T/U3T} \times 2.718^{-kT} \times FQ_{U3}]$

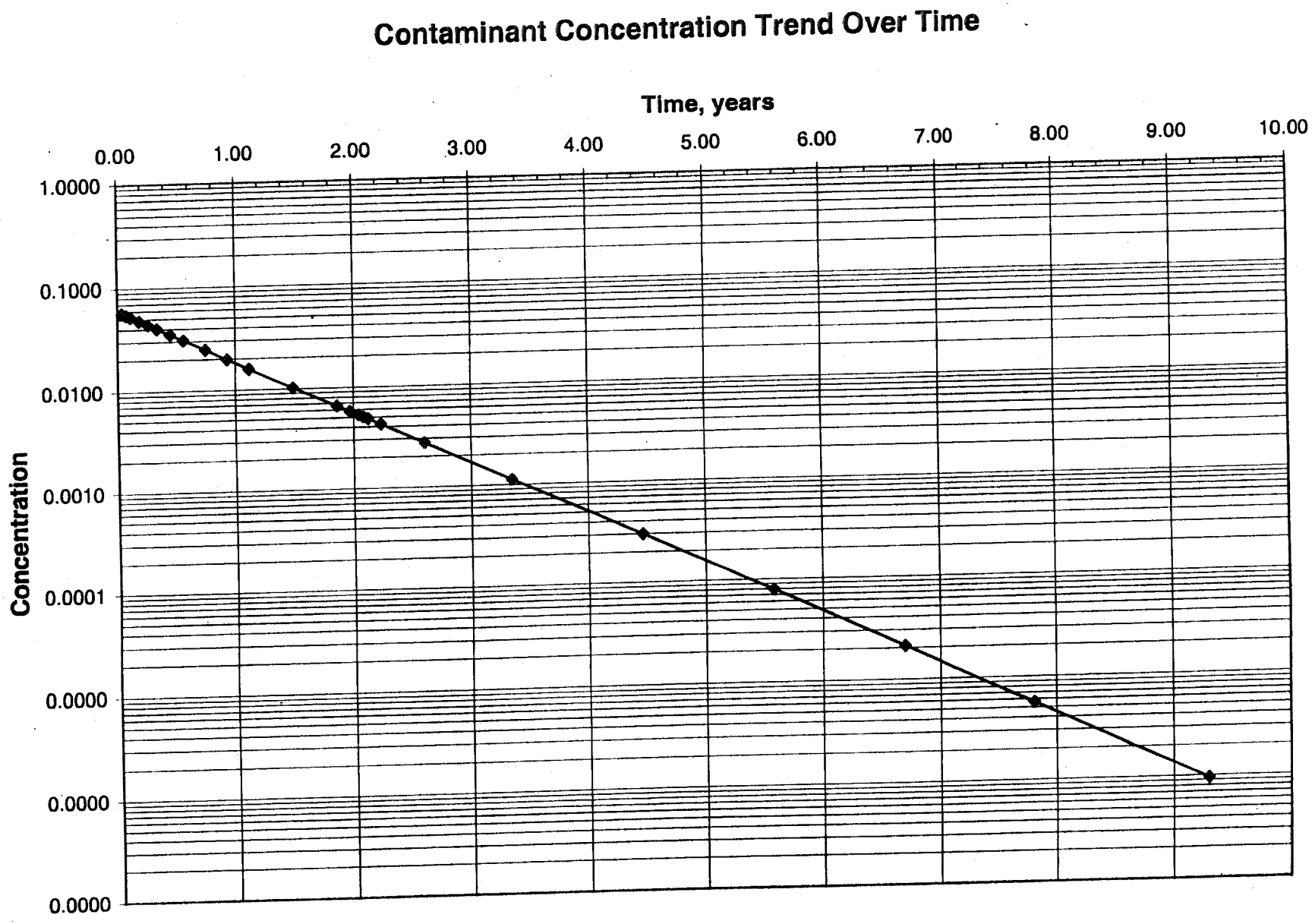
where FQ_{Un} = Fraction of total flow per day, Un unit (volume Un pumped/total volume pumped per day, or volume Un discharged/total volume discharged per day, under natural flushing conditions)

Number of pore volumes (PVs) required to reach target gw concentration Cw_x:

PVs = log (Cw_x/Cw_0) / log (Ms/Mt), for each groundwater flow unit

The last 5 time periods can be modified to evaluate contaminants w/ long cleanup times or more precisely determine the time required to meet a specific residual concentration.

Spreadsheet developed by J. P. Orient, 2/2001


Contaminant Concentration Trend Over Time
Time, years
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Concentration
1.0000
0.1000
0.0100
0.0010
0.0001
0.0000
0.0000
0.0000

Pore Volume Contaminant Concentration Calculations

Project:	Cecil Field Site 25	Proj. No.:	0039.DSO.11E220
Chemical :	beta-BHC	Koc (Kd*) :	2140
Concentration units, water & soil (pick 1):	mg/L & mg/Kg:	ug/L & ug/Kg:	X

Heterogeneous Aquifer Flushing Rate, With or Without Contaminant Decay

This spreadsheet calculates pore volume flushing rates and cleanup times for a groundwater flow system that consists of up to 3 identified groundwater "flow units". Flow units are defined as discrete portions of the aquifer that have unique properties, i.e., a higher or lower average hydraulic conductivity, porosity, or specific gravity relative to other portions of the aquifer, higher or lower average contaminant concentrations, and/or different organic carbon contents. The spreadsheet allows for factoring in different flushing rates for discrete portions of the aquifer based on the differences in the physical/chemical characteristics of the flow units. First-order contaminant decay/degradation processes can also be factored into the cleanup rate prediction, through the optional use of contaminant half-life data. For simple,homogeneous aquifer flushing time simulations, the input parameters for all three flow units can be set at the same values.

Groundwater Flow Unit Physical/Chemical Data

Flow Unit 1 (U1)		Flow Unit 2 (U2)		Flow Unit 3 (U3)	
Cw_{0U1}	0.074	Cw_{0U2}	0.074	Cw_{0U3}	0.074
n	0.250	n	0.250	n	0.250
SG	2.650	SG	2.650	SG	2.650
foc*	0.0075	foc*	0.0075	foc*	0.0075
Kd	16.050	Kd	16.050	Kd	16.050
Mw	0.019	Mw	0.019	Mw	0.019
Cs	1.188	Cs	1.188	Cs	1.188
Ms	2.361	Ms	2.361	Ms	2.361
Mt	2.379	Mt	2.379	Mt	2.379
Ms/Mt	0.9922	Ms/Mt	0.9922	Ms/Mt	0.9922

Cw_{0Un} = initial contaminant concentration in groundwater flow unit n

Groundwater Flow Unit Hydrogeologic Characteristics

Avg. K, ft/day listed highest to lowest	Relative average K, K_{Un}	Fraction of aquifer volume, FV_{Un}	Fraction of total flow, FQ_{Un}	Flow unit designation, Un
1	1	0.333	0.333	U1
1	1	0.333	0.333	U2
1	1	0.333	0.333	U3

NOTE: Input cells are shaded - all other cells are fixed or are automatically calculated.

All groundwater/soil contaminant concentrations are in consistent units, i.e., mg/L & mg/Kg, or ug/L & ug/Kg.

Contaminant Partitioning Formulas :

Mw = Cw x n
Cs = Koc x foc x Cw, or, Kd x Cw
Kd = Koc x foc, or, Cs/Cw
Ms = SG x (1-n) x Cs
Mt = Mw + Ms
$Cw_{n+1} = [Cw_n](Ms_n/Mt_n)$

where:
Cw = contaminant concentration in groundwater
n = aquifer porosity
SG = specific gravity of aquifer solids (default value = 2.65)
Mw = mass of contaminants per unit volume of aquifer water
Cs = contaminant concentration on aquifer solids
Ms = mass of contaminants per unit volume of aquifer solids
Mt = total mass of contaminants per unit volume of aquifer
Koc = organic carbon partition coefficient
foc = fractional organic carbon content of solids
Kd = soil/water distribution coefficient

*** for contaminants that partition between soil and water thru mechanisms other than adsoption onto organic carbon, i.e., metals, the compound's Kd is input directly into the Koc entry cell, with foc then set to 1.**

Fraction of total flow, flow unit n (FQ_{Un}) = $K_{Un} \times FV_{Un}^{2/3} / (K_{U1} \times FV_{U1}^{2/3} + K_{U2} \times FV_{U2}^{2/3} + K_{U3} \times FV_{U3}^{2/3})$

where K_{U1}, K_{U2}, K_{U3} = the relative average hydraulic conductivities of 3 flow units or zones within the aquifer; FV_{U1}, FV_{U2}, FV_{U3} = fractional volume of the aquifer represented by each flow unit or flow zone

Pore Volumes and Pore Volume Removal Rates

Discharge rate, gpm	Discharge rate, ft^3/day, Q_t	Groundwater plume vol., ft^3, PV_t	Volume, U1 discharged, ft^3/day, Q_{U1}	Volume, U2 discharged, ft^3/day, Q_{U2}	Volume, U3 discharged, ft^3/day, Q_{U3}	Plume pore volume, U1, ft^3, PV_{U1}	Plume pore volume, U2, ft^3, PV_{U2}	Plume pore volume, U3, ft^3, PV_{U3}	Time for 1 PV flush, Unit 1, days, U1T	Time for 1 PV flush, Unit 2, days, U2T	Time for 1 PV flush, Unit 3, days, U3T
0.34	65.45	39,270	21.82	21.82	21.82	13076.91	13076.91	13076.91	599.36	599.36	599.36

Groundwater discharged per day from flow unit n (Q_{Un}) = Q_t x FQ_{Un}

One plume pore volume, flow unit n (PV_{Un}) = PV_t x FV_{Un}

Time required for 1 pore volume flush, flow unit n (UnT) = PV_{Un} / Q_{Un}

Contaminant Half-Life Data

Does contaminant have a decay half-life (yes/no):	yes	If yes, give half-life (days):	248	1st order decay coef. (k):	0.002794

1st order decay coefficient = 0.693/half-life

Average Pumped/Discharged and Residual Plume Concentrations Over Time

Time period	Time span, days, T	Avg pumped concentration	Avg residual GW conc.	Time span, years
1	599.36	0.014	0.014	1.64
2	1198.72	0.003	0.003	3.28
3	1798.08	0.000	0.000	4.92
5	2996.79	0.000	0.000	8.20
7	4195.51	0.000	0.000	11.49
9	5394.23	0.000	0.000	14.77
12	7192.30	0.000	0.000	19.69
15	8990.38	0.000	0.000	24.61
20	11987.17	0.000	0.000	32.82
25	14983.96	0.000	0.000	41.02
30	17980.75	0.000	0.000	49.23
40	23974.34	0.000	0.000	65.64
50	29967.92	0.000	0.000	82.05
70	41955.09	0.000	0.000	114.87
90	53942.25	0.000	0.000	147.69
120	71923.01	0.000	0.000	196.91
150	89903.76	0.000	0.000	246.14
180	107884.51	0.000	0.000	295.37
210	125865.26	0.000	0.000	344.60
250	149839.59	0.000	0.000	410.24
0.5	299.68	0.032	0.032	0.82
0.7	419.55	0.023	0.023	1.15
0.8	479.49	0.019	0.019	1.31
0.75	449.52	0.021	0.021	1.23
0.77	461.51	0.020	0.020	1.26

Residual groundwater concentration @ time T = $[Cw_{0U1} \times (Ms/Mt)^{T/U1T} \times 2.718^{-kT} \times FV_{U1}] + [Cw_{0U2} \times (Ms/Mt)^{T/U2T} \times 2.718^{-kT} \times FV_{U2}] + [Cw_{0U3} \times (Ms/Mt)^{T/U3T} \times 2.718^{-kT} \times FV_{U3}]$

where U1T, U2T,U3T = times required to remove 1 pore volume from the U1, U2, and U3 portions of the aquifer; Cw_{0U1}, Cw_{0U2}, Cw_{0U3} = initial groundwater concentrations for the U1, U2, U3 flow units, $2.718^{-kT} = e^{-kT}$ = the 1st order decay term (= 1 if there is no decay half-life for the contaminant)

Average pumped (discharged) conc. @ time T = $[Cw_{0U1} \times (Ms/Mt)^{T/U1T} \times 2.718^{-kT} \times FQ_{U1}] + [Cw_{0U2} \times (Ms/Mt)^{T/U2T} \times 2.718^{-kT} \times FQ_{U2}] + [Cw_{0U3} \times (Ms/Mt)^{T/U3T} \times 2.718^{-kT} \times FQ_{U3}]$

where FQ_{Un} = Fraction of total flow per day, Un unit (volume Un pumped/total volume pumped per day, or volume Un discharged/total volume discharged per day, under natural flushing conditions)

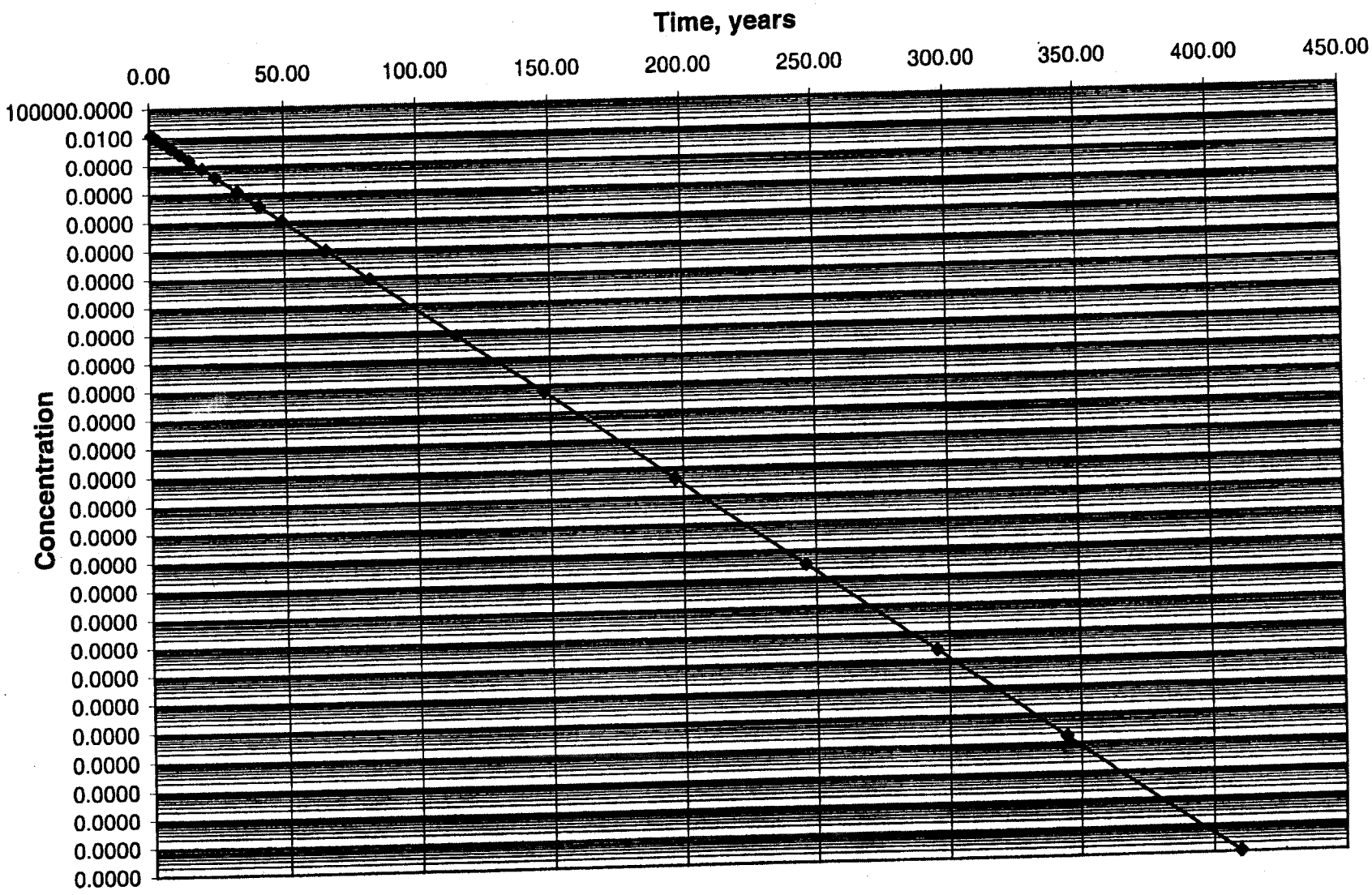
Number of pore volumes (PVs) required to reach target gw concentration Cw_x:

PVs = log (Cw_x/Cw_0) / log (Ms/Mt), for each groundwater flow unit

The last 5 time periods can be modified to evaluate contaminants w/ long cleanup times or more precisely determine the time required to meet a specific residual concentration.

Spreadsheet developed by J. P. Orient, 2/2001

Contaminant Concentration Trend Over Time



Pore Volume Contaminant Concentration Calculations

Project:	Cecil Field Site 25	Proj. No.:	0039.DSO.11E220
Chemical :	beta-BHC	Koc (Kd*) :	2140
Concentration units, water & soil (pick 1):	mg/L & mg/Kg:	ug/L & ug/Kg:	X

NOTE: Input cells are shaded - all other cells are fixed or are automatically calculated.

All groundwater/soil contaminant concentrations are in consistent units, i.e., mg/L & mg/Kg, or ug/L & ug/Kg.

Heterogeneous Aquifer Flushing Rate, With or Without Contaminant Decay

This spreadsheet calculates pore volume flushing rates and cleanup times for a groundwater flow system that consists of up to 3 identified groundwater "flow units". Flow units are defined as discrete portions of the aquifer that have unique properties, i.e., a higher or lower average hydraulic conductivity, porosity, or specific gravity relative to other portions of the aquifer, higher or lower average contaminant concentrations, and/or different organic carbon contents. The spreadsheet allows for factoring in different flushing rates for discrete portions of the aquifer based on the differences in the physical/chemical characteristics of the flow units. First-order contaminant decay/degradation processes can also be factored into the cleanup rate prediction, through the optional use of contaminant half-life data. For simple,homogeneous aquifer flushing time simulations, the input parameters for all three flow units can be set at the same values.

Groundwater Flow Unit Physical/Chemical Data

Flow Unit 1 (U1)		Flow Unit 2 (U2)		Flow Unit 3 (U3)	
Cw_{0U1}	0.074	Cw_{0U2}	0.074	Cw_{0U3}	0.074
n	0.250	n	0.250	n	0.250
SG	2.650	SG	2.650	SG	2.650
foc*	0.0075	foc*	0.0075	foc*	0.0075
Kd	16.050	Kd	16.050	Kd	16.050
Mw	0.019	Mw	0.019	Mw	0.019
Cs	1.188	Cs	1.188	Cs	1.188
Ms	2.361	Ms	2.361	Ms	2.361
Mt	2.379	Mt	2.379	Mt	2.379
Ms/Mt	0.9922	Ms/Mt	0.9922	Ms/Mt	0.9922

Cw_{0Un} = initial contaminant concentration in groundwater flow unit n

Contaminant Partitioning Formulas :

$Mw = Cw \times n$
$Cs = Koc \times foc \times Cw$, or, $Kd \times Cw$
$Kd = Koc \times foc$, or, Cs/Cw
$Ms = SG \times (1-n) \times Cs$
$Mt = Mw + Ms$
$Cw_{n+1} = [Cw_n](Ms_n/Mt_n)$

where:
Cw = contaminant concentration in groundwater
n = aquifer porosity
SG = specific gravity of aquifer solids (default value = 2.65)
Mw = mass of contaminants per unit volume of aquifer water
Cs = contaminant concentration on aquifer solids
Ms = mass of contaminants per unit volume of aquifer solids
Mt = total mass of contaminants per unit volume of aquifer
Koc = organic carbon partition coefficient
foc = fractional organic carbon content of solids
Kd = soil/water distribution coefficient

*** for contaminants that partition between soil and water thru mechanisms other than adsoption onto organic carbon, i.e., metals, the compound's Kd is input directly into the Koc entry cell, with foc then set to 1.**

Groundwater Flow Unit Hydrogeologic Characteristics

Avg. K, ft/day listed highest to lowest	Relative average K, K_{Un}	Fraction of aquifer volume, FV_{Un}	Fraction of total flow, FQ_{Un}	Flow unit designation, Un
1	1	0.333	0.333	U1
1	1	0.333	0.333	U2
1	1	0.333	0.333	U3

Fraction of total flow, flow unit n (FQ_{Un}) = $K_{Un} \times FV_{Un}^{2/3} / (K_{U1} \times FV_{U1}^{2/3} + K_{U2} \times FV_{U2}^{2/3} + K_{U3} \times FV_{U3}^{2/3})$

where K_{U1}, K_{U2}, K_{U3} = the relative average hydraulic conductivities of 3 flow units or zones within the aquifer; FV_{U1}, FV_{U2}, FV_{U3} = fractional volume of the aquifer represented by each flow unit or flow zone

Pore Volumes and Pore Volume Removal Rates

Discharge rate, gpm	Discharge rate, ft^3/day, Q_t	Groundwater plume vol., ft^3, PV_t	Volume, U1 discharged, ft^3/day, Q_{U1}	Volume, U2 discharged, ft^3/day, Q_{U2}	Volume, U3 discharged, ft^3/day, Q_{U3}	Plume pore volume, U1, ft^3, PV_{U1}	Plume pore volume, U2, ft^3, PV_{U2}	Plume pore volume, U3, ft^3, PV_{U3}	Time for 1 PV flush, Unit 1, days, U1T	Time for 1 PV flush, Unit 2, days, U2T	Time for 1 PV flush, Unit 3, days, U3T
5	962.57	39,270	320.86	320.86	320.86	13076.91	13076.91	13076.91	40.76	40.76	40.76

Groundwater discharged per day from flow unit n (Q_{Un}) = Q_t x FQ_{Un}

Time required for 1 pore volume flush, flow unit n (UnT) = PV_{Un} / Q_{Un}

One plume pore volume, flow unit n (PV_{Un}) = PV_t x FV_{Un}

Contaminant Half-Life Data

Does contaminant have a decay half-life (yes/no):	yes	If yes, give half-life (days):	248	1st order decay coef. (k):	0.002794

1st order decay coefficient = 0.693/half-life

Average Pumped/Discharged and Residual Plume Concentrations Over Time

Time period	Time span, days, T	Avg pumped concentration	Avg residual GW conc.	Time span, years
1	40.76	0.066	0.065	0.11
2	81.51	0.058	0.058	0.22
3	122.27	0.051	0.051	0.33
5	203.78	0.040	0.040	0.56
7	285.29	0.032	0.032	0.78
9	366.81	0.025	0.025	1.00
12	489.08	0.017	0.017	1.34
15	611.35	0.012	0.012	1.67
20	815.13	0.006	0.006	2.23
25	1018.91	0.004	0.004	2.79
30	1222.69	0.002	0.002	3.35
40	1630.25	0.001	0.001	4.46
50	2037.82	0.000	0.000	5.58
70	2852.95	0.000	0.000	7.81
90	3668.07	0.000	0.000	10.04
120	4890.76	0.000	0.000	13.39
150	6113.46	0.000	0.000	16.74
180	7336.15	0.000	0.000	20.09
210	8558.84	0.000	0.000	23.43
250	10189.09	0.000	0.000	27.90
10	407.56	0.022	0.022	1.12
11	448.32	0.019	0.019	1.23
10.5	427.94	0.021	0.021	1.17
10.7	436.09	0.020	0.020	1.19
4.6	187.48	0.042	0.042	0.51

Residual groundwater concentration @ time T = $[Cw_{0U1} \times (Ms/Mt)^{T/U1T} \times 2.718^{-kT} \times FV_{U1}] + [Cw_{0U2} \times (Ms/Mt)^{T/U2T} \times 2.718^{-kT} \times FV_{U2}] + [Cw_{0U3} \times (Ms/Mt)^{T/U3T} \times 2.718^{-kT} \times FV_{U3}]$

where U1T, U2T,U3T = times required to remove 1 pore volume from the U1, U2, and U3 portions of the aquifer; Cw_{0U1}, Cw_{0U2}, Cw_{0U3} = initial groundwater concentrations for the U1, U2, U3 flow units, $2.718^{-kT} = e^{-kT}$ = the 1st order decay term (= 1 if there is no decay half-life for the contaminant)

Average pumped (discharged) conc. @ time T = $[Cw_{0U1} \times (Ms/Mt)^{T/U1T} \times 2.718^{-kT} \times FQ_{U1}] + [Cw_{0U2} \times (Ms/Mt)^{T/U2T} \times 2.718^{-kT} \times FQ_{U2}] + [Cw_{0U3} \times (Ms/Mt)^{T/U3T} \times 2.718^{-kT} \times FQ_{U3}]$

where FQ_{Un} = Fraction of total flow per day, Un unit (volume Un pumped/total volume pumped per day, or volume Un discharged/total volume discharged per day, under natural flushing conditions)

Number of pore volumes (PVs) required to reach target gw concentration Cw_x:

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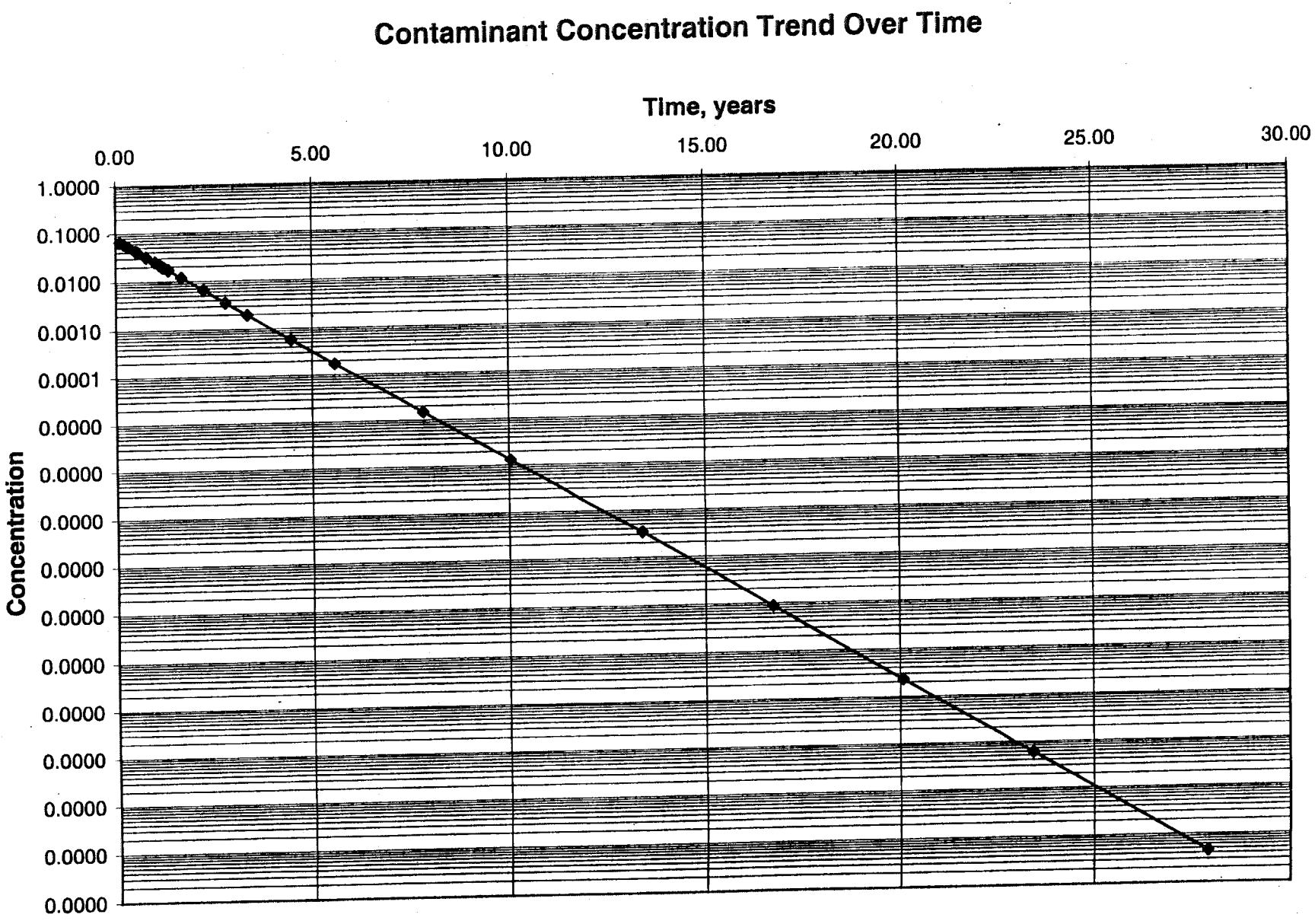
The last 5 time periods can be modified to evaluate contaminants w/ long cleanup times or more precisely determine the time required to meet a specific residual concentration.

Spreadsheet developed by J. P. Orient, 2/2001


Contaminant Concentration Trend Over Time
Time, years
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Concentration
1.0000
0.1000
0.0100
0.0010
0.0001
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000

Pore Volume Contaminant Concentration Calculations

Project:	Cecil Field Site 25	Proj. No.:	0039.DSO.11E220
Chemical :	beta-BHC	Koc (Kd*) :	2140
Concentration units, water & soil (pick 1):	mg/L & mg/Kg:	ug/L & ug/Kg:	X

Heterogeneous Aquifer Flushing Rate, With or Without Contaminant Decay

This spreadsheet calculates pore volume flushing rates and cleanup times for a groundwater flow system that consists of up to 3 identified groundwater "flow units". Flow units are defined as discrete portions of the aquifer that have unique properties, i.e., a higher or lower average hydraulic conductivity, porosity, or specific gravity relative to other portions of the aquifer, higher or lower average contaminant concentrations, and/or different organic carbon contents. The spreadsheet allows for factoring in different flushing rates for discrete portions of the aquifer based on the differences in the physical/chemical characteristics of the flow units. First-order contaminant decay/degradation processes can also be factored into the cleanup rate prediction, through the optional use of contaminant half-life data. For simple,homogeneous aquifer flushing time simulations, the input parameters for all three flow units can be set at the same values.

Groundwater Flow Unit Physical/Chemical Data

Flow Unit 1 (U1)		Flow Unit 2 (U2)		Flow Unit 3 (U3)	
Cw_{0U1}	0.074	Cw_{0U2}	0.074	Cw_{0U3}	0.074
n	0.250	n	0.250	n	0.250
SG	2.650	SG	2.650	SG	2.650
foc*	0.0075	foc*	0.0075	foc*	0.0075
Kd	16.050	Kd	16.050	Kd	16.050
Mw	0.019	Mw	0.019	Mw	0.019
Cs	1.188	Cs	1.188	Cs	1.188
Ms	2.361	Ms	2.361	Ms	2.361
Mt	2.379	Mt	2.379	Mt	2.379
Ms/Mt	0.9922	Ms/Mt	0.9922	Ms/Mt	0.9922

Cw_{0Un} = initial contaminant concentration in groundwater flow unit n

Groundwater Flow Unit Hydrogeologic Characteristics

Avg. K, ft/day listed highest to lowest	Relative average K, K_{Un}	Fraction of aquifer volume, FV_{Un}	Fraction of total flow, FQ_{Un}	Flow unit designation, Un
1	1	0.333	0.333	U1
1	1	0.333	0.333	U2
1	1	0.333	0.333	U3

NOTE: Input cells are shaded - all other cells are fixed or are automatically calculated.

All groundwater/soil contaminant concentrations are in consistent units, i.e., mg/L & mg/Kg, or ug/L & ug/Kg.

Contaminant Partitioning Formulas :

Mw = Cw x n
Cs = Koc x foc x Cw, or, Kd x Cw
Kd = Koc x foc, or, Cs/Cw
Ms = SG x (1-n) x Cs
Mt = Mw + Ms
$Cw_{n+1} = [Cw_n](Ms_n/Mt_n)$

where:
Cw = contaminant concentration in groundwater
n = aquifer porosity
SG = specific gravity of aquifer solids (default value = 2.65)
Mw = mass of contaminants per unit volume of aquifer water
Cs = contaminant concentration on aquifer solids
Ms = mass of contaminants per unit volume of aquifer solids
Mt = total mass of contaminants per unit volume of aquifer
Koc = organic carbon partition coefficient
foc = fractional organic carbon content of solids
Kd = soil/water distribution coefficient

*** for contaminants that partition between soil and water thru mechanisms other than adsoption onto organic carbon, i.e., metals, the compound's Kd is input directly into the Koc entry cell, with foc then set to 1.**

Fraction of total flow, flow unit n (FQ_{Un}) = $K_{Un} \times FV_{Un}^{2/3} / (K_{U1} \times FV_{U1}^{2/3} + K_{U2} \times FV_{U2}^{2/3} + K_{U3} \times FV_{U3}^{2/3})$

where K_{U1}, K_{U2}, K_{U3} = the relative average hydraulic conductivities of 3 flow units or zones within the aquifer; FV_{U1}, FV_{U2}, FV_{U3} = fractional volume of the aquifer represented by each flow unit or flow zone

Pore Volumes and Pore Volume Removal Rates

Discharge rate, gpm	Discharge rate, ft^3/day, Q_t	Groundwater plume vol., ft^3, PV_t	Volume, U1 discharged, ft^3/day, Q_{U1}	Volume, U2 discharged, ft^3/day, Q_{U2}	Volume, U3 discharged, ft^3/day, Q_{U3}	Plume pore volume, U1, ft^3, PV_{U1}	Plume pore volume, U2, ft^3, PV_{U2}	Plume pore volume, U3, ft^3, PV_{U3}	Time for 1 PV flush, Unit 1, days, U1T	Time for 1 PV flush, Unit 2, days, U2T	Time for 1 PV flush, Unit 3, days, U3T
10	1925.13	39,270	641.71	641.71	641.71	13076.91	13076.91	13076.91	20.38	20.38	20.38

Groundwater discharged per day from flow unit n (Q_{Un}) = Q_t x FQ_{Un}

One plume pore volume, flow unit n (PV_{Un}) = PV_t x FV_{Un}

Time required for 1 pore volume flush, flow unit n (UnT) = PV_{Un} / Q_{Un}

Contaminant Half-Life Data

Does contaminant have a decay half-life (yes/no):	yes	If yes, give half-life (days):	248	1st order decay coef. (k):	0.002794

1st order decay coefficient = 0.693/half-life

Average Pumped/Discharged and Residual Plume Concentrations Over Time

Time period	Time span, days, T	Avg pumped concentration	Avg residual GW conc.	Time span, years
1	20.38	0.069	0.069	0.06
2	40.76	0.065	0.065	0.11
3	61.13	0.061	0.061	0.17
5	101.89	0.054	0.053	0.28
7	142.65	0.047	0.047	0.39
9	183.40	0.041	0.041	0.50
12	244.54	0.034	0.034	0.67
15	305.67	0.028	0.028	0.84
20	407.56	0.020	0.020	1.12
25	509.45	0.015	0.015	1.39
30	611.35	0.011	0.011	1.67
40	815.13	0.006	0.006	2.23
50	1018.91	0.003	0.003	2.79
70	1426.47	0.001	0.001	3.91
90	1834.04	0.000	0.000	5.02
120	2445.38	0.000	0.000	6.70
150	3056.73	0.000	0.000	8.37
180	3668.07	0.000	0.000	10.04
210	4279.42	0.000	0.000	11.72
250	5094.55	0.000	0.000	13.95
18	366.81	0.023	0.023	1.00
22	448.32	0.018	0.018	1.23
21	427.94	0.019	0.019	1.17
19	387.19	0.022	0.022	1.06
4.6	93.74	0.055	0.055	0.26

Residual groundwater concentration @ time T = $[Cw_{0U1} \times (Ms/Mt)^{T/U1T} \times 2.718^{-kT} \times FV_{U1}] + [Cw_{0U2} \times (Ms/Mt)^{T/U2T} \times 2.718^{-kT} \times FV_{U2}] + [Cw_{0U3} \times (Ms/Mt)^{T/U3T} \times 2.718^{-kT} \times FV_{U3}]$

where U1T, U2T,U3T = times required to remove 1 pore volume from the U1, U2, and U3 portions of the aquifer; Cw_{0U1}, Cw_{0U2}, Cw_{0U3} = initial groundwater concentrations for the U1, U2, U3 flow units, $2.718^{-kT} = e^{-kT}$ = the 1st order decay term (= 1 if there is no decay half-life for the contaminant)

Average pumped (discharged) conc. @ time T = $[Cw_{0U1} \times (Ms/Mt)^{T/U1T} \times 2.718^{-kT} \times FQ_{U1}] + [Cw_{0U2} \times (Ms/Mt)^{T/U2T} \times 2.718^{-kT} \times FQ_{U2}] + [Cw_{0U3} \times (Ms/Mt)^{T/U3T} \times 2.718^{-kT} \times FQ_{U3}]$

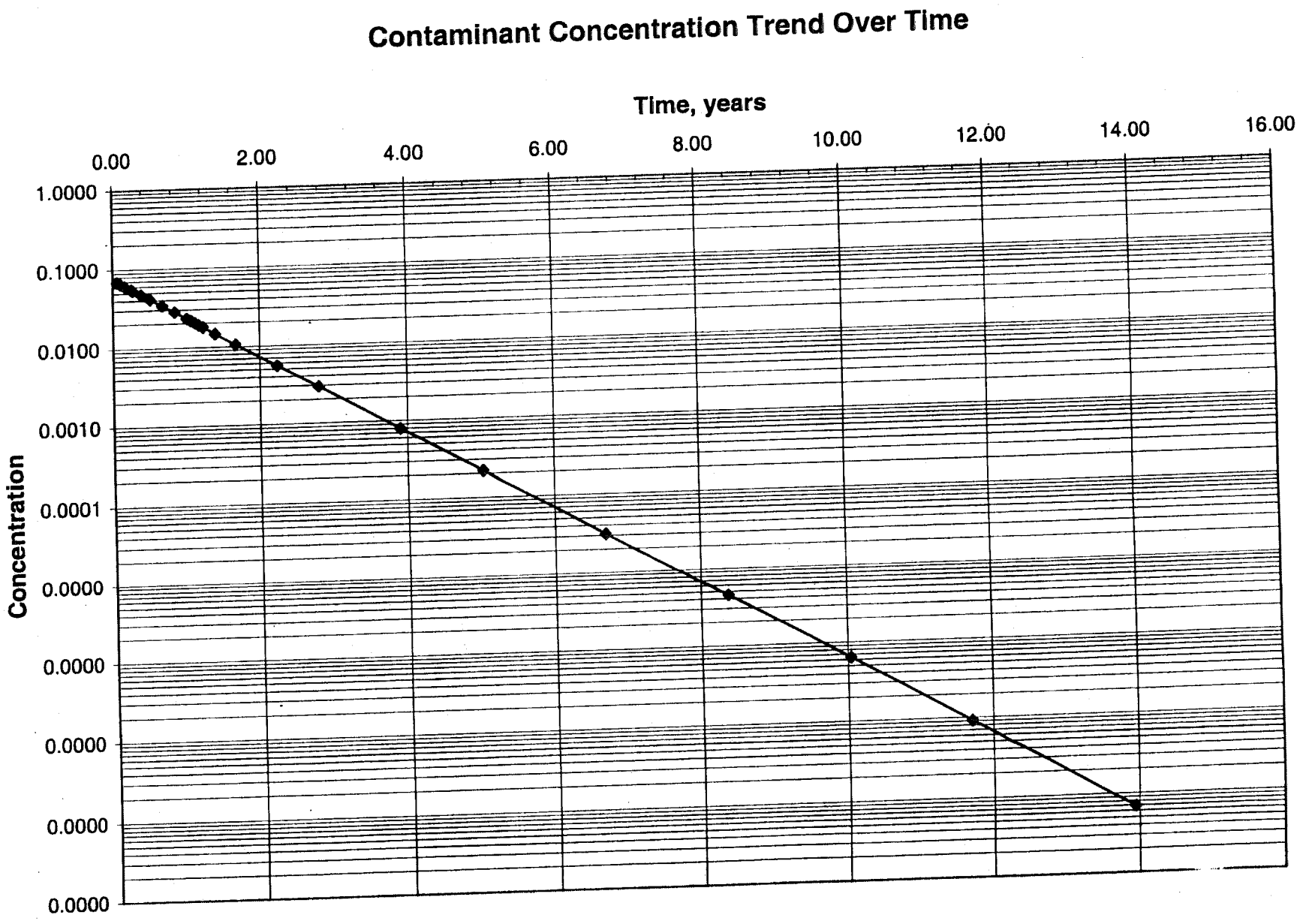
where FQ_{Un} = Fraction of total flow per day, Un unit (volume Un pumped/total volume pumped per day, or volume Un discharged/total volume discharged per day, under natural flushing conditions)

Number of pore volumes (PVs) required to reach target gw concentration Cw_x:

PVs = log (Cw_x/Cw_0) / log (Ms/Mt), for each groundwater flow unit

The last 5 time periods can be modified to evaluate contaminants w/ long cleanup times or more precisely determine the time required to meet a specific residual concentration.

Spreadsheet developed by J. P. Orient, 2/2001


Contaminant Concentration Trend Over Time
Time, years
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Concentration
1.0000
0.1000
0.0100
0.0010
0.0001
0.0000
0.0000
0.0000
0.0000
0.0000

Pore Volume Contaminant Concentration Calculations

Project:	Cecil Field Site 25	Proj. No.:	0039.DSC.11E220
Chemical :	beta-BHC	Koc (Kd*) :	2140
Concentration units, water & soil (pick 1):	mg/L & mg/Kg:	ug/L & ug/Kg:	X

Heterogeneous Aquifer Flushing Rate, With or Without Contaminant Decay

This spreadsheet calculates pore volume flushing rates and cleanup times for a groundwater flow system that consists of up to 3 identified groundwater "flow units". Flow units are defined as discrete portions of the aquifer that have unique properties, i.e., a higher or lower average hydraulic conductivity, porosity, or specific gravity relative to other portions of the aquifer, higher or lower average contaminant concentrations, and/or different organic carbon contents. The spreadsheet allows for factoring in different flushing rates for discrete portions of the aquifer based on the differences in the physical/chemical characteristics of the flow units. First-order contaminant decay/degradation processes can also be factored into the cleanup rate prediction, through the optional use of contaminant half-life data. For simple,homogeneous aquifer flushing time simulations, the input parameters for all three flow units can be set at the same values.

Groundwater Flow Unit Physical/Chemical Data

Flow Unit 1 (U1)		Flow Unit 2 (U2)		Flow Unit 3 (U3)	
Cw_{0U1}	0.074	Cw_{0U2}	0.074	Cw_{0U3}	0.074
n	0.250	n	0.250	n	0.250
SG	2.650	SG	2.650	SG	2.650
foc*	0.0075	foc*	0.0075	foc*	0.0075
Kd	16.050	Kd	16.050	Kd	16.050
Mw	0.019	Mw	0.019	Mw	0.019
Cs	1.188	Cs	1.188	Cs	1.188
Ms	2.361	Ms	2.361	Ms	2.361
Mt	2.379	Mt	2.379	Mt	2.379
Ms/Mt	0.9922	Ms/Mt	0.9922	Ms/Mt	0.9922

Cw_{0Un} = initial contaminant concentration in groundwater flow unit n

Groundwater Flow Unit Hydrogeologic Characteristics

Avg. K, ft/day listed highest to lowest	Relative average K, K_{Un}	Fraction of aquifer volume, FV_{Un}	Fraction of total flow, FQ_{Un}	Flow unit designation, Un
1	1	0.333	0.333	U1
1	1	0.333	0.333	U2
1	1	0.333	0.333	U3

NOTE: Input cells are shaded - all other cells are fixed or are automatically calculated.

All groundwater/soil contaminant concentrations are in consistent units, i.e., mg/L & mg/Kg, or ug/L & ug/Kg.

Contaminant Partitioning Formulas :

$Mw = Cw \times n$
$Cs = Koc \times foc \times Cw$, or, $Kd \times Cw$
$Kd = Koc \times foc$, or, Cs/Cw
$Ms = SG \times (1-n) \times Cs$
$Mt = Mw + Ms$
$Cw_{n+1} = [Cw_n](Ms_n/Mt_n)$

where:
Cw = contaminant concentration in groundwater
n = aquifer porosity
SG = specific gravity of aquifer solids (default value = 2.65)
Mw = mass of contaminants per unit volume of aquifer water
Cs = contaminant concentration on aquifer solids
Ms = mass of contaminants per unit volume of aquifer solids
Mt = total mass of contaminants per unit volume of aquifer
Koc = organic carbon partition coefficient
foc = fractional organic carbon content of solids
Kd = soil/water distribution coefficient

*** for contaminants that partition between soil and water thru mechanisms other than adsoption onto organic carbon, i.e., metals, the compound's Kd is input directly into the Koc entry cell, with foc then set to 1.**

Fraction of total flow, flow unit n (FQ_{Un}) = $K_{Un} \times FV_{Un}^{2/3}/(K_{U1} \times FV_{U1}^{2/3} + K_{U2} \times FV_{U2}^{2/3} + K_{U3} \times FV_{U3}^{2/3})$

where K_{U1}, K_{U2}, K_{U3} = the relative average hydraulic conductivities of 3 flow units or zones within the aquifer; FV_{U1}, FV_{U2}, FV_{U3} = fractional volume of the aquifer represented by each flow unit or flow zone

Pore Volumes and Pore Volume Removal Rates

Discharge rate, gpm	Discharge rate, ft^3/day, Q_t	Groundwater plume vol., ft^3, PV_t	Volume, U1 discharged, ft^3/day, Q_{U1}	Volume, U2 discharged, ft^3/day, Q_{U2}	Volume, U3 discharged, ft^3/day, Q_{U3}	Plume pore volume, U1, ft^3, PV_{U1}	Plume pore volume, U2, ft^3, PV_{U2}	Plume pore volume, U3, ft^3, PV_{U3}	Time for 1 PV flush, Unit 1, days, U1T	Time for 1 PV flush, Unit 2, days, U2T	Time for 1 PV flush, Unit 3, days, U3T
15	2887.70	39,270	962.57	962.57	962.57	13076.91	13076.91	13076.91	13.59	13.59	13.59

Groundwater discharged per day from flow unit n (Q_{Un}) = Q_t x FQ_{Un}

One plume pore volume, flow unit n (PV_{Un}) = PV_t x FV_{Un}

Time required for 1 pore volume flush, flow unit n (UnT) = PV_{Un} / Q_{Un}

Contaminant Half-Life Data

Does contaminant have a decay half-life (yes/no):	yes	If yes, give half-life (days):	248	1st order decay coef. (k):	0.002794

1st order decay coefficient = 0.693/half-life

Average Pumped/Discharged and Residual Plume Concentrations Over Time

Time period	Time span, days, T	Avg pumped concentration	Avg residual GW conc.	Time span, years
1	13.59	0.071	0.071	0.04
2	27.17	0.068	0.067	0.07
3	40.76	0.065	0.064	0.11
5	67.93	0.059	0.059	0.19
7	95.10	0.054	0.054	0.26
9	122.27	0.049	0.049	0.33
12	163.03	0.043	0.043	0.45
15	203.78	0.037	0.037	0.56
20	271.71	0.030	0.030	0.74
25	339.64	0.024	0.024	0.93
30	407.56	0.019	0.019	1.12
40	543.42	0.012	0.012	1.49
50	679.27	0.008	0.007	1.86
70	950.98	0.003	0.003	2.60
90	1222.69	0.001	0.001	3.35
120	1630.25	0.000	0.000	4.46
150	2037.82	0.000	0.000	5.58
180	2445.38	0.000	0.000	6.70
210	2852.95	0.000	0.000	7.81
250	3396.36	0.000	0.000	9.30
28	380.39	0.021	0.021	1.04
29	393.98	0.020	0.020	1.08
21	285.29	0.028	0.028	0.78
19	258.12	0.031	0.031	0.71
4.6	62.49	0.060	0.060	0.17

Residual groundwater concentration @ time T = $[Cw_{0U1} \times (Ms/Mt)^{T/U1T} \times 2.718^{-kT} \times FV_{U1}] + [Cw_{0U2} \times (Ms/Mt)^{T/U2T} \times 2.718^{-kT} \times FV_{U2}] + [Cw_{0U3} \times (Ms/Mt)^{T/U3T} \times 2.718^{-kT} \times FV_{U3}]$

where U1T, U2T,U3T = times required to remove 1 pore volume from the U1, U2, and U3 portions of the aquifer; Cw_{0U1}, Cw_{0U2}, Cw_{0U3} = initial groundwater concentrations for the U1, U2, U3 flow units, $2.718^{-kT} = e^{-kT}$ = the 1st order decay term (= 1 if there is no decay half-life for the contaminant)

Average pumped (discharged) conc. @ time T = $[Cw_{0U1} \times (Ms/Mt)^{T/U1T} \times 2.718^{-kT} \times FQ_{U1}] + [Cw_{0U2} \times (Ms/Mt)^{T/U2T} \times 2.718^{-kT} \times FQ_{U2}] + [Cw_{0U3} \times (Ms/Mt)^{T/U3T} \times 2.718^{-kT} \times FQ_{U3}]$

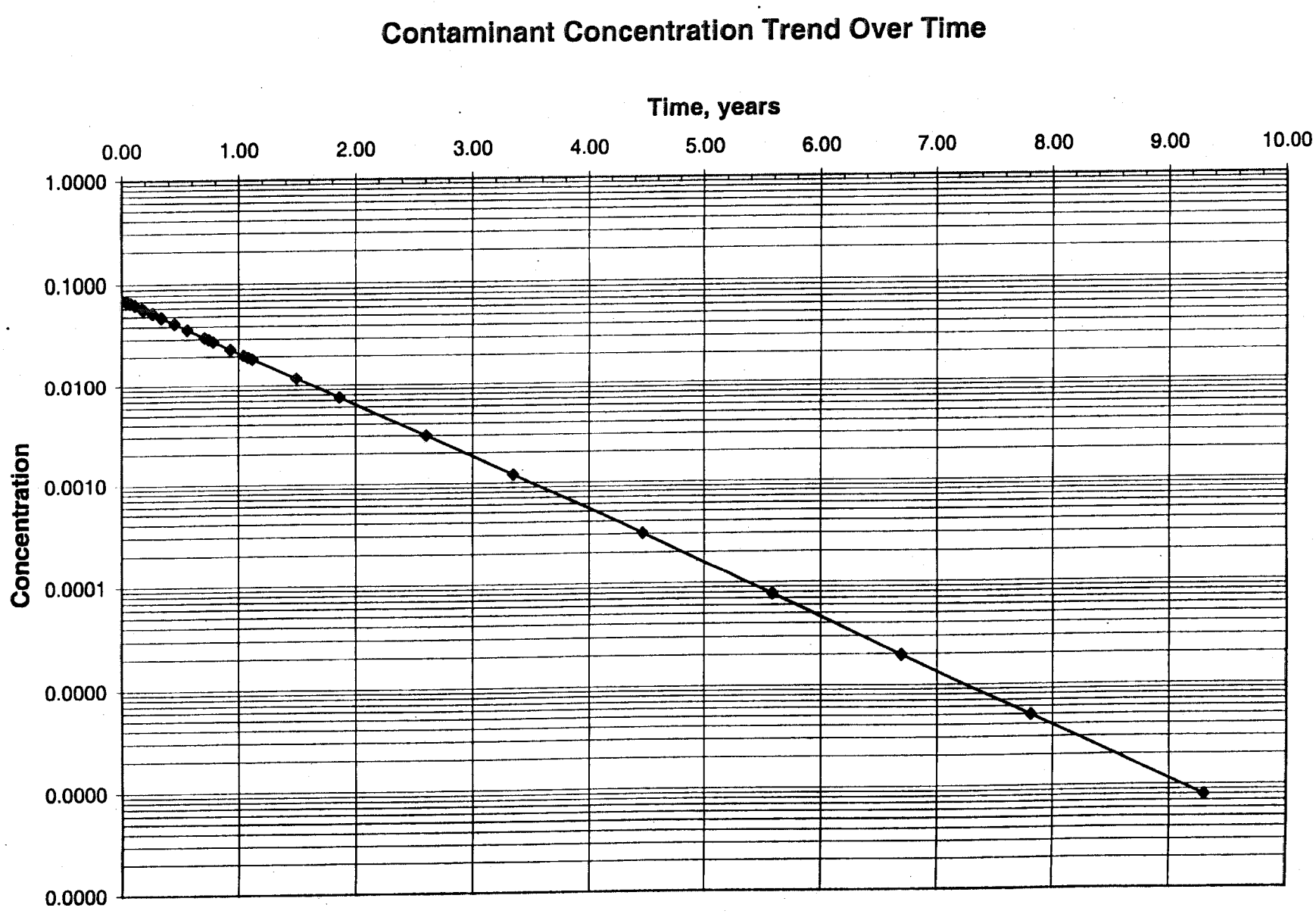
where FQ_{Un} = Fraction of total flow per day, Un unit (volume Un pumped/total volume pumped per day, or volume Un discharged/total volume discharged per day, under natural flushing conditions)

Number of pore volumes (PVs) required to reach target gw concentration Cw_x:

PVs = log (Cw_x/Cw_0) / log (Ms/Mt), for each groundwater flow unit

The last 5 time periods can be modified to evaluate contaminants w/ long cleanup times or more precisely determine the time required to meet a specific residual concentration.

Spreadsheet developed by J. P. Orient, 2/2001


Contaminant Concentration Trend Over Time
Time, years
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Concentration
1.0000
0.1000
0.0100
0.0010
0.0001
0.0000
0.0000
0.0000

A.3

GROUNDWATER TREATMENT SYSTEM DESIGN

1.0 DESIGN ASSUMPTIONS

The following design assumptions are made based upon the results of the RI and previous investigations:

- The only COCs are α-BHC and β-BHC.
- The contaminant plume where α-BHC and β-BHC concentrations exceed PRGs (0.06 and 0.2 μg/L) extends in a circular area 100 ft in diameter and centered on well CEF-P25-01S
- The depth to which α-BHC and β-BHC concentrations exceed PRGs extends to 15 ft bgs.
- Average total BHC (α-, β-, γ-) concentration within the contaminant plume is approximately 0.48 μg/L, which is the mathematical average of the concentrations detected at well CEF-P25-01S. Maximum total BHC concentration is 0.67 μg/L.

2.0 CONTAMINANT PLUME AREA AND VOLUME

Contaminant plume area, as shown on Figure 4-5: $\pi \times (100)^2 \div 4 = 7{,}854\ ft^2$.

Based upon a typical groundwater table depth of 5 ft bgs and on the above assumption for depth of BHC contamination, the average thickness of the contaminant plume is approximately 10 ft (5 to 15 ft bgs).

Based on a porosity of 0.25, that is typical at NAS Cecil Field, the design volume of the contaminant plume is:

$7{,}854\ ft^2 \times 10\ ft \times 0.25 = 19{,}635\ ft^3$ or 147,000 gallons.

3.0 TREATMENT SCHEME

Groundwater Alternative 4 would consist of a "pump-and-treat" system extracting and treating groundwater from the contaminant plume and featuring the following elements:

- Groundwater extraction wells and pumps
- Filtration
- Liquid-phase granular activated carbon (GAC) adsorption
- Surface discharge

4.0 GROUNDWATER EXTRACTION WELLS AND PUMPS

As per calculations provided in Appendix A.1, the design of groundwater extraction system would consist of two wells (EW-1, EW-2) screened in the shallow zone of the surficial aquifer (5-17 ft bgs), each pumping and pumping at the rate of 7.5 gpm for a total extraction rate of 15 gpm.

EW-1 and EW-2 would be located near the center of the BHC plume as shown on Figure 4-5. A 7.5 gpm @ 100 ft TDH (0.5 HP motor) multi-stage submersible centrifugal pumps would be installed in each well.

5.0 FILTRATION

Use bag type filter unit to avoid liquid residual stream from backwashing.

Size bag filter unit for replacement of filter bag element no more frequently than once a week.

Assuming approximately 5 mg/L TSS in untreated groundwater and 90% removal, TSS accumulation in the filter within a week would be:

15 gpm x 1,440 min/day x 7 days/week x 8.34 lbs/gal x [(5 – 0.5) mg/l] x 10^{-6} = 5.67, say 6 lbs dry TSS /week

Assuming a typical solids capture capacity of approximately 1.0 lbs dry TSS per square foot of bag filter element, required surface of bag element is:

6 lbs ÷ 1.0 lbs/ft^2 = 6 ft^2

→ Call two (one spare) 15 gpm multi-bag pressurized filter unit with a total filter area of 6 ft^2

6.0 LIQUID-PHASE GRANULAR ACTIVATED CARBON ADSORPTION

Filtered groundwater would be treated in a liquid-phase GAC adsorption system to remove BHC prior to discharge.

The liquid-phase GAC adsorption system would feature two absorption units operating in series with each unit providing an empty bed contact time (EBCT) of 5 minutes.

Required GAC capacity per adsorption unit:

(15 gpm x 5 minutes) ÷ 7.485 gal/ ft^3 = 10 ft^3 GAC or, @ approximately 35 lbs/ft^3, 350 lbs GAC

Check expected duration of GAC adsorption unit based upon an assumed groundwater TOC concentration of up to 2 mg/L and an adsorption capacity of 0.1 pound of TOC per pound of GAC:

Predicted daily GAC use:

(15 gpm x 1,440 min/day x 8.34 lbs/gal x 2 mg/L TOC x 10^{-6}) ÷ 0.1 lbs TOC/lbs GAC = 3.6 lbs GAC/day

GAC adsorption unit cycle duration:

350 lbs GAC ÷ 3.6 lbs GAC/day = 97 days **OK**

Closest commercially available GAC adsorption unit (Carbonair PC-5 or equivalent) holds 575 lbs GAC

→ Call for a liquid-phase GAC adsorption system consisting of two (2) adsorption units operating in series, each holding 575 lbs GAC (Carbonair PC-5 or equivalent).

Re-compute estimated GAC adsorption unit initial cycle duration:

575 lbs GAC÷ 3.6 lbs GAC/day = 160 days

APPENDIX B

NATURAL ATTENUATION MODELING

CLIENT SOUTHDIV		JOB NUMBER 0039 DSO 11E 220	
SUBJECT Cecil Field Site 25 FS			
BASED ON		DRAWING NUMBER	
BY RRM	CHECKED BY JPO	APROVED BY	DATE 10-5-01

Objective: To determine the length of time required for natural attenuation to reduce the concentrations of alpha-BHC and beta-BHC in groundwater to FDEP GCTLs.

Site Data:

Plume diameter = 100-foot circle
Plume area = 7,845 sq ft
Plume thickness = 10 feet
Porosity (n) = 0.25
K = 7.65 ft/day
i = 0.0009
Aquifer thickness (b) = 95 ft
Infiltration = 1.13 ft/yr
Horizontal seepage velocity (V) = Ki/n

V = 7.65 ft/day(0.0009)/0.25 = 2.75 ft/day = 10 ft/yr

Contaminant Data:

K_{oc} alpha-BHC = 1,790 L/kg (published value)
K_{oc} beta-BHC = 2,140 L/kg (published value)
f_{oc} = 0.0075 (Site 25 TOC sample)

Initial groundwater concentrations: alpha-BHC = 0.06 ug/L
beta-BHC = 0.074 ug/L

FDEP GCTLs:
alpha-BHC = 0.005 ug/L
beta-BHC = 0.02 ug/L

Initial soil concentrations alpha-BHC = 0.806 ug/kg = 8.06×10^{-4} mg/kg
beta-BHC = 1.188 ug/kg = 1.188×10^{-3} mg/kg

(For intital soil concentrations, used C_s = contaminant concentration on aquifer solids at pore volume = 0 from groundwater extraction system calculations)

K_d alpha-BHC = $K_{oc} \times f_{oc}$ = 1,790 L/kg x 0.0075 = 13.425 L/kg
K_d beta-BHC = $K_{oc} \times f_{oc}$ = 2,140 L/kg x 0.0075 = 16.05 L/kg

Half-life: alpha-BHC = 0.740 year
beta-BHC = 0.680 year

Using ECTran with parameters as previously defined, estimated times for the groundwater concentrations to decrease to GCTLs under source area by natural attenuation only (no action):

alpha-BHC = 2.6 years
beta-BHC = 1.28 years

See attached ECTran printouts

ECTran Version 2.0 for Excel 4.0 & 5.0

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TETRA TECH NUS, INC.

SITE: Site 25 | Job # 0039 | INVESTIGATOR: RRM | DATE: 10/05/2001

CHEMICAL CHARACTERISTICS				ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	alpha-BHC	EXPOSURE POINT: (UNDERS, FL)	UNDERS	LEACHATE CONCENTRATION (YES,NO) ?	NO
		UNDERS: Under source, FL: Fenceline		INPUT SOLID-PHASE CONCENTRATION (MG/KG)	8.060E-04
		WATER CRITERIA (UG/L):	5.00E-03	CONSTANT CONCENTRATION (YES,NO)?	NO
HALF-LIFE (YRS):	7.40E-01			TRY NEW GOAL:	6.72E-05
SPECIFIC ACTIVITY (Ci/g):	0.00E+00	TIME FRAME (YRS):	5	ACCEPTABLE!	DECREASE

SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke:	1.00	INFILT(FT/YR):	1.13E+00
Kl (L/KG):	1.34E+01	LENGTH (FT):	50
		WIDTH (FT):	50
DEPLETING SOURCE:		IS THERE A CLAY LINER LAYER (YES,NO)?	NO
WASTE CHARACTERISTICS:		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	8.06E-04	HOW MANY SUBLAYERS (1 - 10)?	3
INPUT FOLLOWING PARAMETERS:		TOTAL THICKNESS (UP TO 30 FT) (FT):	10
THICKNESS (FT):	5	SATURATION RATE:	0.95
SATURATION RATE:	0.6	POROSITY:	0.2
POROSITY:	0.25	BULK DENSITY (G/CM^3):	1.78
BULK DENSITY (G/CM^3)	1.5	Kd (L/KG):	1.00E-05

IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	NO
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3)	1.5
Kd (L/KG):	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0

SATURATED LAYER			
TOTAL SATURATED ZONE THICKNESS, B (FT):	95	VERTICAL SEEPAGE VELOCITY, Vzo (FT/YR):	2.1
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	10	DOWNGRADIENT AREA INFILTRATION RATE, q (FT/YR)	1.13
Kd (L/KG):	1.34E+01	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.25	MIXING DEPTH, H (FT):	14.1
VERTICAL DISPERSIVITY, Az (FT):	0.17	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, Ax (FT):	5.0	AGE (YRS):	0
LATERAL DISPERSIVITY, Ay (FT):	0.5	CONC. IN UPGRADIENT GROUNDWATER,CU2 (UG/L)	0
INITIAL CONC. (ug/L):	0.06	DISTANCE TO F.L.:	50

PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)
SATURATED LAYER CONCENTRATION:	6.00E-02 (UG/L)	0
FENCE LINE CONCENTRATION:	0.00E+00 (UG/L)	5

n Version 2.0 for Excel 4.0 & 5.0

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BROWN & ROOT ENVIRONMENTAL

SCREENING-LEVEL EXCEL-CRYSTAL BALL TRANSPORT (ECTran) MODEL

SITE:	Job # 0039	CONTAMINANT:	alpha-BHC
		HALF-LIFE (YRS):	
		LAYER 2:	7.40E-01
INVESTIGATOR:	RRM	SATURATED LAYER	7.40E-01
DATE:	10/05/2001	DOWNGRADIENT	7.40E-01
		INITIAL CONC. (ug/L):	6.00E-02

SATURATED LAYER

INFILT (FT/YR):	1.13			B (FT):	95	Vzo (FT/YR):	2.1
LENGTH (FT):	50			GW Q3 (L/DAY):	3.56E+02		
WIDTH (FT):	50	Kd (L/KG):	1.34E+01	GW V. (FT/YR):	10.00	Kd (L/KG):	13.425
POROSITY 2:	0.3	SATURATION:	1.00	H (FT):	14.0636	RETARDATION:	81.55
POROSITY SAT. LAYER:	0.25	THICKNESS (FT):	14.06	EFF. POROSITY:	0.25	q (FT/YR) :	1.13
DENSITY 2 (G/CM3):	1.5	DECAY (1/DAY):	2.57E-03	DISPERSIVITY:		DECAY (1/YR):	9.8E-01
DENSITY GMA (G/CM3):	1.50	CBo (PPB):	6.00E-02	Az (FT):	0.17		
		CU2 (PPB):	0.00E+00	Ax (FT):	5.00	P&T (YEARS):	0
AGE (YEARS):	0	Q1 (L/DAY): 2.19E+02	Q2 (L/DAY): 1.36E+02	Ay (FT):	0.50	DISTANCE TO F.L. (FT):	50

TIME INTERVAL (YRS)	0.1	SOURCE AREA CONC.(GMA)	FENCE LINE CONC.
ELAPSED TIME - YRS	LAYER 2(PPB)	(UG/L)	(UG/L)
0	6.00E-02	6.00E-02	0.00E+00
0.1	5.46E-02	5.46E-02	0.00E+00
0.2	4.97E-02	4.97E-02	0.00E+00
0.3	4.52E-02	4.53E-02	0.00E+00
0.4	4.11E-02	4.12E-02	0.00E+00
0.5	3.74E-02	3.75E-02	0.00E+00
0.6	3.40E-02	3.41E-02	0.00E+00
0.7	3.09E-02	3.11E-02	0.00E+00
0.8	2.81E-02	2.83E-02	0.00E+00
0.9	2.56E-02	2.58E-02	0.00E+00
1	2.33E-02	2.35E-02	0.00E+00
1.1	2.12E-02	2.14E-02	0.00E+00
1.2	1.93E-02	1.94E-02	0.00E+00
1.3	1.75E-02	1.77E-02	0.00E+00
1.4	1.59E-02	1.61E-02	0.00E+00
1.5	1.45E-02	1.47E-02	0.00E+00
1.6	1.32E-02	1.33E-02	0.00E+00
1.7	1.20E-02	1.22E-02	0.00E+00
1.8	1.09E-02	1.11E-02	0.00E+00
1.9	9.92E-03	1.01E-02	0.00E+00
2	9.02E-03	9.17E-03	0.00E+00
2.1	8.20E-03	8.35E-03	0.00E+00
2.2	7.46E-03	7.60E-03	0.00E+00
2.3	6.79E-03	6.92E-03	0.00E+00
2.4	6.17E-03	6.30E-03	0.00E+00
2.5	5.61E-03	5.73E-03	0.00E+00
2.6	5.11E-03	5.22E-03	0.00E+00
2.7	4.65E-03	4.75E-03	0.00E+00
2.8	4.23E-03	4.32E-03	0.00E+00
2.9	3.84E-03	3.94E-03	0.00E+00
3	3.50E-03	3.58E-03	0.00E+00
3.1	3.18E-03	3.26E-03	0.00E+00
3.2	2.89E-03	2.97E-03	0.00E+00
3.3	2.63E-03	2.70E-03	0.00E+00
3.4	2.39E-03	2.46E-03	0.00E+00
3.5	2.18E-03	2.24E-03	0.00E+00
3.6	1.98E-03	2.04E-03	0.00E+00
3.7	1.80E-03	1.86E-03	0.00E+00
3.8	1.64E-03	1.69E-03	0.00E+00
3.9	1.49E-03	1.54E-03	0.00E+00
4	1.35E-03	1.40E-03	0.00E+00
4.1	1.23E-03	1.27E-03	0.00E+00
4.2	1.12E-03	1.16E-03	0.00E+00
4.3	1.02E-03	1.06E-03	0.00E+00
4.4	9.27E-04	9.62E-04	0.00E+00
4.5	8.43E-04	8.76E-04	0.00E+00
4.6	7.67E-04	7.97E-04	0.00E+00
4.7	6.98E-04	7.26E-04	0.00E+00
4.8	6.35E-04	6.61E-04	0.00E+00
4.9	5.77E-04	6.01E-04	0.00E+00
5	5.25E-04	5.47E-04	0.00E+00
MAXIMUM:	6.00E-02	6.00E-02	0.00E+00

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TETRA TECH NUS, INC.

SITE: Site 25 | Job # 0039 | INVESTIGATOR: RRM | DATE: 10/05/2001

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX			
		EXPOSURE POINT: (UNDERS, FL)	UNDERS	LEACHATE CONCENTRATION (YES,NO) ?	NO
CONTAMINANT:	beta-BHC	UNDERS: Under source, FL: Fenceline		INPUT SOLID-PHASE CONCENTRATION (MG/KG)	1.188E-03
		WATER CRITERIA (UG/L):	2.00E-02	CONSTANT CONCENTRATION (YES,NO)?	NO
HALF-LIFE (YRS):	6.80E-01			TRY NEW GOAL:	3.21E-04
SPECIFIC ACTIVITY (Ci/g):	0.00E+00	TIME FRAME (YRS):	2	ACCEPTABLE!	DECREASE

SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke:	1.00	INFILT(FT/YR):	1.13E+00
Kl (L/KG):	1.61E+01	LENGTH (FT):	50
		WIDTH (FT):	50
DEPLETING SOURCE:		**IS THERE A CLAY LINER LAYER (YES,NO)?**	NO
WASTE CHARACTERISTICS:		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	1.188E-03	HOW MANY SUBLAYERS (1 - 10)?	3
INPUT FOLLOWING PARAMETERS:		TOTAL THICKNESS (UP TO 30 FT) (FT):	10
THICKNESS (FT):	5	SATURATION RATE:	0.95
SATURATION RATE:	0.6	POROSITY:	0.2
POROSITY:	0.25	BULK DENSITY (G/CM^3):	1.78
BULK DENSITY (G/CM^3)	1.5	Kd (L/KG):	1.00E-05

IS THERE A TYPE 1 LAYER (YES,NO)?	NO	**IS THERE A TYPE 2 LAYER (YES,NO)?**	NO
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3)	1.5
Kd (L/KG):	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0

SATURATED LAYER

TOTAL SATURATED ZONE THICKNESS, B (FT):	95	VERTICAL SEEPAGE VELOCITY, Vzo (FT/YR):	2.1
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	10	DOWNGRADIENT AREA INFILTRATION RATE, q (FT/YR)	1.13
Kd (L/KG):	1.61E+01	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.25	MIXING DEPTH, H (FT):	14.1
VERTICAL DISPERSIVITY, Az (FT):	0.17	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, Ax (FT):	5.0	AGE (YRS):	0
LATERAL DISPERSIVITY, Ay (FT):	0.5	CONC. IN UPGRADIENT GROUNDWATER,CU2 (UG/L)	0
INITIAL CONC. (ug/L):	0.074	DISTANCE TO F.L.:	50

PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)
SATURATED LAYER CONCENTRATION:	7.40E-02 (UG/L)	0
FENCE LINE CONCENTRATION:	2.37E-31 (UG/L)	0.04

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BROWN & ROOT ENVIRONMENTAL

SCREENING-LEVEL EXCEL-CRYSTAL BALL TRANSPORT (ECTran) MODEL

SITE:	Job # 0039	CONTAMINANT:	beta-BHC
		HALF-LIFE (YRS):	
		LAYER 2:	6.80E-01
INVESTIGATOR:	RRM	SATURATED LAYER	6.80E-01
DATE:	10/05/2001	DOWNGRADIENT	6.80E-01
		INITIAL CONC. (ug/L):	7.40E-02

SATURATED LAYER

INFILT (FT/YR):	1.13			B (FT):	95	Vzo (FT/YR):	2.1
LENGTH (FT):	50			GW Q3 (L/DAY):	3.56E+02		
WIDTH (FT):	50	Kd (L/KG):	1.61E+01	GW V. (FT/YR):	10.00	Kd (L/KG):	16.05
POROSITY 2:	0.3	SATURATION:	1.00	H (FT):	14.0636	RETARDATION:	97.3
POROSITY SAT. LAYER:	0.25	THICKNESS (FT):	14.06	EFF. POROSITY:	0.25	q (FT/YR) :	1.13
DENSITY 2 (G/CM3):	1.5	DECAY (1/DAY):	2.79E-03	DISPERSIVITY:		DECAY (1/YR):	1.1E+00
DENSITY GMA (G/CM3):	1.50	CBo (PPB):	7.40E-02	Az (FT):	0.17		
		CU2 (PPB):	0.00E+00	Ax (FT):	5.00	P&T (YEARS):	0
AGE (YEARS): 0	Q1 (L/DAY): 2.19E+02	Q2 (L/DAY):	1.36E+02	Ay (FT):	0.50	DISTANCE TO F.L. (FT):	50

TIME INTERVAL (YRS)	0.04	SOURCE AREA CONC.(GMA)	FENCE LINE CONC.
ELAPSED TIME - YRS	LAYER 2(PPB)	(UG/L)	(UG/L)
0	7.40E-02	7.40E-02	0.00E+00
0.04	7.10E-02	7.10E-02	2.37E-31
0.08	6.82E-02	6.82E-02	-9.50E-33
0.12	6.54E-02	6.55E-02	-9.12E-33
0.16	6.28E-02	6.28E-02	-8.76E-33
0.2	6.03E-02	6.03E-02	-8.41E-33
0.24	5.78E-02	5.79E-02	-8.07E-33
0.28	5.55E-02	5.56E-02	-7.75E-33
0.32	5.33E-02	5.34E-02	-7.44E-33
0.36	5.11E-02	5.12E-02	-7.14E-33
0.4	4.91E-02	4.92E-02	-6.85E-33
0.44	4.71E-02	4.72E-02	-6.58E-33
0.48	4.52E-02	4.53E-02	-6.31E-33
0.52	4.34E-02	4.35E-02	-6.06E-33
0.56	4.16E-02	4.18E-02	-5.82E-33
0.6	3.99E-02	4.01E-02	-5.59E-33
0.64	3.83E-02	3.85E-02	-5.36E-33
0.68	3.68E-02	3.69E-02	-5.15E-33
0.72	3.53E-02	3.55E-02	-4.94E-33
0.76	3.39E-02	3.40E-02	-4.74E-33
0.8	3.25E-02	3.27E-02	-4.55E-33
0.84	3.12E-02	3.14E-02	-4.37E-33
0.88	2.99E-02	3.01E-02	-4.20E-33
0.92	2.87E-02	2.89E-02	-4.03E-33
0.96	2.76E-02	2.78E-02	-3.87E-33
1	2.65E-02	2.66E-02	-3.71E-33
1.04	2.54E-02	2.56E-02	-3.56E-33
1.08	2.44E-02	2.46E-02	-3.42E-33
1.12	2.34E-02	2.36E-02	-3.28E-33
1.16	2.24E-02	2.26E-02	-3.15E-33
1.2	2.15E-02	2.17E-02	-3.03E-33
1.24	2.07E-02	2.09E-02	-2.91E-33
1.28	1.98E-02	2.00E-02	-2.79E-33
1.32	1.90E-02	1.92E-02	-2.68E-33
1.36	1.83E-02	1.84E-02	-2.57E-33
1.4	1.75E-02	1.77E-02	-2.47E-33
1.44	1.68E-02	1.70E-02	-2.37E-33
1.48	1.61E-02	1.63E-02	-2.27E-33
1.52	1.55E-02	1.57E-02	-2.18E-33
1.56	1.49E-02	1.50E-02	-2.10E-33
1.6	1.43E-02	1.44E-02	-2.01E-33
1.64	1.37E-02	1.39E-02	-1.93E-33
1.68	1.31E-02	1.33E-02	-1.85E-33
1.72	1.26E-02	1.28E-02	-1.78E-33
1.76	1.21E-02	1.23E-02	-1.71E-33
1.8	1.16E-02	1.18E-02	-1.64E-33
1.84	1.12E-02	1.13E-02	-1.57E-33
1.88	1.07E-02	1.08E-02	-1.51E-33
1.92	1.03E-02	1.04E-02	-1.45E-33
1.96	9.86E-03	9.99E-03	-1.39E-33
2	9.46E-03	9.59E-03	-1.34E-33
MAXIMUM:	7.40E-02	7.40E-02	2.37E-31

APPENDIX C

DETAILED COST ESTIMATES

C.1 Alternative 2
C.2 Alternative 3
C.3 Alternative 4

C.1

ALTERNATIVE 2

NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA
SITE 25
ALTERNATIVE 2, NATURAL ATTENUATION, INSTITUTIONAL CONTROLS, AND MONITORING
CAPITAL COST

Item	Quantity	Unit	Unit Cost Subcontract	Unit Cost Material	Unit Cost Labor	Unit Cost Equipment	Extended Cost Subcontract	Extended Cost Material	Extended Cost Labor	Extended Cost Equipment	Subtotal	Comments
1 INSTITUTIONAL CONTROLS												
1.1 Prepare Deed Restrictions	100	hours			$35.00		$0	$0	$3,500	$0	$3,500	
Subtotal							$0	$0	$3,500	$0	$3,500	
Local Area Adjustments							100.0%	123.0%	88.0%	88.0%		
Subtotal							$0	$0	$3,080	$0	$3,080	
Overhead on Labor Cost @ 30%									$924		$924	
G & A on Labor Cost @ 10%									$308		$308	
G & A on Material Cost @ 10%								$0			$0	
G & A on Subcontract Cost @ 10%							$0				$0	
Total Direct Cost							$0	$0	$4,312	$0	$4,312	
Indirects on Total Direct Cost @ 0%											$0	
Profit on Total Direct Cost @ 10%											$431	
Subtotal											$4,743	
Health & Safety Monitoring @ 0%											$0	
Total Field Cost											$4,743	
Contingency on Total Field Cost @ 0%											$0	
Engineering on Total Field Cost @ 0%											$0	
TOTAL COST											**$4,743**	

NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA
SITE 25
ALTERNATIVE 2, NATURAL ATTENUATION, INSTITUTIONAL CONTROLS, AND MONITORING
Annual Cost

Item	Item Cost Year 1 (1)	Item Cost Years 2 & 3 (2)	Item Cost Year 4 (3)	Item Cost Year 5	Notes
Sampling	$15,000	$7,500	$3,750		Labor, Mobilization/Demobilization, Field Supplies
Analysis/Water	$4,400	$2,200	$1,100		Analyze samples from 5 wells for pesticides including QA samples. Quarterly year 1, semi-annually years 2 - 3, and annually years 4 - 30.
Report	$16,000	$8,000	$4,000		Document sampling events and results
Site Inspection	$1,000	$1,000	$1,000		One day annual inspection to verify continued implementation of institutional controls
Site Review				$5,500	
TOTALS	$36,400	$18,700	$9,850	$5,500	

(1) Sampling would occur quarterly for the first year.
(2) Sampling would occur semi-annually for the years 2 - 3.
(3) Sampling would occur annually for years 4 - 5.

NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA
SITE 25
ALTERNATIVE 2, NATURAL ATTENUATION, INSTITUTIONAL CONTROLS, AND MONITORING
Present Worth Analysis

Year	Capital Cost	Annual Cost	Total Year Cost	Annual Discount Rate at 7%	Present Worth
0	$4,743		$4,743	1.000	$4,743
1		$36,400	$36,400	0.935	$34,034
2		$18,700	$18,700	0.873	$16,325
3		$18,700	$18,700	0.816	$15,259
4		$9,850	$9,850	0.763	$7,516
5		$15,350	$15,350	0.713	$10,945
				TOTAL PRESENT WORTH	$88,822

C.2

ALTERNATIVE 3

NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA
SITE 25
ALTERNATIVE 3, IN-SITU ENHANCED BIODEGRADATION (HRC), INSTITUTIONAL CONTROLS, AND MONITORING
CAPITAL COST, FIRST APPLICATION

Item	Quantity	Unit	Unit Cost Subcontract	Unit Cost Material	Unit Cost Labor	Unit Cost Equipment	Extended Cost Subcontract	Extended Cost Material	Extended Cost Labor	Extended Cost Equipment	Subtotal	Comments
1 PROJECT PLANNING												
1.1 Prepare Remedial Action Plan	300	hr			$35.00		$0	$0	$10,500	$0	$10,500	
2 PROJECT OVERSIGHT												
2.1 Professional Oversight (2p * 1 mo)	8	mwk			$1,200.00		$0	$0	$9,600	$0	$9,600	
3 DECONTAMINATION												
3.1 Decontamination Trailer	1	mo	$2,250.00				$2,250	$0	$0	$0	$2,250	
3.2 Temporary Decon Pad	1	ls		$500.00	$450.00	$155.00	$0	$500	$450	$155	$1,105	
3.3 Decon Water	1,000	gal		$0.20			$0	$200	$0	$0	$200	
3.4 Decon Water Storage Tank, 6,000 gallon	1	mo	$600.00				$600	$0	$0	$0	$600	
3.5 Clean Water Storage Tank, 4,000 gallon	1	mo	$540.00				$540	$0	$0	$0	$540	
3.6 PPE (3 p * 5 days * 4 weeks)	60	day		$30.00			$0	$1,800	$0	$0	$1,800	
3.7 Disposal of Decon Waste (liquid & solid)	1	mo	$4,500.00				$4,500	$0	$0	$0	$4,500	
4 IN-SITU BIOLOGICAL TREATMENT												
4.1 Treatability Study	1	ls	$25,000.00				$25,000	$0	$0	$0	$25,000	
4.2 Direct Push Holes (mob/demob)	1	ls	$5,000.00				$5,000	$0	$0	$0	$5,000	
4.3 Direct Push Holes	13	day	$2,500.00				$32,500	$0	$0	$0	$32,500	125 holes at 15 ft each
4.4 Inject HRC	9,000	lb		$6.00			$0	$54,000	$0	$0	$54,000	7500 lb + 20%
5 INSTITUTIONAL CONTROLS												
5.1 Prepare Deed Restrictions	100	hours			$35.00		$0	$0	$3,500	$0	$3,500	
6 SITE RESTORATION												
6.1 Vegetate Disturbed Areas	1	ls		$250.00	$250.00		$0	$250	$250	$0	$500	
Subtotal							$70,390	$56,750	$24,300	$155	$151,595	
Local Area Adjustments							100.0%	123.0%	88.0%	88.0%		
Subtotal							$70,390	$69,803	$21,384	$136	$161,713	
Overhead on Labor Cost @ 30%									$6,415		$6,415	
G & A on Labor Cost @ 10%									$2,138		$2,138	
G & A on Material Cost @ 10%								$6,980			$6,980	
G & A on Subcontract Cost @ 10%							$7,039				$7,039	
Total Direct Cost							$77,429	$76,783	$29,938	$136	$184,286	
Indirects on Total Direct Cost @ 30%											$55,286	
Profit on Total Direct Cost @ 10%											$18,429	
Subtotal											$258,000	
Health & Safety Monitoring @ 2%											$5,160	
Total Field Cost											$263,160	
Contingency on Total Field Cost @ 20%											$52,632	
Engineering on Total Field Cost @ 15%											$39,474	
TOTAL COST											**$355,266**	

NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA
SITE 25
ALTERNATIVE 3, IN-SITU ENHANCED BIODEGRADATION (HRC), INSTITUTIONAL CONTROLS, AND MONITORING
CAPITAL COST, SECOND APPLICATION

Item	Quantity	Unit	Unit Cost Subcontract	Unit Cost Material	Unit Cost Labor	Unit Cost Equipment	Extended Cost Subcontract	Extended Cost Material	Extended Cost Labor	Extended Cost Equipment	Subtotal	Comments
1 PROJECT PLANNING												
1.1 Revise Remedial Action Plan	100	hr			$35.00		$0	$0	$3,500	$0	$3,500	
2 PROJECT OVERSIGHT												
2.1 Professional Oversight (2p * 1 mo)	8	mwk			$1,200.00		$0	$0	$9,600	$0	$9,600	
3 DECONTAMINATION												
3.1 Decontamination Trailer	1	mo	$2,250.00				$2,250	$0	$0	$0	$2,250	
3.2 Temporary Decon Pad	1	ls		$500.00	$450.00	$155.00	$0	$500	$450	$155	$1,105	
3.3 Decon Water	1,000	gal		$0.20			$0	$200	$0	$0	$200	
3.4 Decon Water Storage Tank, 6,000 gallon	1	mo	$600.00				$600	$0	$0	$0	$600	
3.5 Clean Water Storage Tank, 4,000 gallon	1	mo	$540.00				$540	$0	$0	$0	$540	
3.6 PPE (3 p * 5 days * 4 weeks)	60	day		$30.00			$0	$1,800	$0	$0	$1,800	
3.7 Disposal of Decon Waste (liquid & solid)	1	mo	$4,500.00				$4,500	$0	$0	$0	$4,500	
4 IN-SITU BIOLOGICAL TREATMENT												
4.1 Direct Push Holes (mob/demob)	1	ls	$5,000.00				$5,000	$0	$0	$0	$5,000	
4.2 Direct Push Holes	13	day	$2,500.00				$32,500	$0	$0	$0	$32,500	125 holes at 15 ft each
4.3 Inject HRC	3,000	lb		$6.00			$0	$18,000	$0	$0	$18,000	2500 lb + 20%
5 SITE RESTORATION												
5.1 Vegetate Disturbed Areas	1	ls		$250.00	$250.00		$0	$250	$250	$0	$500	
Subtotal							$45,390	$20,750	$700	$155	$66,995	
Local Area Adjustments							100.0%	123.0%	88.0%	88.0%		
Subtotal							$45,390	$25,523	$616	$136	$71,665	
Overhead on Labor Cost @ 30%									$185		$185	
G & A on Labor Cost @ 10%									$62		$62	
G & A on Material Cost @ 10%								$2,552			$2,552	
G & A on Subcontract Cost @ 10%							$4,539				$4,539	
Total Direct Cost							$49,929	$28,075	$862	$136	$79,003	
Indirects on Total Direct Cost @ 30%											$23,701	
Profit on Total Direct Cost @ 10%											$7,900	
Subtotal											$110,604	
Health & Safety Monitoring @ 2%											$2,212	
Total Field Cost											$112,816	
Contingency on Total Field Cost @ 10%											$11,282	
Engineering on Total Field Cost @ 5%											$5,641	
TOTAL COST											**$129,738**	

NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA
SITE 25
ALTERNATIVE 3, IN-SITU ENHANCED BIODEGRADATION (HRC), INSTITUTIONAL CONTROLS, AND MONITORING
Annual Cost

Item	Item Cost Quarterly (1)	Item Cost Semi-Annually (2)	Item Cost Annually (3)	Item Cost at 5 years	Notes
Sampling	$18,800	$9,400	$4,700		Labor, Mobilization/Demobilization, Field Supplies
Analysis/Water	$4,400	$2,200	$1,100		Analyze samples from 5 wells for pesticides including QA samples. Quarterly year 1, semi-annually years 2 - 3, and annually years 4 - 5.
Analysis/Water	$6,400	$3,200	$1,600		Analyze samples from 1 well for natural attenuation parameters including QA sample. Quarterly year 1, semi-annually years 2 - 3, and annually years 4 - 5.
Report	$16,000	$8,000	$4,000		Document sampling events and results
Site Review				$5,500	
TOTALS	$45,600	$22,800	$11,400	$5,500	

(1) Sampling would occur quarterly for the first year.
(2) Sampling would occur semi-annually for the years 2 - 3.
(3) Sampling would occur annually for years 4 - 5.

NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA
SITE 25
ALTERNATIVE 3, IN-SITU ENHANCED BIODEGRADATION (HRC), INSTITUTIONAL CONTROLS, AND MONITORING
Present Worth Analysis

Year	Capital Cost	Annual Cost	Total Year Cost	Annual Discount Rate at 7%	Present Worth
0	$355,266		$355,266	1.000	$355,266
1	$129,738	$45,600	$175,338	0.935	$163,941
2		$22,800	$22,800	0.873	$19,904
3		$22,800	$22,800	0.816	$18,605
4		$11,400	$11,400	0.763	$8,698
5		$16,900	$16,900	0.713	$12,050
				TOTAL PRESENT WORTH	$578,464

C.3

ALTERNATIVE 4

NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA
SITE 25
ALTERNATIVE 4: EXTRACTION, ON-SITE TREATMENT, SURFACE DISCHARGE, INSTITUTIONAL CONTROLS, AND MONITORING
CAPITAL COST

Item	Quantity	Unit	Unit Cost Subcontract	Unit Cost Material	Unit Cost Labor	Unit Cost Equipment	Extended Cost Subcontract	Extended Cost Material	Extended Cost Labor	Extended Cost Equipment	Subtotal	Comments
1 PROJECT PLANNING												
1.1 Prepare Remedial Action Plan	300	hr			$35.00		$0	$0	$10,500	$0	$10,500	
2 MOBILIZATION/DEMOBILIZATION AND FIELD SUPPORT												
2.1 Equipment Mobilization/Demobilization	1	ea			$45.50	$229.00	$0	$0	$46	$229	$275	
2.2 Temporary Site Utilities	3	mo	$1,000.00				$3,000	$0	$0	$0	$3,000	
2.3 Professional Oversight (5p*3 mo)	60	mwk			$1,200.00		$0	$0	$72,000	$0	$72,000	
3 DECONTAMINATION												
3.1 Decontamination Trailer	3	mo	$2,250.00				$6,750	$0	$0	$0	$6,750	
3.2 Temporary Decon Pad	3	ls		$500.00	$450.00	$155.00	$0	$1,500	$1,350	$465	$3,315	
3.3 Decon Water	3000	gal		$0.20			$0	$600	$0	$0	$600	
3.4 Decon Water Storage Tank, 6,000 gallon	3	mo	$600.00				$1,800	$0	$0	$0	$1,800	
3.5 Clean Water Storage Tank, 4,000 gallon	3	mo	$540.00				$1,620	$0	$0	$0	$1,620	
3.6 PPE (3 p * 5 days * 12 Weeks)	180	day		$30.00			$0	$5,400	$0	$0	$5,400	
3.7 Disposal of Decon Waste (liquid & solid)	3	mo	$4,500.00				$13,500	$0	$0	$0	$13,500	
4 GROUNDWATER EXTRACTION SYSTEM												
4.1 Extraction Wells, 6" dia	34	lf	$35.00				$1,190	$0	$0	$0	$1,190	2 @ 17 ft
4.2 Well Development	12	hour	$35.00				$420	$0	$0	$0	$420	
4.3 Collect/Containerize IDW	6	drum	$50.00				$300	$0	$0	$0	$300	3 drums per well
4.4 Transport/Dispose IDW Off Site	6	drum	$150.00				$900	$0	$0	$0	$900	
4.5 Survey Well Locations	1	ls	$800.00				$800	$0	$0	$0	$800	
4.6 Extraction Pumps, 7.5 gpm, 0.5 HP	2	ea		$1,550.00	$250.00		$0	$3,100	$500	$0	$3,600	
4.7 Collection Piping, 1" PVC, buried	100	lf		$0.82	$9.74	$1.65	$0	$82	$974	$165	$1,221	
4.8 Vault Boxes and Misc. Piping/Valves at Well Head	2	ea		$399.50	$299.63		$0	$799	$599	$0	$1,398	
4.9 Instruments and Controls	1	ls		$143.00	$480.00		$0	$143	$480	$0	$623	
5 GROUNDWATER TREATMENT SYSTEM												
5.1 Building Foundation	200	sf	$3.89				$778	$0	$0	$0	$778	
5.2 Treatment System Building	200	sf	$11.03				$2,206	$0	$0	$0	$2,206	
5.3 Building Misc. (doors/vents/insulation/lights,etc.)	1	ls	$5,725.00				$5,725	$0	$0	$0	$5,725	
5.4 Install Utilities for Treatment System	1	ls	$15,000.00				$15,000	$0	$0	$0	$15,000	
5.5 Bag Filter, 15 gpm dual-element, 25-micron	1	ea		$3,500.00	$800.00		$0	$3,500	$800	$0	$4,300	
5.6 GAC Canister Unit (575 lb each)	2	ea		$4,545.00	$210.35	$70.45	$0	$9,090	$421	$141	$9,652	
5.7 Instruments and Controls	1	ls		$5,000.00	$2,000.00		$0	$5,000	$2,000	$0	$7,000	
5.8 Plumb/Electrify System	1	ls		$500.00	$1,150.00		$0	$500	$1,150	$0	$1,650	1 plumber, 1 electrician
5.9 System Start-up and Testing	1	ls		$50.00	$1,700.00		$0	$50	$1,700	$0	$1,750	
6 INSTITUTIONAL CONTROLS												
6.1 Prepare Deed Restrictions	100	hour			$35.00		$0	$0	$3,500	$0	$3,500	
7 SITE RESTORATION												
7.1 Vegetate Disturbed Areas	1	ls		$250.00	$400.00		$0	$250	$400	$0	$650	
Subtotal							$53,989	$30,014	$96,419	$1,000	$181,422	
Local Area Adjustments							100.0%	123.0%	88.0%	88.0%		
Subtotal							$53,989	$36,917	$84,849	$880	$176,635	
Overhead on Labor Cost @ 30%									$25,455		$25,455	
G & A on Labor Cost @ 10%									$8,485		$8,485	
G & A on Material Cost @ 10%								$3,692			$3,692	
G & A on Subcontract Cost @ 10%							$5,399				$5,399	
Total Direct Cost							$59,388	$40,609	$118,789	$880	$219,666	
Indirects on Total Direct Cost @ 30%											$65,900	
Profit on Total Direct Cost @ 10%											$21,967	
Subtotal											$307,532	
Health & Safety Monitoring @ 2%											$6,151	

NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA
SITE 25
ALTERNATIVE 4: EXTRACTION, ON-SITE TREATMENT, SURFACE DISCHARGE, INSTITUTIONAL CONTROLS, AND MONITORING
CAPITAL COST

Item	Quantity	Unit	Unit Cost Subcontract	Unit Cost Material	Unit Cost Labor	Unit Cost Equipment	Extended Cost Subcontract	Extended Cost Material	Extended Cost Labor	Extended Cost Equipment	Subtotal	Comments
Total Field Cost											$313,682	
Contingency on Total Field Cost @ 20%											$62,736	
Engineering on Total Field Cost @ 15%											$47,052	
TOTAL COST											**$423,471**	

NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA
SITE 25
ALTERNATIVE 4: EXTRACTION, ON-SITE TREATMENT, SURFACE DISCHARGE, INSTITUTIONAL CONTROLS, AND MONITORING
Operation and Maintenance Costs per Year

	Item	Qty	Unit	Unit Cost	Subtotal Cost	Notes
1	Energy - Electric	19,000	kWh	$0.06	$1,140	
2	Maintenance	1	ls	$1,389.69	$1,390	5% of Installation Cost
3	Labor, Per Diem, Supplies	52	day	$530.00	$27,560	1 visit per week - 1 day
4	Replace lead GAC absorption unit twice a year	1150	lb	$3.00	$3,450	twice a year
6	Analysis of influent & effluent water	52	wk	$500.00	$26,000	weekly, pesticides
7	Quarterly Reports	4	ea	$4,000.00	$16,000	
	Subtotal Cost for One Year Operation*				$75,540	

*Operate for three years

NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA
SITE 25
ALTERNATIVE 4: EXTRACTION, ON-SITE TREATMENT, SURFACE DISCHARGE, INSTITUTIONAL CONTROLS, AND MONITORING
Annual Cost

Item	Item Cost Quarterly (1)	Item Cost Semi-Annually (2)	Item Cost Annually (3)	Item Cost at 5 years	Notes
Sampling	$15,000	$7,500	$3,750		Labor, Mobilization/Demobilization, Field Supplies
Analysis/Water	$4,400	$2,200	$1,100		Analyze samples from 5 wells for pesticidesincluding QA samples. Quarterly year 1, semi-annually years 2 - 3, and annually years 4 - 5.
Report	$16,000	$8,000	$4,000		Document sampling events and results
Site Review				$5,500	
TOTALS	$35,400	$17,700	$8,850	$5,500	

(1) Sampling would occur quarterly for the first year.
(2) Sampling would occur semi-annually for the years 2 - 3.
(3) Sampling would occur annually for years 4 - 5.

NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA
SITE 25
ALTERNATIVE 4: EXTRACTION, ON-SITE TREATMENT, SURFACE DISCHARGE, INSTITUTIONAL CONTROLS, AND MONITORING
Present Worth Analysis

Year	Capital Cost	Operation and Maintenance Cost	Annual Cost	Total Year Cost	Annual Discount Rate at 7%	Present Worth
0	$423,471			$423,471	1.000	$423,471
1		$75,540	$35,400	$110,940	0.935	$103,729
2		$75,540	$17,700	$93,240	0.873	$81,398
3		$75,540	$17,700	$93,240	0.816	$76,084
4		$0	$8,850	$8,850	0.763	$6,753
5		$0	$14,350	$14,350	0.713	$10,232
					TOTAL PRESENT WORTH	$701,666