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FINAL FEASIBILITY STUDY FOR OPERABLE UNIT 10 (OU 10) SITE 21 GOLF COURSE MAINTENANCE AREA NAS CECIL FIELD FL

9/30/2002

TETRA TECH NUS INC

Feasibility Study Report
for
OU 10, Site 21
Golf Course
Maintenance Area

Naval Air Station Cecil Field
Jacksonville, Florida

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

Contract Task Order 0078

September 2002

FEASIBILITY STUDY REPORT
FOR
OU 10, SITE 21
GOLF COURSE MAINTENANCE AREA

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 21, 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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CERTIFICATION OF TECHNICAL
DATA CONFORMITY

The Contractor, Tetra Tech NUS, Inc., hereby certifies that, to the best of its knowledge and belief, the technical data delivered herewith under Contract No. N62467-94-D-0888 are complete and accurate and comply with all requirements of this contract.

DATE: September 30, 2002

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LIST OF ACRONYMS AND ABBREVIATIONS

µg/L	microgram per liter
ABB-ES	ABB Environmental Services, Inc.
AOI	area of interest
ARAR	Applicable or Relevant and Appropriate Requirement
AWQC	Ambient Water Quality Criteria
bgs	below ground surface
BRAC	Base Realignment and Closure
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CKD	chemical kiln dust
CLEAN	Comprehensive Long-Term Environmental Action Navy
COC	chemical of concern
CSF	Cancer Slope Factor
CTO	Contract Task Order
CWA	Clean Water Act
DOT	Department of Transportation
ºC	degree(s) Celcius
ºF	degree(s) Farenheit
EBCT	empty bed contact time
EBS	Environmental Baseline Survey
FAC	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FS	feasibility study
ft	foot/feet
ft^2	square foot/feet
ft^3	cubic foot/feet
GAC	granular activated carbon
GCTL	Groundwater Cleanup Target Level
gpm	gallons per minute
GRA	general response action
HASP	Health and Safety Plan
HI	Hazard Index
HLA	Harding Lawson Associates
HQ	Hazard Quotient
IBDS	Inorganic Background Data Set

ICR	incremental cancer risk
IR	Installation Restoration
IRA	Interim Removal Action
IWTP	industrial waste treatment plant
LUC	land use control
MCL	Maximum Contaminant Level
mg/L	milligram per liter
NAS	Naval Air Station
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
NPW	net present worth
O&M	operation and maintenance
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
PCB	polychlorinated biphenyl
POTW	publicly owned treatment works
PPE	personal protection equipment
PRB	permeable reactive barrier
PRE	preliminary risk evaluation
PRG	preliminary remediation goal
PSC	potential source of contamination
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RI	remedial investigation
SCTL	Soil Contaminant Target Level
SMCL	Secondary Maximum Contaminant Level
SOC	soluble organic carbon
SOUTHNAVFACENGCOM	Southern Division Naval Facilities Engineering Command
SPECAP	specific capacity (test)
SPLP	Synthetic Precipitation Leachate Procedure
STP	sewage treatment plant
SVOC	semivolatile organic compound
SWDA	Solid Waste Disposal Act
TAL	Target Analyte List
TBC	to be considered (criterion)

TCL	Target Compound List
TRPH	total recoverable petroleum hydrocarbons
TtNUS	Tetra Tech NUS, Inc.
UCL	upper confidence limit
U.S. EPA	United States Environmental Protection Agency
UST	underground storage tank
VOC	volatile organic compound

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 21 – Golf Course Maintenance Area at Naval Air Station (NAS) Cecil Field in Jacksonville, Florida. No further action is required for soil.

E.2 SITE DESCRIPTION AND HISTORY

OU 10, Site 21, the Golf Course Maintenance Area, is located at the north end of the former I Avenue in the center of the golf course at NAS Cecil Field. The site includes Buildings 238, 370, 371, 397, 398, and 874, and the surrounding land area. Building 238 is the Golf Course maintenance building and includes office space, a repair shop, and fenced, sheltered storage area. Buildings 370 and 371 are metal storage sheds. Building 397 is the Pesticide Storage building, and is secured by a fence and includes a paved mixing area and secondary containment. A septic system south of Building 397 serves Building 397. Building 874 is an abandoned public toilet that was served by a small adjacent septic field. All of the buildings date to the 1950s, except Building 397, which was built in 1981. The site is primarily unpaved and covers an area of about 1.5 acres. A drainage ditch forms part of the east border of the site. A fence and trees isolate the site from the golf course on the east, northeast and south. A large wooded area isolates the site from the golf course on the northwestern and western sides.

To the north of Building 238 and adjacent to the ditch is a small concrete washdown pad. Prior to the construction of this pad, equipment was washed down on the eastern side of Building 238 and the rinse water followed a swale to the ditch. An empty drum/can disposal pile was once located to the northwest of Building 371. Most of these drums and cans were removed prior to 1992.

Since its construction, the site has always been used as the Golf Course Maintenance Area. Prior to construction, the area was undeveloped. Site activities included the storage and maintenance of golf course maintenance equipment. This included the cleaning and rinsing of chemical-dispensing equipment, and the preparation of chemical solutions. Chemicals included fungicides, nematocides, insecticides, and herbicides. Rinsing occurred at one of two places, on the eastern side of Building 238, or on a concrete pad on the northern side of the site. At both sites, rinse water discharged into a ditch along the eastern side of the site.

The name of Site 21 has been changed over the course of several investigations. In a 1992 screening study, it was referred to as Site A in the Golf Course Maintenance Area. For the Base Realignment and

Closure (BRAC) Environmental Baseline Study (EBS), the site was designated as Area of Interest (AOI) 21. When it was determined that soil contamination was over a large area, the area was re-designated Potential Source of Contamination (PSC) 21 in March 1999. When the presence of groundwater contamination was confirmed, the area was designated as Installation Restoration (IR) Site 21, in February 2000.

Several environmental investigations were performed at Site 21, starting with the BRAC Phase II investigation of AOI 21 in January 1997 through the RI of Site 21 in February 2001. These investigations showed that soil was contaminated with total recoverable petroleum hydrocarbons (TRPH), arsenic, chlordane, DDT, toxaphene, and dieldrin. Most of the contaminated soil was excavated and disposed off-site in May and June 2001 as part of an Interim Remedial Action (IRA). A second IRA was conducted on August 2, 2002 to remove additional soil that was contaminated with arsenic. As a result, no further action is required for the soil to meet an unrestricted future use. These investigations also showed that groundwater is contaminated with chlordane, DDD, and manganese and evaluation of that contamination was the primary objective of the RI.

E.3 SUMMARY OF THE INVESTIGATIONS FINDINGS

Several pesticides (4,4'-DDT, chlordane, dieldrin, and toxaphene), and TRPH were detected in soil at concentrations in excess of the Florida Department of Environmental Protection (FDEP) Soil Cleanup Target Levels (SCTLs) for direct residential exposure. Arsenic was also detected at concentrations greater than the site-specific Inorganic Background Data Set (IBDS) value [Harding Lawson Associates (HLA), 1998]. Exceedances covered one area approximately 31,880 square feet (ft^2) in size (0.9 acres) and down to a depth of 6 feet (ft) below ground surface (bgs) around Buildings 238 and 371 and one area approximately 7,290 ft^2 in size (0.2 acres) and down to a depth of 1 ft bgs along the drainage ditch at the eastern edge of the site.

In May and June 2001, a removal action was conducted at the site during which soil with concentrations of pesticides, arsenic, and TRPH greater than the FDEP SCTLs for direct industrial exposure were excavated and disposed offsite (CH_2M Hill, 2001). As a result of this removal action, the 95 percent upper confidence limit (UCL) of the concentrations of pesticides and TRPH in the remaining soil no longer exceeds the FDEP residential SCTLs. However, the 95-percent UCL of the remaining concentrations of arsenic still exceeds the IBDS value in three areas, totaling approximately 1,132 ft^2 in size and down to a depth of 1 ft bgs. Two of these areas are located at the southern end of the drainage ditch at the eastern edge of the site and the third is located immediately south of Building 370. These remaining areas were removed by an IRA conducted on August 2, 2002. Upon the completion of this removal, the 95 percent UCL concentration of arsenic was below the IBDS value for the site soils.

During the Phase II investigation in 1997, chlordane and DDD were detected in one groundwater sample at concentrations greater than their respective FDEP Groundwater Cleanup Target Levels (GCTLs) of 2.0 and 0.10 micrograms per liter (µg/L) (FDEP, 1999a). During a subsequent investigation in 1999, chlordane was again found at a concentration exceeding its FDEP GCTL in the same monitoring well; however, during this sampling event DDD was found to be undetected although the detection limit was greater than the GCTL. Because the DDD exceedance concentration in 1997 was so close to the GCTL and because the chlordane is present at a higher concentration at the same location, DDD was not retained as a chemical of concern (COC) in the RI.

The horizontal extent of the chlordane contaminant plume, as defined by exceedance of the GCTL, was determined to be approximately 30 ft in diameter and centering around well location 90G00101. The vertical extent of contamination did not exceed approximately 15 ft below ground surface (bgs). Manganese was found in two groundwater wells upgradient from the chlordane plume at concentrations in exceedance of background levels.

The preliminary risk evaluation (PRE) for groundwater, performed as part of the RI, indicated that sample concentrations of chlordane in groundwater exceed the FDEP GCTL. The average manganese concentration is less than twice the site average background concentration and is also less than the United States Environmental Protection Agency (U.S. EPA) Region IX Preliminary Remediation Goal (PRG) that corresponds to a Hazard Quotient (HQ) of 1.0. Therefore, exposure to the average concentration of manganese would not pose a significant risk to human health.

The ecological risk assessment (ERA) completed at Site 21 as part of the RI indicated that surface soil at the site poses negligible risk to ecological receptors.

E.4 REMEDIAL ACTION OBJECTIVES AND CLEANUP GOALS

The Remedial Action Objectives (RAOs) identified for Site 21 are as follows:

- Prevent unacceptable risk from ingestion of groundwater with concentrations of chlordane greater than the FDEP GCTL.
- Restore groundwater quality at Site 21.

The cleanup goal for chlordane in the Site 21 groundwater is 2.0 µg/L, which is the FDEP GCTL.

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 21:

General Response Action	Remediation Technology	Process Options
No Action	None	Not Applicable
Limited Action	Monitoring	Sampling and Analysis
	Institutional Controls	LUCs and groundwater use restrictions
	Natural Attenuation	Dispersion and Dilution
Removal	Groundwater Extraction	Extraction Wells
Ex-situ Treatment	Physical	Filtration
		Granular Activated Carbon (GAC) Adsorption
Discharge/Disposal	Onsite Surface Discharge	Direct Discharge

E.6 DEVELOPMENT OF REMEDIAL ALTERNATIVES

The following remedial alternatives were developed for the Site 21 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 chlordane cleanup goal 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. At the end of 5 years, a site review would be conducted to verify that groundwater cleanup has been achieved, as predicted by modeling.

- **Alternative 3: Extraction, On-Site Treatment, Surface Discharge, Institutional Controls, and Monitoring**. This alternative would consist of extracting the contaminated groundwater through three

new extraction wells, each pumping at the rate of 3.33 gallons per minute (gpm). The extracted groundwater would be treated by GAC to remove chlordane prior to discharge to surface water. Institutional controls would be the same as for Alternative 2. Monitoring would also be the same as for Alternative 2 with the in-plume groundwater sampling and analysis being used to evaluate the progress of the extraction process. At the end of 5 years, a site review would be conducted to verify that groundwater cleanup has been achieved, as predicted by modeling.

E.7 DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

The remedial alternatives were analyzed in detail using seven of the nine criteria provided in the National Oil and Hazardous Substances Pollution 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 chlordane would remain above its cleanup goal. 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 chlordane is not taking place.

Alternative 3 would be more protective of human health and the environment than Alternative 2 because, in addition to institutional controls and monitoring, this alternative would accelerate the remediation of the site through active removal and treatment processes. This alternative would extract and treat groundwater from the contaminant plume and thus control expansion of the plume, which would be verified through monitoring.

- **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 and 3 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 be achieved slightly earlier 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.

Alternatives 2 and 3 would have long-term effectiveness and permanence because institutional controls and monitoring would effectively prevent unacceptable exposure to contaminated groundwater until the chlordane cleanup goal has been met through natural attenuation and/or treatment.

- **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.

Alternative 3 would significantly reduce contaminant toxicity and volume through treatment. The treatment system of Alternative 3 would be designed to remove an estimated 1.6 pounds of chlordane from the contaminant plume through its operating life. The contaminant removal achieved by this alternative would be 100 percent irreversible.

- **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 and 3 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 and significant for Alternative 3. However, regardless of its magnitude, the risk of exposure could 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 protection equipment (PPE).

Alternative 1 would not achieve the RAOs and, although the chlordane cleanup goal would eventually be attained through natural attenuation, there would be no means of determining when this had occurred. Alternatives 2 and 3 would achieve the first RAO immediately upon implementation of institutional controls. It is estimated that Alternatives 2 and 3 would achieve the second RAO and attain the chlordane cleanup goal within approximately 49 months and 38 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 and 3 would be relatively simple to implement.

The technical implementability of Alternative 3 would be slightly more difficult than that of Alternative 2 because, in addition to monitoring, this alternative would require the installation and operation and maintenance of a relatively small groundwater extraction and on-site treatment systems (10 gpm).

Alternatives 2 and 3 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. Alternative 3 would require construction permits for the installation of extraction wells and an on-site treatment system. Alternative 3 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, which are significantly more stringent than the chlordane FDEP GCTL. All of these requirements would be readily implementable.

- **Cost**

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

Alternative	Capital ($)	5-year NPW of O&M ($)	5-year NPW ($)
1	0	0	0
2	26,000	72,000	98,000
3	453,000	331,000	784,000

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 21 – Golf Course Maintenance Area 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 (SOUTHNAVFACENGCOM) under the Comprehensive Long-Term Environmental Action Navy (CLEAN) Program, Contract Number N62467-94-D-0888, Contract Task Order (CTO) 0078. This report describes the formulation and evaluation of remedial alternatives for contaminated groundwater at Site 21. No further action is required for soil.

This FS was conducted to establish remedial action objectives (RAOs) and cleanup goals; screen remedial technologies; and assemble, evaluate, and compare remedial alternatives. The FS focuses on the groundwater plume that was identified during the RI and previous investigations.

1.1 SITE BACKGROUND

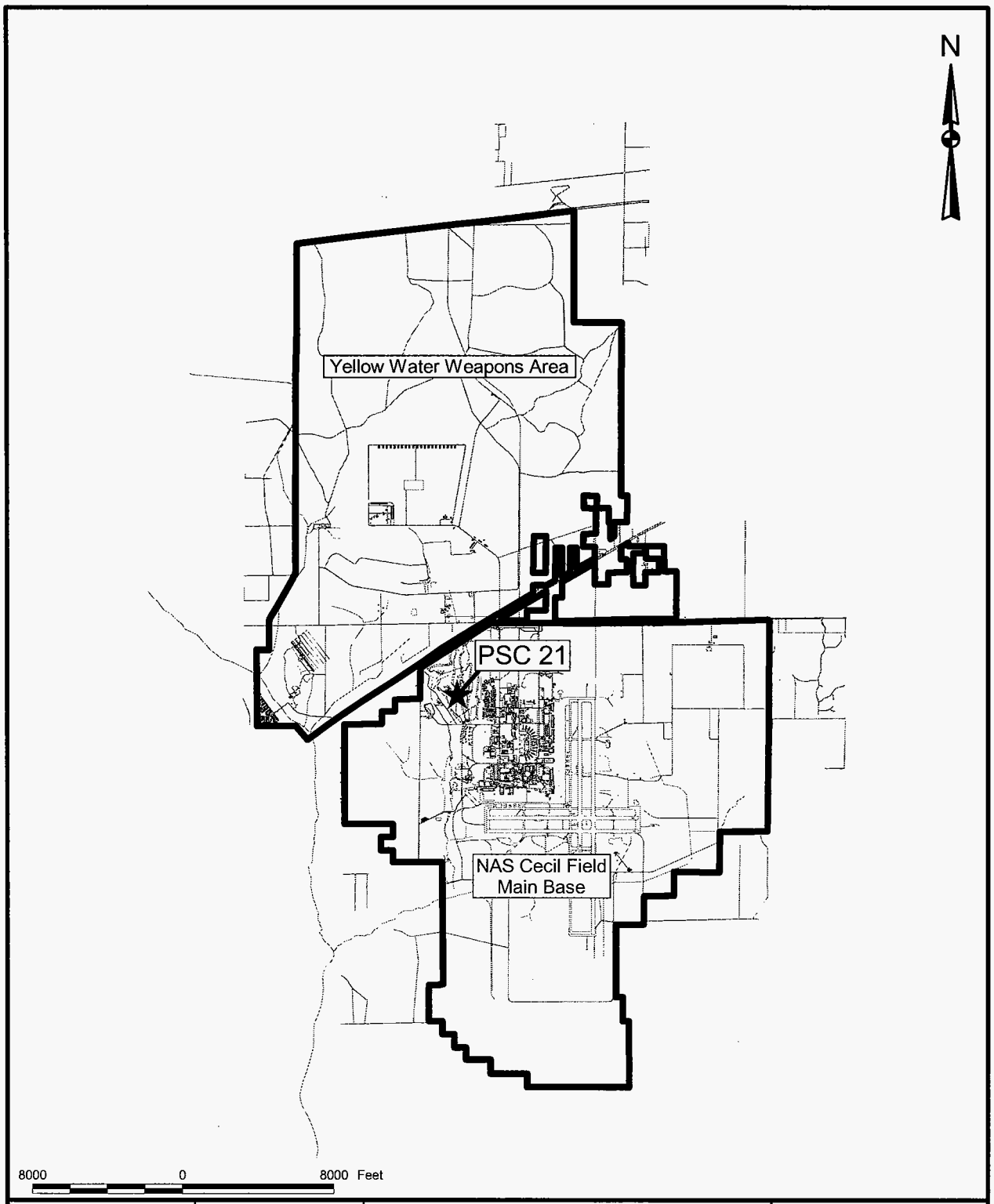
The following paragraphs describe the background of Site 21. Figure 1-1 provides a site location map, Figure 1-2 shows the vicinity of the site, and Figure 1-3 provides the current general arrangement of the site.

1.1.1 Site Description

OU 10, Site 21, the Golf Course Maintenance Area, is located at the northern end of the former I Avenue in the center of the golf course at NAS Cecil Field. The site includes Buildings 238, 370, 371, 397, 398, and 874 and the surrounding land area [Harding Lawson Associates (HLA), 1999a].

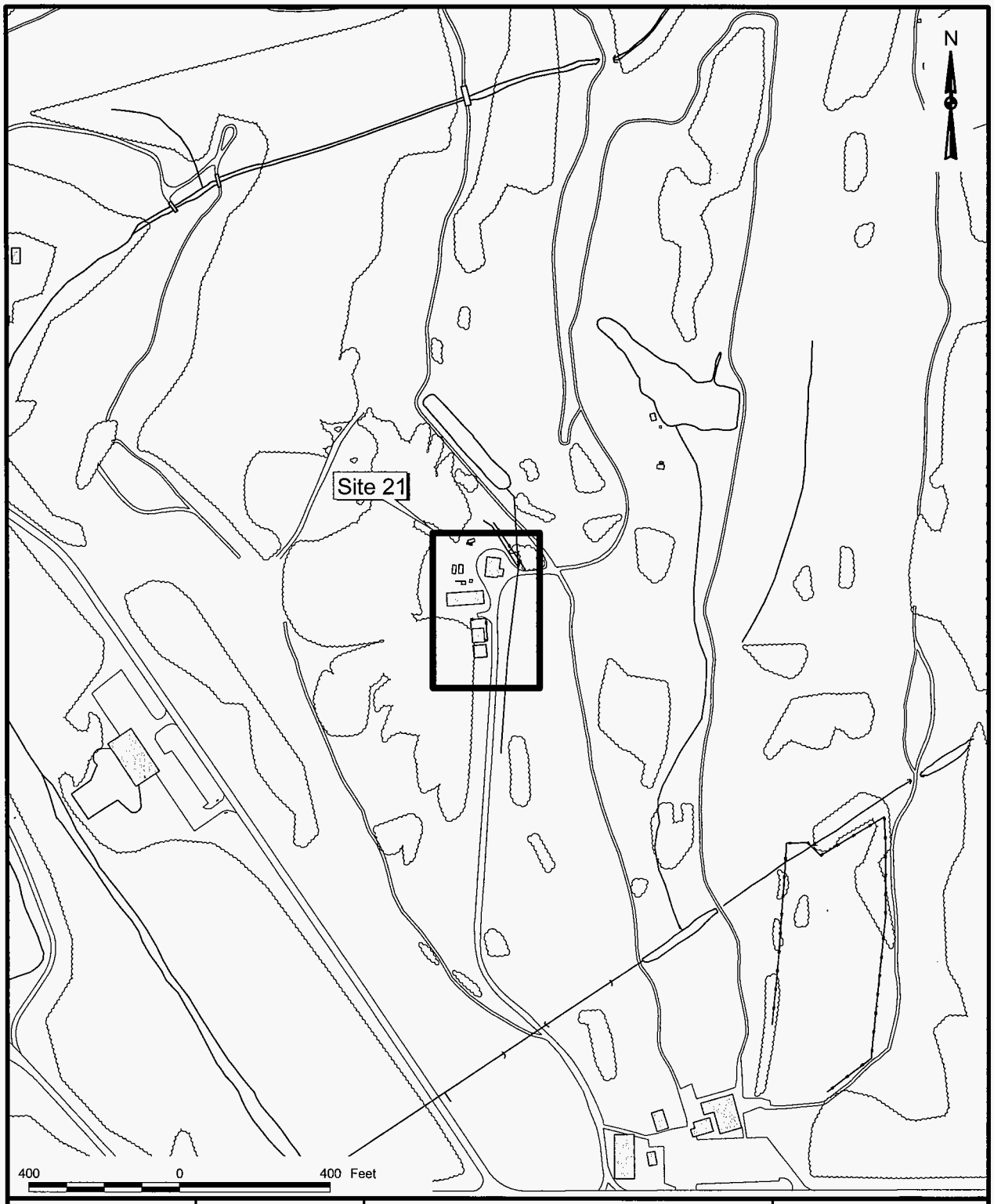
The site is primarily unpaved and covers an area of about 1.5 acres. A drainage ditch forms part of the eastern border of the site. A fence and trees isolate the site from the golf course on the east, northeast and south. A large wooded area isolates the site from the golf course on the northwestern and western sides.

Building 238 is the golf course maintenance building and includes office space, a repair shop, and fenced, sheltered storage area. Buildings 370 and 371 are metal storage sheds. Building 397, the pesticide storage building, is secured by a fence and includes a paved mixing area and secondary containment around the paved mixing area. A septic system south of Building 397 serves that building. A valve system is in place to prevent discharge of contaminated water into the septic field adjacent to Building 397. Building 398, the golf course storage building, is a Quonset hut with an earthen floor that is used to



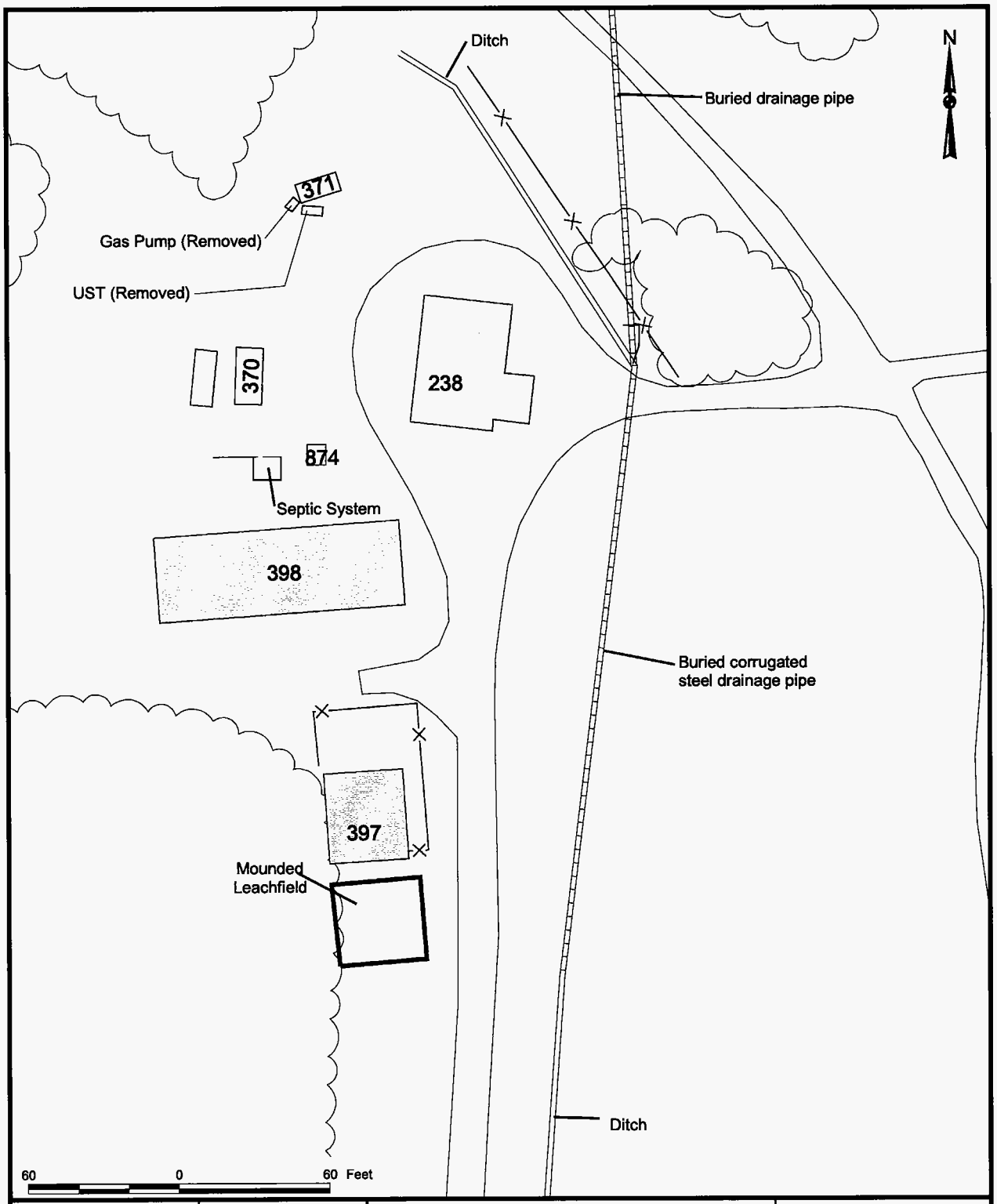
DRAWN BY MJJ	DATE 08May00	GENERAL LOCATION MAP SITE 21 FEASIBILITY STUDY REPORT NAVAL AIR STATION CECIL FIELD JACKSONVILLE, FLORIDA	CONTRACT NUMBER 0039
CHECKED BY	DATE		APPROVED BY DATE 09/27/02
COST/SCHEDULE-AREA			APPROVED BY DATE
SCALE AS NOTED			DRAWING NO. FIGURE 1-1 REV 0

P:\GIS\NAS_CecilField\PSC21_FS.apr 15Jan01 MJJ Site Location Map Layout



DRAWN BY MJJ	DATE 02Oct00	SITE VICINITY MAP SITE 21 FEASIBILITY STUDY REPORT NAVAL AIR STATION CECIL FIELD JACKSONVILLE, FLORIDA	CONTRACT NUMBER 0039
CHECKED BY	DATE		APPROVED BY — DATE 09/27/02
COST/SCHEDULE-AREA			APPROVED BY — DATE
SCALE AS NOTED			DRAWING NO. FIGURE 1-2 — REV 0

P:\GIS\NAS_CecilField\PSC21_FS.apr 15Jan01 MJJ 1-2_Site Vicinity Layout



DRAWN BY MJJ	DATE 08May00	GENERAL SITE ARRANGEMENT SITE 21 FEASIBILITY STUDY REPORT NAVAL AIR STATION CECIL FIELD JACKSONVILLE, FLORIDA	CONTRACT NUMBER 0039
CHECKED BY	DATE		APPROVED BY DATE 09/27/02
COST/SCHEDULE-AREA			APPROVED BY DATE
SCALE AS NOTED			DRAWING NO. FIGURE 1-3 / REV 0

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store maintenance equipment and vehicles. Building 874 is an abandoned public restroom that was served by a small adjacent septic field. All the buildings date to the 1950s, except Building 397 which was built in 1981 (HLA, 1999a).

North of Building 238 and adjacent to the ditch is a small concrete washdown pad. Prior to the construction of this pad, equipment was washed down on the eastern side of Building 238, and the rinse water followed a swale to the ditch (HLA, 1999a). An empty drum/can disposal pile was once located northwest of Building 371. Most of these drums and cans were removed prior to 1992 (HLA, 1999b).

Soil contaminated with arsenic, pesticides, and total recoverable petroleum hydrocarbons (TRPH) was delineated and most of this soil was excavated and disposed off site during a first Interim Removal Action (IRA) conducted in May and June 2001 (TtNUS, 2000 and CH_2M Hill, 2001). A second IRA was conducted on August 2, 2002 to remove soil contaminated with arsenic. Groundwater contaminated by DDD and chlordane was also identified in earlier studies; this groundwater contamination was further investigated during the RI (TtNUS, 2001). In addition, manganese was detected in two wells at concentrations greater than the background levels.

The name of this site has been changed over the course of the various investigations. In a 1992 screening study, it was referred to as Site A in the Golf Course Maintenance Area. In the Base Realignment and Closure (BRAC) Environmental Baseline Study (EBS) [ABB Environmental Services, Inc. (ABB-ES), 1994], the site was designated as Area of Interest (AOI) 21. In March 1999, when it was determined that soil contamination was over a large area, the area was re-designated Potential Source of Contamination (PSC) 21. When the presence of groundwater contamination was confirmed, the area was designated as Installation Restoration (IR) Site 21, in February 2000.

1.1.2 Site History

Since its construction, the site has always been used as the golf course maintenance area. Prior to construction, the area was undeveloped. The buildings were constructed in the 1950s with the exception of Building 397, which was built in 1981. Site activities included the storage and maintenance of golf course maintenance equipment. This included cleaning and rinsing chemical-dispensing equipment and the preparation of chemical solutions. The chemicals that were used included fungicides, nematocides, insecticides, and herbicides. Rinsing occurred at one of two places, on the eastern side of Building 238 or on a concrete pad on the northern side of the site. At both locations, rinse water discharged into a ditch along the eastern side of the site (HLA, 1999b). An empty drum/can disposal pile was once located northwest of Building 371, but most of these drums and cans were removed prior to 1992 (HLA, 1999b).

1.1.3 Site Investigations

The following investigations and studies have been conducted in and around Site 21:

- November 1991 – A Site Screening Study was performed. Six surface soil samples and three sediment samples were collected and analyzed for Target Compound List (TCL) volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides and polychlorinated biphenyls (PCBs), and Target Analyte List (TAL) inorganic compounds (ABB-ES, 1994).

- January 1997 through December 1998 – Phase II Investigation of AOI 21 was performed. Twenty-nine surface soil samples and eight subsurface soil samples were collected and analyzed for TCL VOCs, SVOCs, pesticides and PCBs, organophosphate pesticides and herbicides, and TAL inorganic compounds. One shallow monitoring well was installed in each septic field. The groundwater samples were analyzed for TCL VOCs, SVOCs, pesticides and PCBs, and TAL inorganic compounds (HLA, 1999a).

- June 1999 through March 2000 – Investigation of PSC 21. Samples were collected to delineate soil and groundwater contamination. Seventy-two surface soil samples and 15 subsurface soil samples were collected. Six wells were installed and sampled, and two existing wells were sampled. Analyses were limited to the contaminants that had been detected in previous investigations. Typically, samples were analyzed for pesticides, herbicides, and arsenic. The results were used to delineate the soil contamination for excavation and disposal. The groundwater investigation identified one area with DDD and chlordane concentrations greater than the Florida Department of Environmental Protection (FDEP) criteria. Three samples were collected and analyzed using the Synthetic Precipitation Leachate Procedure (SPLP) method to evaluate the impact of soil contamination on groundwater.

- April 2000 through February 2001 – Site 21 RI. Samples were collected to evaluate risks in the preliminary risk evaluation (PRE) and to evaluate remedial alternatives for the FS. One permanent monitoring well was installed and sampled at a location outside the area of DDD and chlordane exceedances where a previous soil sample SPLP result suggested that dieldrin would leach into the groundwater (TtNUS, 2001a). The groundwater sample was analyzed for pesticides using a modified method to ensure that the low detection limit required for dieldrin could be obtained. In addition, geotechnical soil samples were collected and specific capacity (SPECAP) tests were performed on two existing monitoring wells to determine site-specific hydrogeological conditions (TtNUS, 2001a).

- May - June 2001 - First IRA. Approximately 2,975 tons of soil with concentrations of pesticides (DDT, chlordane, dieldrin, and toxaphene), arsenic, and TRPH, greater than the FDEP Soil Cleanup Target

Levels (SCTLs) for industrial land use were excavated and disposed off site (TtNUS, 2001 b and CH_2M Hill 2001).

- August 2002 - Second IRA. A total of 78.87 tons of non-hazardous soil was removed which contained arsenic contamination above the FDEP residential SCTL. All soil as delineated by a registered surveyor was removed in accordance with the Final Dig and Haul Design (TtNUS, 2002a). The soil was disposed off site. The removal of this soil resulted in the site sols being remediated to unrestricted use. Following this second IRA, the 95 percent upper confidence level (UCL) of the remaining concentrations of soil COCs are below the FDEP residential SCTLs, except the 95 percent UCL of the remaining concentrations of arsenic which is below the NAS Cecil Field site specific Inorganic Background Data Set (IBDS) value.

1.1.4 Summary of Investigation Findings

1.1.4.1 Nature and Extent of Soil Contamination

During the RI, several pesticides (4,4'-DDT, chlordane, dieldrin, toxaphene), arsenic, and TRPH were detected in soil at concentrations in excess of the FDEP SCTLs for direct industrial exposure. Methylene chloride, 4-nitrophenol, and alpha-, beta, and gamma-benzene hexachloride (BHC) were also detected in soil but at concentrations below the SCTL for direct industrial exposure. The presence of these chemicals in the soil is probably due to golf course maintenance activities, including the handling and application of pesticides. A statistical evaluation was conducted to determine the areas of soil requiring removal to achieve a site-wide 95-percent UCL that is below the SCTLs for direct industrial exposure. The results of this statistical evaluation are presented in the Action Memorandum for PSC 21 (TtNUS, 2000b).

A first IRA was conducted in May and June 2001 (CH_2M Hill, 2001). During this IRA approximately 2,975 tons of contaminated material were excavated and disposed offsite so that the 95-percent UCL of the residual concentrations of pesticides, arsenic, and TRPH in soil is equal to or less than the SCTL for direct industrial exposure.

At the completion of the first IRA, the residual soils were evaluated for risk. Based on this evaluation it was determined that approximately 40 cubic yards would require remediation for arsenic to achieve unrestricted re-use for the site soils. Based on this analysis, a second IRA was conducted on August 2, 2002. This IRA removed the soil contaminated with arsenic and disposed of the soil off site.

Table 1-1 presents a summary of post-removal action soil analytical data, including minimum and maximum detected concentrations and 95-percent UCLs of remaining concentrations of arsenic,

TABLE 1-1

SUMMARY OF POST-REMOVAL ACTION SOIL ANALYTICAL DATA
OU 10, SITE 21 FEASIBILITY STUDY
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

Analyte	Unit	Minimum Detected Concentration	Maximum Detected Concentration	Residential UCL[1]					SCTL Direct Exposure Residential[2]	SCTL Leachability[2]	IBDS
				No. 1	No. 2	No. 3	No. 4	No. 5			
Arsenic	mg/kg	0.36	7.3	1.54	1.43	1.54	1.25	1.24	0.8	29	2.04
4,4'-DDT	µg/kg	4.2	5,740	NA	69	3.1	10	312	3,300	11,000	NA
Chlordane	µg/kg	4.0	3,860	NA	617	32	192	96	3,100	9,600	NA
Dieldrin	µg/kg	0.85	1.8	NA	ND	ND	ND	ND	70	4	NA
Toxaphene	µg/kg	410	3,620	NA	ND	ND	271	ND	1,000	31,000	NA
TRPH	mg/kg	12	152	NA	ND	42	57	85	340	340	NA

NOTES:

1. 95-percent upper confidence limit (UCL) of residual concentrations computed over each of five 0.5-acre parcels
2. Florida Department of Environmental Protection (FDEP) draft Soil Cleanup Target Levels (SCTLs) (FDEP, 1999a).

IBDS NAS Cecil Field site-specific Inorganic Background Data Set (HLA, 1998c)
µg/kg micrograms per kilogram
mg/kg milligrams per kilogram
NA not available
ND not detected
TRPH: total recoverable petroleum hydrocarbon

pesticides (4,4'-DDT, chlordane, dieldrin, toxaphene), and TRPH computed for each of five 0.5-acre parcels, to reflect a potential future residential land use scenario (shown in Figure 1-4). Table 1-1 also compares this data to the FDEP residential and leachability SCTLs and to site-specific IBDS values (HLA, 1998). As can be seen from Table 1-1, the 95-percent UCLs of the remaining concentrations of pesticides and TRPH no longer exceed the FDEP residential or leachability SCTLs in any of the Site 21 parcels. The 95-percent UCL of remaining concentrations of arsenic is below the IBDS value in all parcels. As a result, Site 21 soil is considered acceptable for unrestricted use.

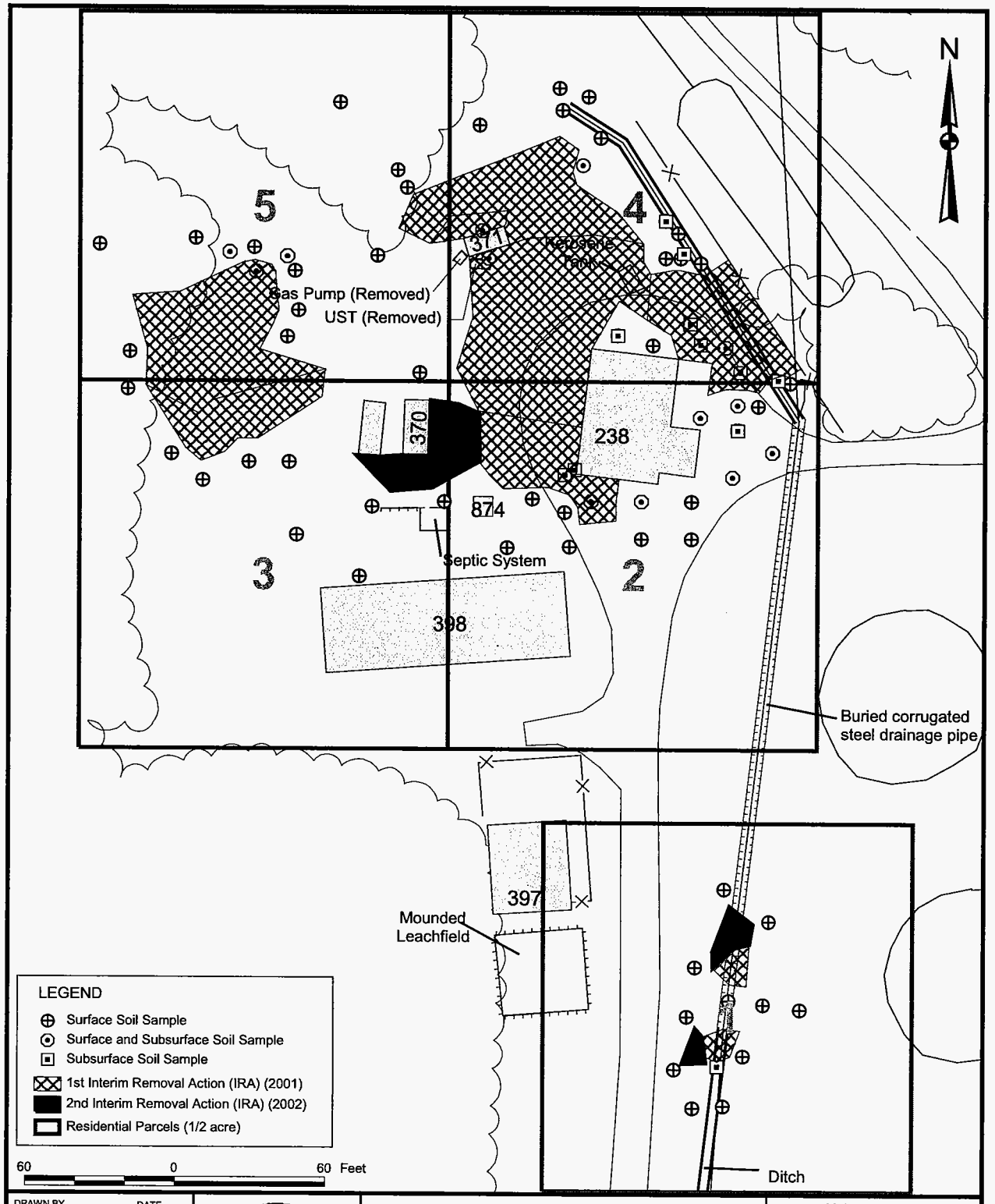
1.1.4.2 Nature and Extent of Groundwater Contamination

During the RI, neither dieldrin nor any other pesticides were detected in the groundwater sample (CEF-P21-07S) collected from the newly installed monitoring well at the location where a soil sample SPLP result suggested that dieldrin would leach into the groundwater. DDD and chlordane had been detected in the groundwater at well 90G001 at concentrations greater than their respective FDEP Groundwater Cleanup Target Levels (GCTLs) of 0.10 and 2.0 µg/L (FDEP, 1999a) during previous investigations. Tables 1-2 and 1-3 present a summary of DDD and chlordane detections in groundwater during the pre-RI and RI sampling events, respectively.

As shown in Table 1-2, DDD was detected slightly in excess of its FDEP GCTL at location 90G001 during the January 1997 sampling event. During a subsequent sampling event at that same location in May 1999, the DDD concentration was reported to be undetected; however, the detection limit (0.4 µg/L) for this sample was greater than the GCTL. Total chlordane, the sum of α-chlordane and γ-chlordane, was also detected in excess of its FDEP GCTL (2.0 µg/L) at location 90G001 (renamed CEF-P21-GW-01S during the 1999 sampling event) during both the January 1997 sampling event (3.4 µg/L) and the June 1999 sampling event (2.9 µg/L). Because the DDD exceedance concentration in 1997 was so close to the GCTL, and because the chlordane is present at a higher concentration at the same location, DDD was not retained as a COC in the RI.

The chlordane had been previously delineated; it is limited to the shallow zone of the surficial aquifer and does not extend beyond approximately 15 feet below ground surface (bgs). Because the concentration of chlordane was only slightly higher than the GCTL, no deeper wells were installed during the RI. Except for DDD, which is an intermediary breakdown product of DDT, and manganese, which was not used at Site 21, no other organic compounds or inorganic analytes were detected above GCTLs during previous investigations, and, therefore, the RI focused exclusively on manganese, DDD, and chlordane contamination.

Figure 1-5 includes the DDD and chlordane results from previous investigations and the RI. This figure also shows the plume outline as defined by the FDEP groundwater criteria for total chlordane (2.0 µg/L).



DRAWN BY MJJ	DATE 05Oct01	PARCELS FOR RESIDENTIAL UCL ANALYSIS OU 10, SITE 21 FEASIBILITY STUDY REPORT NAVAL AIR STATION CECIL FIELD JACKSONVILLE, FLORIDA	CONTRACT NUMBER 0039
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SCALE AS NOTED			DRAWING NO. FIGURE 1-4 REV 0

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TABLE 1-2

SUMMARY OF GROUNDWATER DDD AND CHLORDANE DETECTIONS
PRE-RI SAMPLING EVENTS
OU 10, SITE 21 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

Sample Location	Sample Name	Detected Concentrations (μg/L)							
		1/29/97				5/26/99			
		4,4'-DDD	α-chlordane	γ-chlordane	total chlordane	4,4'-DDD	α-chlordane	γ-chlordane	total chlordane
90G001	90G00101	**0.12**	1.9	1.5	**3.4**	NS	NS	NS	NS
90G002	90G00201	0.1 U	0.05 U	0.05 U	0.05 U	NS	NS	NS	NS
90G001	CEF-P21-GW-01S (1)	NS	NS	NS	NS	0.4 U	1.4	1.5	**2.9**
CEF-P21-01S	CEF-P21-GW-001	NS	NS	NS	NS	2.5 U	2.5 U	2.5 U	2.5 U
CEF-P21-01S	CEF-P21-GW-001-2 (2)	NS	NS	NS	NS	0.5 U	0.5 U	0.5 U	0.5 U
CEF-P21-01S	CEF-P21-GW-001-2D (2)	NS	NS	NS	NS	0.5 U	0.5 U	0.5 U	0.5 U
CEF-P21-02S	CEF-P21-GW-002	NS	NS	NS	NS	0.1 U	0.1 U	0.1 U	0.1 U
CEF-P21-02S	CEF-P21-GW-002-D	NS	NS	NS	NS	0.1 U	0.1 U	0.1 U	0.1 U
CEF-P21-03S	CEF-P21-GW-003	NS	NS	NS	NS	0.1 U	0.1 U	0.1 U	0.1 U

Sample Location	Sample Name	Detected Concentrations (μg/L)							
		7/29/99				8/25/99			
		4,4'-DDD	α-chlordane	γ-chlordane	total chlordane	4,4'-DDD	α-chlordane	γ-chlordane	total chlordane
CEF-P21-04S	CEF-P21-GW-04S-01	0.1 U	0.1 U	0.1 U	0.1 U	NS	NS	NS	NS
CEF-P21-04S	CEF-P21-GW-04S-01-D	0.1 U	0.1 U	0.1 U	0.1 U	NS	NS	NS	NS
CEF-P21-05S	CEF-P21-GW-05S-01	NS	NS	NS	NS	1 U	1 U	1 U	1 U
CEF-P21-05S	CEF-P21-GW-05S-01-D	NS	NS	NS	NS	1 U	1 U	1 U	1 U
CEF-P21-06S	CEF-P21-GW-06S-01	NS	NS	NS	NS	0.2 U	0.2 U	0.2 U	0.2 U

NOTES

Bolded values indicate an exceedance of the Florida Department of Environmental Protection (FDEP) Groundwater Cleanup Target Level (GCTL) of 0.1 μg/L for 4,4'-DDD or 2.0 μg/L for total chlordane.

1 - Sample collected on June 21, 1999.
2 - Duplicate samples collected on September 27, 1999.
NS Not sampled.
U Not detected at the indicated detection limit.

TABLE 1-3

SUMMARY OF GROUNDWATER DDD AND CHLORDANE DETECTIONS
RI SAMPLING EVENT
OU 10, SITE 21 FEASIBILITY STUDY REPORT
NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA

Sample Location	Sample Name	Detected Concentrations (μg/L)			
		4/24/00			
		4,4'-DDD	α – chlordane	γ – chlordane	total chlordane
CEF-P21-07S	CEF-P21-GW-07S	0.1 U	0.1 U	0.1 U	0.1 U
CEF-P21-07S	CEF-P21-GW-07S-D	0.11 U	0.11 U	0.11 U	0.11 U

NOTES

U Not detected at the indicated detection limit.

Figure 1-5 includes the DDD and chlordane results from previous investigations and the RI. This figure also shows the plume outline as defined by the FDEP groundwater criteria for total chlordane (2.0 µg/L). The size of the chlordane plume is estimated to be less than 30 feet in diameter and centered on well CEF-P21-015 (previously 90G001). The groundwater gradient is not very steep and this appears to have limited the expansion of the plume.

Several of the highest concentrations of chlordane in soil were found distant from the groundwater plume. No chlordane was detected in groundwater samples from wells near the soil contamination. However, the chlordane groundwater contamination is centered beneath a septic field, which may be the source of the contamination. The contaminated soil was removed in accordance with the action memorandum (TtNUS, 2000). The origin of the chlordane is likely from the handling of the pesticides in this area.

1.1.4.3 Contaminant Fate and Transport

Chlordane was detected in groundwater at concentrations greater than the FDEP criterion but in a small area. Other chemicals have been detected in the soil elsewhere on the site, but not in groundwater. This finding is consistent with the low mobility of these types of compounds.

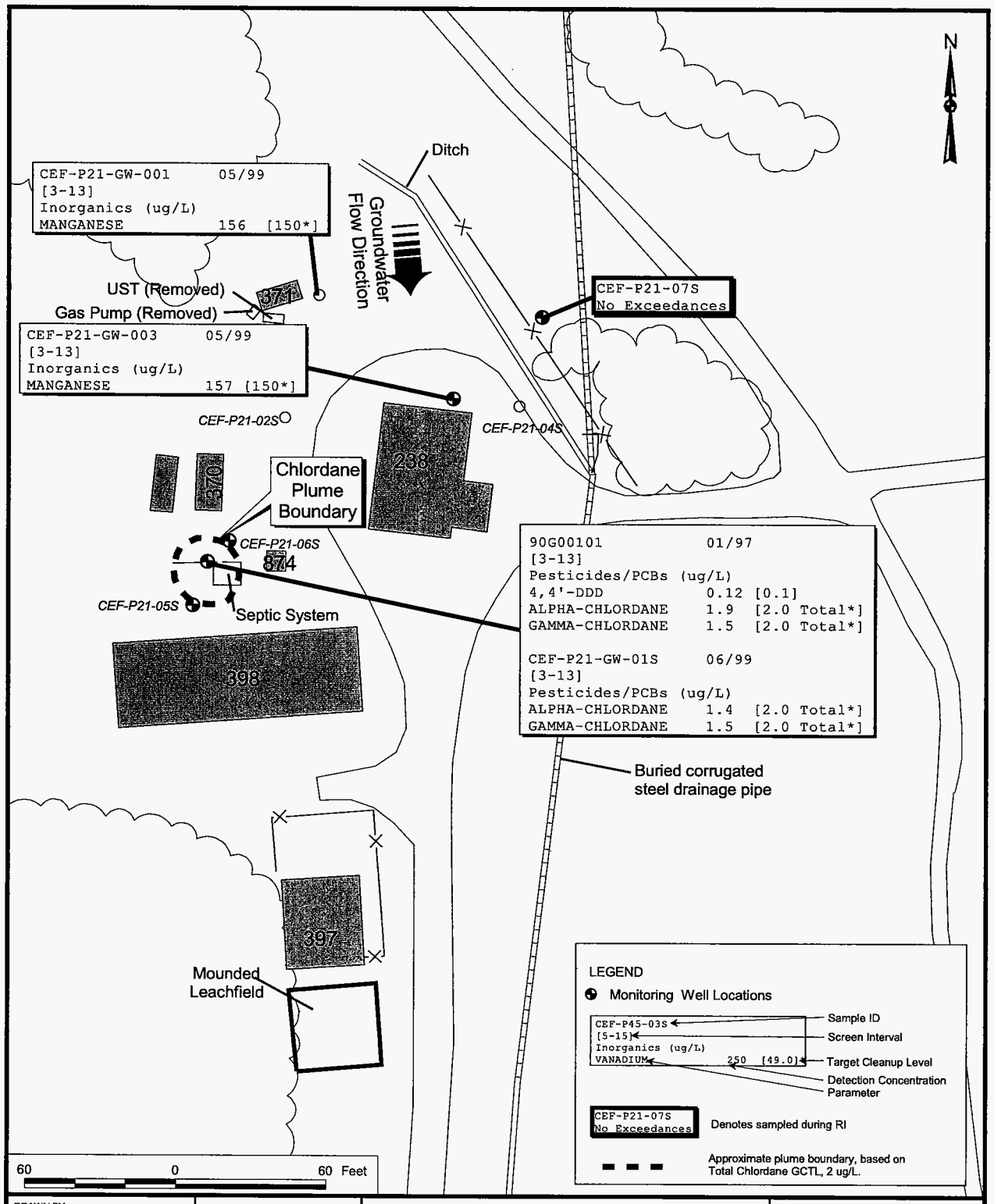
1.1.4.4 Human Health Risk Assessment

Exposure to soil no longer represents a human health risk based on future residential land use. The 95-percent UCL concentrations of the soil remaining at the site are less than the FDEP residential SCTLs or the IBDS values. The incremental cancer risks (ICRs) for the residential parcels shown on Figure 1-4 range from 3.0E-06 to 4.0E-06 and the hazard indices (HIs) are all below one. Although the ICRs exceed the FDEP target of 1.0E-06, all of the post-removal 95-percent UCL concentrations of arsenic are below the IBDS value of 2.04 mg/kg (TtNUS, 2002b).

The PRE for groundwater, performed as part of the RI, indicated that sample concentrations of chlordane in groundwater exceed the FDEP GCTL. The average manganese concentration is less than twice the site average background concentration and is also less than the U.S. EPA Region IX criterion that corresponds to a Hazard Quotient (HQ) of 1.0. Therefore, exposure to the average concentration of manganese would not pose a significant risk to human health (TtNUS, 2002b).

1.1.4.5 Ecological Risk Assessment

Exposure to surface soil contaminants poses minimal risks to ecological receptors at the site. Concentrations of pesticides in some surface soil samples were elevated relative to EPA Region 4 ecological screening values. Potential pesticide-related risks in most of these samples are minor based



DRAWN BY MJJ	DATE 02Oct00	GROUNDWATER RESULTS ABOVE CRITERIA - EXISTING DATA AND RI DATA SITE 21 FEASIBILITY STUDY REPORT NAVAL AIR STATION CECIL FIELD JACKSONVILLE, FLORIDA	CONTRACT NUMBER 0039
CHECKED BY	DATE		APPROVED BY DATE 01/17/01
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SCALE AS NOTED			DRAWING NO. FIGURE 1-5 / REV 0

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from the central portion of the site, where ecological habitat is essentially absent. Thus, pesticide-related risks in the central portion of the site are negligible.

Concentrations of pesticides (primarily DDD, DDE, and DDT) were elevated in a sample collected from the western portion of the site. However, pesticide concentrations were relatively low in nearby samples, indicating that potential risk at this location is minimal due to the extremely small area represented by this sample. Similarly, mercury was slightly elevated in one sample location; however, mercury was not detected in samples collected to the west, and was below site-wide background concentrations in samples collected to the east of this location. Thus, potential risk from mercury is negligible due to the extremely small area represented by one sample.

1.2 DOCUMENT ORGANIZATION

This FS report has been organized with the intent of meeting the general format requirements specified in the October 1988 RI/FS guidance document [United States Environmental Protection Agency (U.S. EPA), 1988]. This report features the following five sections:

- 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, RAOs and General Response Actions (GRAs), presents the RAOs, identifies Applicable or Relevant and Appropriate Requirements (ARARs) and "To Be Considered" (TBC) criteria, develops groundwater cleanup goals 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 which technologies are to 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 with 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 cleanup goals 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 chemicals of concern (COCs) identified in Section 1 and the conceptual pathways through which these chemicals may affect human health and derives the environmental media of concern. The cleanup goals for the contaminated media are developed in this section, and GRAs that may be suitable to achieve the cleanup goals 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 21 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., cleanup goals) for the site.

The development of cleanup goals 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 Site 21. To protect the public from potential current and future health risks, as well as to protect the environment, the following RAOs has been developed:

- Prevent unacceptable risk from ingestion of groundwater with total chlordane concentrations greater than the FDEP GCTL.
- Restore groundwater quality at Site 21.

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, criterion, 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 U.S. EPA 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, that 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 U.S. EPA 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 U.S. EPA 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 selected remedial action 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.

- 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 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 U.S. EPA Maximum Contaminant Levels (MCLs) and Clean Water Act (CWA) Ambient Water Quality Criteria (AWQC).

- Location-Specific: Requirements that 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 general response actions.

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's location-specific ARARs and TBCs for this FS.

2.1.3 Media of Concern

Based upon the discussion in Section 1.0 involving toxicity and risk assessment for both human and ecological receptors, the media of concern at OU 10, Site 21 were determined to be groundwater.

2.1.4 Chemicals of Concern for Remediation

The RI PRE (TtNUS, 2001) identified several chemicals in the groundwater as a concern to human receptors. Analytical groundwater data for the site were compared to the U.S. EPA's current drinking water standards (U.S. EPA, 1998), The FDEP drinking water criteria (FDEP, 1999b), the FDEP GCTLs (FDEP, 1999a), and to the NAS Cecil Field site-specific IBDS screening criteria (HLA, 1998).

Three chemicals, DDD, chlordane, and manganese were detected in the groundwater above the higher of their respective FDEP GCTLs or IBDS criteria. However, as discussed in Section 1.1.4 of this report, only chlordane was retained as a COC.

2.2 CLEANUP GOALS

A cleanup goal 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. Cleanup goals are developed to ensure that contaminant concentration levels left on site are protective of human and ecological receptors.

TABLE 2-1

FEDERAL CHEMICAL-SPECIFIC ARARs
OU 10, SITE 21 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 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 (TBC)	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.
U.S. EPA Office of Drinking Water, Health Advisories		Potential TBC	Estimates of non-carcinogenic risk due to consumption of contaminated drinking water.	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)		TBC	Guidance values used to evaluate the potential carcinogenic hazard caused by exposure to contaminants.	Would be considered for development of human health protection PRGs for soil and groundwater at this site.
Reference Doses (RfDs)		TBC	Guidance values used to evaluate the potential noncarcinogenic hazard caused by exposure to contaminants.	Would be considered for development of human health protection PRGs for soil and groundwater at this site.

TABLE 2-2

STATE CHEMICAL-SPECIFIC ARARs
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Requirement	Citation	Status	Synopsis	Evaluation/Action To Be Taken
Surface Water Quality Standards	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 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 and 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 62-520	TBC	This rule provides primary and secondary drinking water quality criteria.	This rule would be considered for the development 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 development of PRGs.

TABLE 2-3

FEDERAL LOCATION-SPECIFIC ARARs
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Requirement	Citation	Status	Synopsis	Evaluation/Action To Be Taken
Endangered Species Act Regulations	50 CFR Parts 81, 225, 402	Potentially Applicable	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 on site, including remedial investigations.
Fish and Wildlife Coordination Act Regulations	33 CFR Subsection 320.3	Potentially Applicable	Requires that the U.S. Fish and Wildlife Service, 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.

TABLE 2-3

FEDERAL LOCATION-SPECIFIC ARARs
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Requirement	Citation	Status	Synopsis	Evaluation/Action To Be Taken
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 wetland protection. Appendix A states that no remedial alternative may 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.
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 must be 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.	U.S. Fish and Wildlife Service officials would be consulted on how to minimize impacts of any remedial activities on any wildlife.

TABLE 2-4

STATE LOCATION-SPECIFIC ARARs
OU 10, SITE 21 FEASIBILITY STUDY REPORT
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Requirement	Citation	Status	Synopsis	Evaluation/Action To Be Taken

There are no State Location-Specific ARARs

For Site 21, cleanup goals were established based on the following criteria:

- Protection of human health from direct exposure to contaminated soil and groundwater
- Compliance with ARARs and TBCs to the extent practicable

2.2.1 Groundwater Cleanup Goal

The total chlordane cleanup goal for the Site 21 groundwater was established as 2.0 µg/L, which is the FDEP GCTL for this chemical.

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 RAOs. 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 an RAO for the site. Remedial action alternatives will then be composed using GRAs 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 OU 10, Site 21:

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

2.4 ESTIMATED VOLUMES OF CONTAMINATED MEDIA

For remedial action purposes, preliminary volumes of contaminated groundwater were estimated based on the location of samples where chlordane was detected in excess of its cleanup goal.

Based on the analytical results from previous investigations, it was established that the groundwater contaminant plume, where the total chlordane concentration exceeds 2.0 µg/L, extends over a circular area approximately 700 square feet (ft^2) in size and down to a depth of 15 feet bgs. Based on a water table elevation of 5 ft bgs and a porosity of 0.25 that are typical at NAS Cecil Field, the estimated volume of contaminated groundwater at Site 21 was computed at 1,750 cubic feet (ft^3), or 13,100 gallons. The areal extent of the chlordane plume is illustrated on Figure 1-5 and computations of the estimated contaminated groundwater volume are presented in Appendix B.

TABLE 2-5

FEDERAL ACTION-SPECIFIC ARARs
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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 permits are required for any discharges to navigable waters. If remedial activities include such a discharge, the NPDES standards would be ARARs.	Any alternative that would discharge into any navigable water would require compliance with these regulations including treatment, if necessary.
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
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Requirement	Citation	Status	Synopsis	Evaluation/Action To Be Taken
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 a publicly owned treatment works (POTW) in order to control pollutants that pass through, cause interference with, 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 off-site 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 on-site 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 off-site treatment. These regulations do not apply to the above-ground 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
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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 on-site 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
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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 on site, 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 SWDA standards for reinjection prior to well injection.

TABLE 2-6

STATE ACTION-SPECIFIC ARARs
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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 wastes on site were deemed hazardous and needed to be stored, transported, or disposed 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. This rule mainly addresses the discharge of domestic wastewater to wetlands. Discharge limits are established for biochemical oxygen demand, total suspended solids, 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 Storm water Discharge –May 1993	FAC Chapter 62-25	Potentially Relevant and Appropriate	Establishes requirements for discharges of untreated storm water to ensure protection of the surface water of the state.	Remedial actions would consider the impact of the discharge of untreated storm water.

TABLE 2-6

STATE ACTION-SPECIFIC ARARs
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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.

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 remedial alternatives for Site 21 at 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:

- Development of RAOs
- Identification of ARARs
- Identification of GRAs
- Identification of volume of contaminated media

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 are 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" (U.S. EPA, 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 cleanup goal 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 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:

General Response Action	**Remediaton Technology**	Process Options
No Action	None	Not Applicable
Limited Action	Monitoring	Sampling and Analysis
	Institutional Controls	Land Use Controls and Groundwater Use Restrictions
	Natural Attenuation	Naturally Occurring Dispersion and Dilution
Removal	Groundwater Extraction	Extraction Wells or Collection Trenches
Ex-situ Treatment	Physical	Sedimentation
		Filtration
		GAC Adsorption
	Chemical	Neutralization/pH Adjustment
		Coagulation/Flocculation
Discharge/Disposal	Onsite Surface Discharge	Direct Discharge
		Indirect Discharge

TABLE 3-1

PRELIMINARY SCREENING OF GROUNDWATER REMEDIATION TECHNOLOGIES AND PROCESS OPTIONS
OU 10, SITE 21 FEASIBILITY STUDY REPORT
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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	Active Controls: Physical Barriers/ Security Guards	Fencing, markers, and warning signs to restrict site access.	Eliminate – plume is beneath an active area where golf course equipment is stored and equipment maintenance is performed.
		Passive Controls: Deed and Land Use Restrictions	Administrative action using property deeds to restrict future site activities and use of groundwater as source of drinking water.	Retain to limit human exposure to contaminated groundwater.
	Natural Attenuation	Naturally-Occurring Dispersion and Dilution	Groundwater monitoring to assess the contaminant dilution or degradation.	Retain
Containment	Vertical Barriers	Slurry Wall	Low-permeability wall formed in a perimeter trench to restrict horizontal migration of groundwater.	Eliminate – the depth of the nearest impervious layer (approximately 80-90 ft bgs) makes this technology impractical.
		Grout Curtain	Pressure injection of grout to form a low-permeability perimeter wall to restrict horizontal migration of groundwater.	Eliminate – the depth of the nearest impervious layer (approximately 80-90 ft bgs) makes this technology impractical.
		Sheet Piling	Metal sheet piling driven into the ground to restrict horizontal migration of groundwater.	Eliminate – the depth of the nearest impervious layer (approximately 80-90 ft bgs) makes this technology impractical.
	Horizontal Barriers	Physical Barrier	Injection of bottom sealing slurry beneath source to minimize vertical migration of groundwater.	Eliminate – low mobility of COCs and low level of COC contamination results in minimal vertical migration

TABLE 3-1

PRELIMINARY SCREENING OF GROUNDWATER REMEDIATION TECHNOLOGIES AND PROCESS OPTIONS
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General Response Action	Technology	Process Options	Description	Screening Comment
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	Aerobic	Enhancement of biodegradation in an aerobic environment by addition of chemical additives.	Eliminate – biological degradation has not proven to be an effective process in reducing low concentrations of chlorinated pesticides.
		Anaerobic	Enhancement of biodegradation in an anaerobic (oxygen-deficient) environment by addition of chemical additives.	Eliminate – biological degradation has not proven to be an effective process in reducing low concentrations of chlorinated pesticides.
	Physical/ Chemical	Air Sparging/ Soil Vapor Extraction	Volatilization and enhancement of biodegradation by supply of air and extraction of vapors.	Eliminate – low concentrations of chlorinated pesticides are not amenable to volatilization or biological degradation.
		Permeable Reactive Barrier (PRB)	Use of a permeable barrier that allows the passage of groundwater and reacts with the contaminants.	Eliminate – low mobility and reactivity of pesticides are not amenable to this treatment.
		Enhanced Oxidation	Chemical treatment of contaminants through oxidation using a solution of ferrous iron and dilute hydrogen peroxide or potassium permanganate.	Eliminate – proven ineffectiveness for the treatment of low concentrations of pesticides in a treatability study at a related site.
Ex-Situ Treatment	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 – chlorinated pesticides are not amenable to volatilization.

TABLE 3-1

PRELIMINARY SCREENING OF GROUNDWATER REMEDIATION TECHNOLOGIES AND PROCESS OPTIONS
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General Response Action	Technology	Process Options	Description	Screening Comment
Ex-Situ Treatment (Continued)	Physical (Continued)	Granular Activated Carbon (GAC) Adsorption	Separation of dissolved contaminants from water via adsorption onto activated carbon.	Retain for removal of low concentrations of chlordane at Site 21.
		Solvent Extraction	Separation of contaminants from a solution by contact with an immiscible liquid with a higher affinity for the contaminants of concern.	Eliminate - not effective for the removal of low concentrations of chlorinated pesticides.
		Enhanced Oxidation	Use of oxidizers such as air, ozone, peroxide, chlorine, or permanganate or use of high pressure/temperature to chemically increase the oxidation state of organic and inorganic compounds.	Eliminate - proven ineffective for the treatment of low concentrations of pesticides in a treatability study at a related site.
		Sedimentation	Separation of solids from water via gravity settling.	Retain as a pretreatment step prior to potential treatment processes.
	Chemical	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 for the removal of pesticides.
		Chemical Precipitation	Use of reagents to convert soluble constituents into insoluble constituents.	Eliminate – not effective for the removal of low concentrations of chlorinated pesticide compounds.
		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.

TABLE 3-1

PRELIMINARY SCREENING OF GROUNDWATER REMEDIATION TECHNOLOGIES AND PROCESS OPTIONS
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General Response Action	Technology	Process Options	Description	Screening Comment
Ex-Situ Treatment (Continued)	Biological	Aerobic	Natural degradation of organic contaminants via microorganisms in an aerobic (oxygen) environment.	Eliminate – biological degradation has not proven to be an effective process in removing low concentrations of chlorinated pesticides.
		Anaerobic	Natural degradation of organic contaminants via microorganisms in an anaerobic (oxygen-deficient) environment.	Eliminate – biological degradation has not proven to be an effective process in removing low concentrations of chlorinated pesticides.
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 NAS Cecil Field STP or regional publicly owned treatment works (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 21 for deep well injection.

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 alternatives and their effectiveness in mitigating risks posed by site contaminants. Since no remedial actions are taken under this alternative, there are no costs associated with "walking away from" the site. There is no reduction in risk through exposure control or treatment.

Effectiveness

No action would be ineffective in meeting the RAOs for the site. No action would also be ineffective 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 action 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 River Water Management District stating that the county should not issue permits for installation of wells that would draw water from the surficial aquifer at Site 21.

Effectiveness

Land and 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 the reclassification of IR sites at NAS Cecil Field from military to private ownership, provisions were incorporated into property transfer documents to ensure 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 the migration of contaminants and the potential for contamination of nearby residential, municipal, and commercial wells. Monitoring could also be used to track the progress of natural attenuation or active groundwater remediation.

Effectiveness

Monitoring would not reduce the toxicity, mobility, or volume of contaminants in the groundwater but it would allow for the evaluation of 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 21. Local and state permits would be required for monitoring well installation.

Cost

Capital and O&M costs for 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 dispersion, dilution, and adsorption.

Effectiveness

Naturally occurring processes are likely to reduce contaminant concentrations in the aquifer over the long term. The results of the sampling and analysis of groundwater at Site 21, which show that a downward trend in concentration of chlordane has occurred, support this. Continued monitoring of chlordane concentrations within the aquifer would verify the expected reduction in concentrations in the groundwater beneath Site 21.

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 that is considered under this GRA is groundwater extraction. Extraction wells and collection trenches were the two methods for groundwater extraction that were retained from the preliminary screening.

3.2.3.1 Extraction Wells

Extraction wells are wells that 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, which induces additional 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 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 feet), surface pumps may be used. Centrifugal pumps are not practical for use at low extraction rates of less than 1 gallon per minute (gpm), pneumatic ejector type pumps are preferred in this case.

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. Although 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. However, it should be noted 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 cleanup goals 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 easy to install and pumps are widely available for a variety of flow rates and aquifer conditions. Implementation of this technology would require long-term operation and maintenance of the system. Well screens require regular inspection and 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 and 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.

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. A backhoe or clamshell is commonly used for the excavation. The 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 feet bgs, no confining layer is reached until approximately 80 to 90 feet bgs, and this technology would therefore be ineffective to prevent potential downward contaminant migration.

Implementability

Collection trenches would be relatively easy to install. 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 of the depth of the confining layer beneath the surficial aquifer, extraction wells would be more effective than collection trenches.

3.2.4 Ex-Situ Physical Treatment

3.2.4.1 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 suspended solids and produce a clear effluent. This technology may be used in conjunction with chemical precipitation. Two slightly different sedimentation options are used including clarification, which typically produces sludge consisting of 2 - 8 percent solids, and thickening, which further concentrates clarification sludges to 8 - 15 percent solids.

Effectiveness

Sedimentation alone would not be effective for the removal of COCs from groundwater at Site 21. However, this technology could be effective as a pretreatment step for the removal of excessive concentrations of suspended solids that would otherwise undermine the efficiency of suspended solid sensitive treatment technologies such as granular activated carbon (GAC) adsorption. However, based upon previous characterization of the groundwater at Site 21, 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 excessive concentrations of suspended solids are anticipated in the extracted groundwater.

3.2.4.2 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 flow of water or backwash that carries away the solids retained on the filter medium.

Effectiveness

Filtration alone would not be effective for the removal of chlordane from the groundwater at Site 21. However, this technology would effectively reduce excessive concentrations of suspended particles in the groundwater that might otherwise undermine the efficiency of downstream treatment processes 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 the observation of fines in the surficial aquifer at Site 21 and the other Cecil Field sites, 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.

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.

3.2.4.3 GAC Adsorption

GAC adsorption is a frequently applied technology for the removal of contaminants from air or water. GAC adsorption is principally targeted toward 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 the GAC, contaminants are captured on the active sites of the carbon grains and eventually occupy all these sites. The exhausted GAC must then be either regenerated or disposed.

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, which 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 the removal of many organic compounds. Chlordane in the Site 21 groundwater is considered to be more soluble than most pesticides but, in the realm of all organic compounds, the solubility of this pesticide is considered to be relatively low, and therefore, GAC adsorption would likely be effective in reducing its concentration. However, because the concentrations of chlordane in the extracted groundwater would be very low, most of the GAC would be used to adsorb other organic compounds that may be present at higher concentrations but not exceeding criteria, resulting in an inefficient use of GAC.

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, an oil and grease concentration greater than 10 mg/L, or calcium or magnesium concentrations greater than 500 mg/L. At Site 21, 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 in a hazardous waste landfill. Thermal, steam, and solvent treatments are the most common types of GAC regeneration technologies, which 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, and 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.

3.2.5 Ex-Situ Chemical Treatment

3.2.5.1 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 21, neutralization/pH adjustment would not be effective for the removal of pesticides in groundwater. However, this technology could 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 pesticide COCs from solution.

3.2.5.2 Coagulation/Flocculation

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

Effectiveness

Coagulation/flocculation alone would not be effective for the removal of chlordane from the groundwater at Site 21. However, this technology would be effective to optimize the removal of excessive concentrations of suspended solids that would otherwise undermine the efficiency of treatment processes such as GAC adsorption. Based on previous characterization of the groundwater at Site 21, 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.

3.2.6 Disposal

3.2.6.1 Direct Discharge

This technology would consist of discharging the treated (or untreated) groundwater to the NAS Cecil Field storm water drainage system. In the vicinity of Site 21, this storm water drainage ditch system eventually flows into Rowell Creek.

Effectiveness

Direct discharge of groundwater to the storm water drainage ditch system would be an effective means of disposal for groundwater at Site 21. However, the groundwater would have to undergo adequate treatment for this option to be environmentally acceptable.

Implementability

Direct discharge of groundwater to the storm water drainage 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.

3.2.6.2 Indirect Discharge

This technology would consist of discharging the treated (or untreated) groundwater to a 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 means for the disposal of the Site 21 groundwater. It is unlikely that the local STP could provide the necessary chlordane removal for ultimate discharge to surface water.

Implementability

Indirect discharge to a local STP would be implementable. Connection to the local sanitary sewer network should not be a problem, and the STP could probably accommodate the relatively low flow of extracted groundwater. However, discharge of untreated groundwater would require a thorough evaluation of impacts to the STP and a modification to 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 OU 10, Site 21:

- No Action
- Institutional Controls
- Monitoring
- Natural Attenuation
- Extraction Wells
- Filtration
- 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, or Volume through Treatment,
- Short-term Effectiveness,
- Implementability,
- Cost,
- State Acceptance, and
- Community Acceptance

Overall Protection of Human Health and the Environment

Alternatives must be assessed for adequate protection of human health and environment, in the short and the 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.

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.

Long-Term Effectiveness and Permanence

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

Magnitude of Residual Risk

This refers to 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 to be reliable. These include 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.

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 persistence, 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.

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 mitigation measures during implementation.
- Time until protection is achieved.

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 to obtain 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.

Cost

Capital costs shall include both direct and indirect costs. Annual O&M costs shall be provided. A net present-worth (NPW) value 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.

State Acceptance

The state's concerns must be assessed to 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 because the state has not reviewed and commented on the RI/FS. These concerns will be discussed, to the extent possible, in the proposed plan to be issued for public comment.

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 only 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 are considered to be the primary balancing criteria:

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

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

The remaining two of the nine criteria, 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 State of Florida has reviewed this FS and the Proposed Plan has been discussed in a public meeting and opened to public comment. 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 submitted 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 consultation with the State of Florida to determine whether or not the preferred alternative continues to be the most appropriate remedial action for the site.

4.2 ASSEMBLY AND DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

Based on the technology screening presented in Section 3.0, the following three groundwater remedial alternatives were developed for OU 10, Site 21:

- Alternative 1: No Action
- Alternative 2: Natural Attenuation, Institutional Controls, and Monitoring
- Alternative 3: 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. Alternative 3 was 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 Alternative 1: No Action

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, and other attenuating factors. Existing monitoring programs and institutional controls would be discontinued, and the site would be available for unrestricted use.

4.3.1.2 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. In addition, under this alternative, Site 21 could be developed for residential use and this might result in unacceptable risk to human receptors. If the contaminant plume were to expand, the groundwater could be intercepted by Rowell Creek and its tributaries to the west and south. Although this migration would not have an immediate negative impact since Rowell Creek is about 1,400 feet away, such a negative impact could eventually develop. Since no monitoring would be performed, potential chlordane 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 the contaminated groundwater would remain. Because there would be no institutional controls to limit surficial aquifer use or prevent residential development, the potential would also 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 processes but no monitoring would be performed to verify this.

NATURAL ATTENUATION, INSTITUTIONAL CONTROLS, AND MONITORING

INSTITUTIONAL CONTROLS
- PREPARE AND IMPLEMENT DEED RESTRICTIONS TO PREVENT USE OF SURFICIAL AQUIFER GROUNDWATER
- PERFORM REGULAR SITE INSPECTIONS TO VERIFY CONTINUED IMPLEMENTATION OF GROUNDWATER USE RESTRICTIONS

→

COLLECT GROUNDWATER SAMPLES FROM 3 EXISTING WELLS & 1 NEW WELL AND ANALYZE FOR CHLORDANE.
* QUARTERLY FOR 1 YEAR
* SEMI-ANNUALLY FOR 2 YEARS
* ANNUALLY THEREAFTER

→

PERFORM 5-YEAR REVIEWS

DRAWN BY HJB DATE 9/25/02	DEPARTMENT OF THE NAVY SOUTHERN DIV FACILITIES ENGINEERING COMD	BLOCK FLOW DIAGRAM ALTERNATIVE 2 SITE 21 FS NAS CECIL FIELD JACKSONVILLE, FLORIDA	CONTRACT NO. 0039
CHECKED BY DATE			APPROVED BY DATE 09/27/02
COST/SCHED-AREA			APPROVED BY DATE
SCALE NOT TO SCALE			DRAWING NO. FIGURE 4-1 REV. 1

FORM CADD NO. SDIV_AH.DWG - REV 0 - 1/20/98

Short-Term Effectiveness

Since no action would occur, implementation of Alternative 1 would not pose any risks to on-site workers or result in short-term adverse impact to the local community and the environment. Alternative 1 would not achieve the RAOs and, although the chlordane cleanup goal might eventually be achieved through natural attenuation processes, it would not be known when.

Implementability

Since no action would occur, Alternative 1 would be readily implementable. The technical feasibility criteria, including constructibility, 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 cost 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 chlordane. Dispersion through aquifer movement and adsorption on soil particles would be mostly responsible for this. Aquifer conditions would be routinely monitored to ensure that concentrations are being adequately reduced through natural processes.

Component 2: Institutional Controls

Institutional controls would include the prohibition of surficial aquifer use. These controls would eliminate or reduce pathways of exposure to contaminated groundwater.

Use of groundwater would be controlled through deed restrictions and a formal notice would be issued to the St. John River Water Management District stating that the county should not issue permits for installation of any Site 21 drinking water wells that would draw water from the surficial aquifer.

Regular site inspections would be conducted to verify the continued implementations of institutional controls until the chlordane cleanup goal has been met.

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 verify that no contaminant migration is occurring.

Monitoring would consist of collecting samples from three existing monitoring wells and one new monitoring well, as shown on Figure 4-2, and analyzing them for chlordane. Monitoring would be performed for a period of 5 years. Sampling frequency would be quarterly for the first year, semi-annually for the next two years, and annually for the remaining years.

At the end of 5 years, a site review would be conducted to verify that the chlordane cleanup goal has been met, as predicted by the modeling presented in Appendix A. If this is not the case, a more active remedial approach would be evaluated and might be implemented.

4.3.2.2 Detailed Analysis

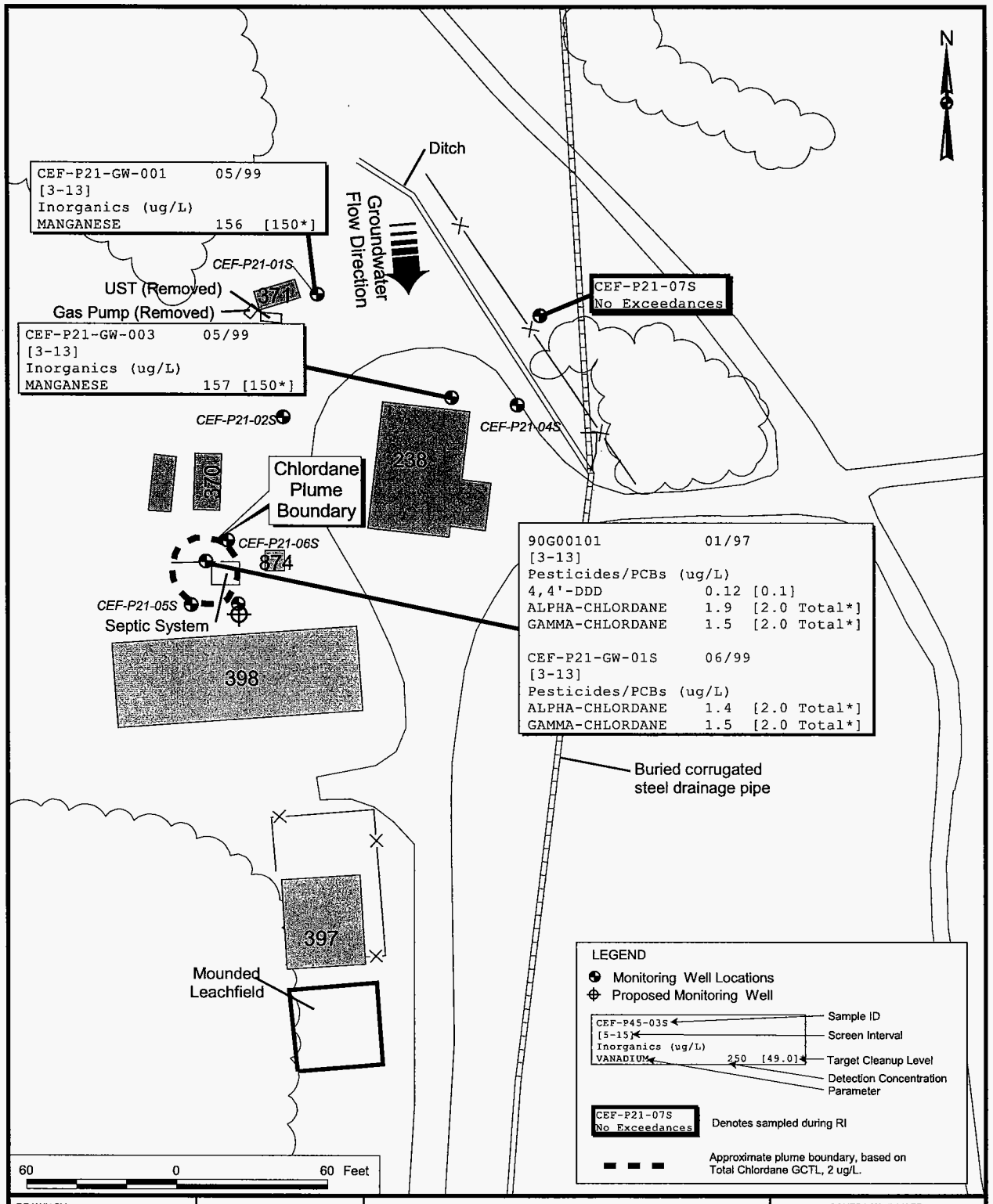
Overall Protection of Human Health and the Environment

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

Natural attenuation would be protective of human health and the environment because it would eventually reduce chlordane concentrations at Site 21 to below the cleanup goal of 2.0 µg/L.

Institutional controls would be protective of human health and the environment. Preventing 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.



DRAWN BY MJJ	DATE 02Oct00	PROPOSED SAMPLING LOCATIONS OU 10, SITE 21 FEASIBILITY STUDY REPORT NAVAL AIR STATION CECIL FIELD JACKSONVILLE, FLORIDA	CONTRACT NUMBER 0039
CHECKED BY	DATE		APPROVED BY DATE 04/27/02
COST/SCHEDULE-AREA			APPROVED BY DATE
SCALE AS NOTED			DRAWING NO. FIGURE 4-2 / REV 0

P:\GIS\NAS_CecilField\PSC21_FS.apr 25Sept02 MJJ 4-4_Proposed MW Layout

Workers could incur some short-term risks from exposure to contamination during implementation of this alternative. However, the potential for such exposure would be minimized by use of the 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 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 Florida GCTLs, but eventually compliance would be achieved as natural processes within the aquifer reduce chlordane concentrations.

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 and adsorption, would reduce chlordane concentrations in the aquifer over the long term to a level that complies with the FDEP GCTL. However, time would be required for these processes to achieve the chlordane cleanup goal, 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 chlordane cleanup goal has 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. Alternative 2 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 chlordane in groundwater. Human health toxicity posed by ingestion of chlordane

in groundwater would remain until the concentration of chlordane 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. Use of appropriate PPE and compliance with site-specific health and safety procedures would minimize exposure of workers to contamination during groundwater sampling and installation of the new monitoring well. Alternative 2 would not adversely impact the surrounding community or the environment.

The first RAO would be achieved immediately upon implementation of institutional controls and monitoring. Based upon the results of the preliminary modeling presented in Appendix A, it is estimated that Alternative 2 would achieve the second RAO and meet the groundwater cleanup goal for chlordane through natural attenuation within approximately 49 months. As additional site-specific data become available, the modeling can be further refined and the remedial duration revised.

Implementability

Alternative 2 would be readily implementable.

Installation of a new monitoring well, maintenance of new and existing 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 transition 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 2 are as follows:

- Capital Cost: $26,000
- 5-Year NPW of O&M Costs: $72,000
- 5-Year NPW: $98,000

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

4.2.3 Alternative 3: Extraction, On-Site Treatment, Surface Discharge, Institutional Controls, and Monitoring

4.2.3.1 Description

Alternative 3 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) monitoring, and (5) institutional controls. 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 groundwater extraction wells and operating these wells for a period of 5 years. Preliminary design calculations for this component are provided in Appendix B.

Based upon analysis of the known hydrogeological characteristics of Site 21, the groundwater extraction system would consist of three wells (EW-1 through EW-3) as shown on Figure 4-5. Each extraction well would be screened from approximately 5 to 15 feet bgs and would pump at the rate of 3.33 gpm, for an overall groundwater extraction rate of 10 gpm.

A submersible centrifugal pump equipped with level controls would be installed in each groundwater extraction well. Each of these pumps would be connected to a piping 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 5 years. The groundwater treatment system would be housed in a 300-square-foot pre-engineered and pre-fabricated building and would consist of the following sequence of unit processes:

- Equalization
- Filtration
- Liquid-Phase GAC Adsorption

The design flow of the treatment system would be 10 gpm. Conceptual design calculations for the groundwater treatment system are provided in Appendix B.

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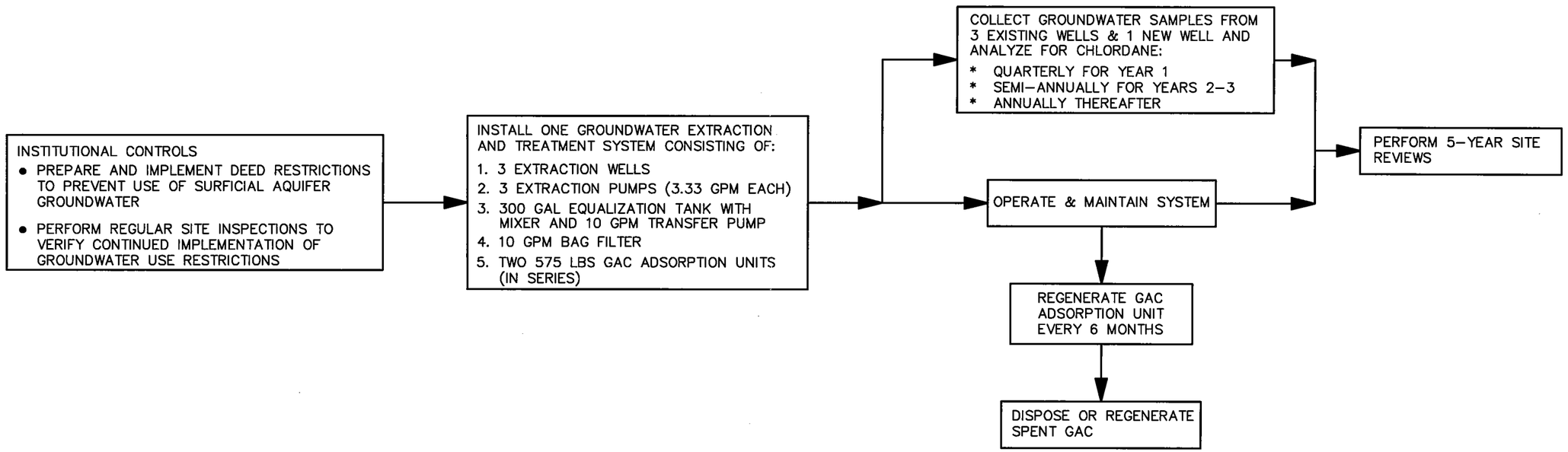
EXTRACTION, ON-SITE TREATMENT, SURFACE DISCHARGE INSTITUTIONAL CONTROLS, AND MONITORING



NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY MF DATE 1/23/00
CHECKED BY DATE
COST/SCHED-AREA
SCALE NOT TO SCALE

DEPARTMENT OF THE NAVY ★ SOUTHERN DIV FACILITIES ENGINEERING COMD

BLOCK FLOW DIAGRAM
ALTERNATIVE 3
SITE 21 FS
NAS CECIL FIELD
JACKSONVILLE, FLORIDA

CONTRACT NO. 0039
APPROVED BY DATE 09/27/02
APPROVED BY DATE
DRAWING NO. FIGURE 4-3
REV. 1

FORM CADD NO. SDIV_BH.DWG - REV 0 - 1/20/98

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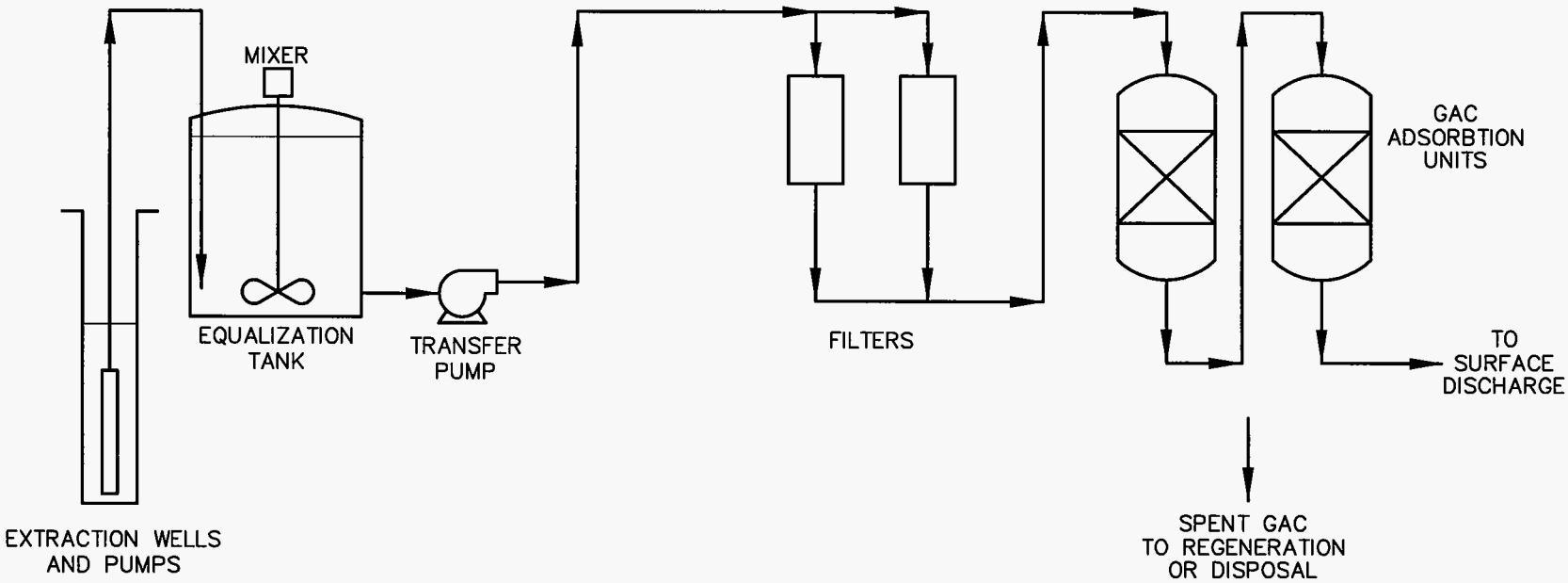
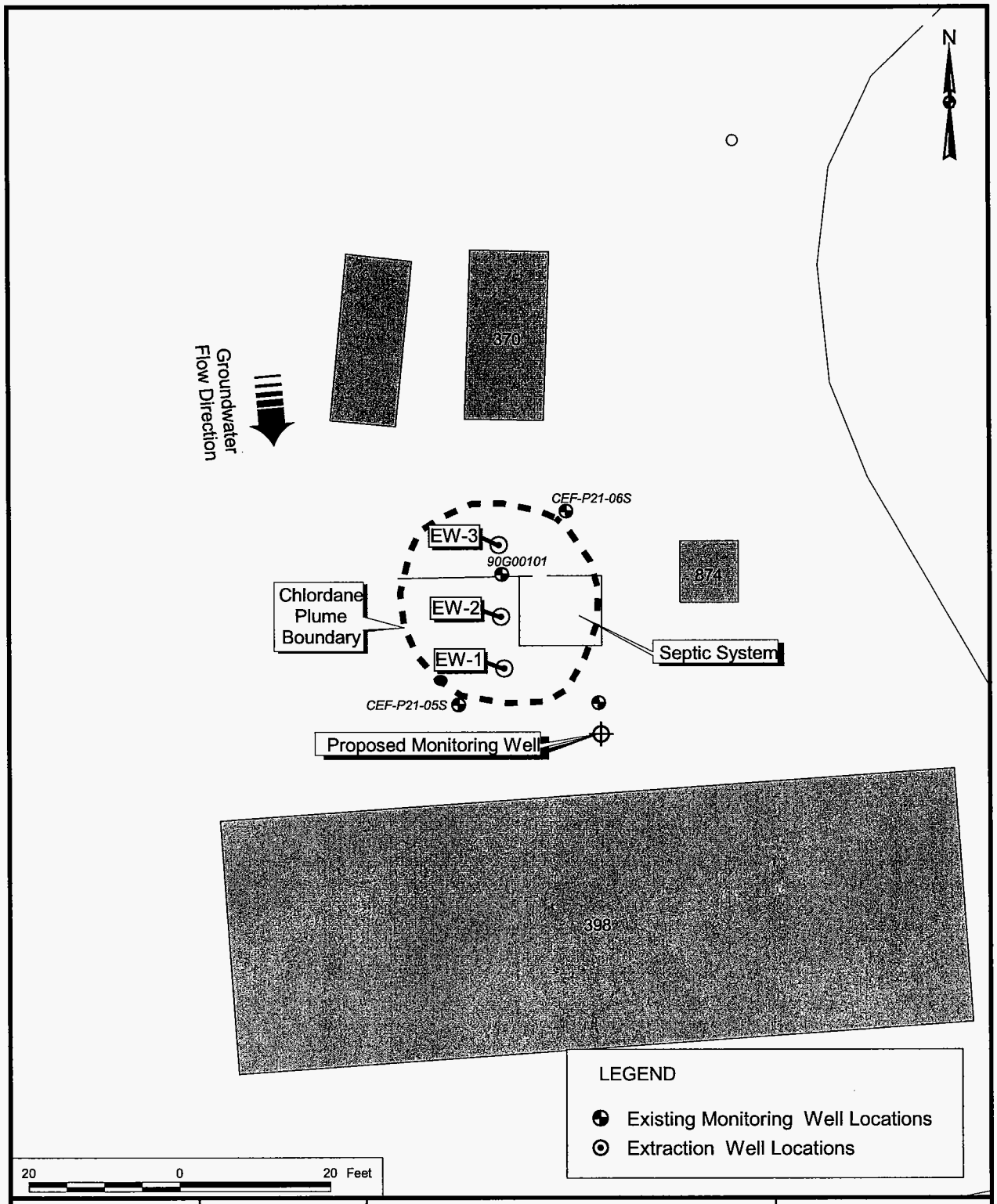


DRAWN BY HJB DATE 9/25/02	DEPARTMENT OF THE NAVY SOUTHERN DIV FACILITIES ENGINEERING COMD	PROCESS FLOW DIAGRAM TYPICAL GROUNDWATER EXTRACTION & TREATMENT SYSTEM ALTERNATIVE 3 – SITE 21 FS NAS CECIL FIELD JACKSONVILLE, FLORIDA	CONTRACT NO. 0039
CHECKED BY DATE			APPROVED BY DATE 09/27/02
COST/SCHED–AREA			APPROVED BY DATE
SCALE NOT TO SCALE			DRAWING NO. FIGURE 4–4 REV. 1

FORM CADD NO. SDIV_AH.DWG - REV 0 - 1/20/98



DRAWN BY MJJ	DATE 12Feb01	GROUNDWATER EXTRACTION WELL LOCATIONS GROUNDWATER ALTERNATIVE 3 OU 10, SITE 21 FEASIBILITY STUDY REPORT NAVAL AIR STATION CECIL FIELD JACKSONVILLE, FLORIDA	CONTRACT NUMBER 0039
CHECKED BY	DATE		APPROVED BY / DATE 09/27/01
COST/SCHEDULE-AREA			APPROVED BY / DATE
SCALE AS NOTED			DRAWING NO. FIGURE 4-5 / REV 0

P:\GIS\NAS_CecilField\PSC21_FS.apr 25Sept02 MJJ 4-7_Extraction Wells Layout

The extracted groundwater would enter the treatment system through an equalization tank. The purpose of this equalization tank would be to blend the groundwater from the various extraction wells to equalize the quality of the influent to the downstream unit processes. The equalization tank could also be used to provide additional treatment, as may be required, such as pH adjustment. For this purpose, the equalization tank would be equipped with a mixer and sized at 300 gallons to provide approximately 30 minutes detention time under design flow conditions.

The equalized groundwater flow would be pumped from the equalization tank to a filter unit by one of two (one spare) 10-gpm centrifugal pumps. The purpose of this filter unit would be to remove most of the suspended solids that might be present in the groundwater at Site 21. If these suspended solids are not removed, they 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 would be discharged under pressure to the liquid-phase GAC adsorption unit, which would be used to remove chlordane down to its surface water quality standard of 0.0043 µg/L. It should be noted that the analytical method detection limit for γ-chlordane in "clean" groundwater is higher (0.0167 µg/L) than the water quality standard for total chlordane. This GAC unit, which would also remove incidental humic materials and other organic compounds present in the Site 21 groundwater, would consist of two activated carbon-packed bed canisters connected in series. Manifolding and valving would be provided so that each of the two canisters could operate in either the lead or lag position. Each canister would contain approximately 600 pounds of GAC, and based upon a usage rate of 3.6 pounds per day (3,000 µg/L of total organic materials adsorbed), the lead canister would require replacement approximately every 5 to 6 months during the 5 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.

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 total chlordane (α–chlordane plus γ–chlordane) and soluble organic carbon (SOC). SOC would be analyzed for the purpose of determining the amount organic materials in the groundwater that are being removed by the GAC. This will result in a more accurate determination of the carbon usage rate.

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 a NPDES permit, as administered by the FDEP. Permit monitoring requirements would be similar to that described for treatment system performance monitoring under Component 2, but would ultimately be determined by the FDEP.

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.

4.2.3.2 Detailed Analysis

Overall Protection of Human Health and the Environment

Alternative 3 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 chlordane 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 chlordane cleanup goal is met. Preventing the use of the surficial aquifer groundwater would be protective of human health and the environment by preventing unacceptable risks of exposure to contaminated groundwater.

Monitoring would be protective by evaluating the effectiveness of the groundwater extraction and treatment system 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 use of appropriate PPE and compliance with site-specific health and safety procedures would minimize the potential for this exposure.

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

Compliance with ARARs and TBCs

Groundwater Alternative 3 would eventually comply with chemical-specific ARARs and TBCs through a combination of groundwater extraction and 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.

Extraction and on-site treatment of the groundwater from the contaminant plume would effectively remove chlordane from groundwater. Groundwater extraction and treatment are well-established remedial approaches that would effectively remove chlordane-contaminated groundwater.

Groundwater use restrictions would effectively prevent the use of the surficial aquifer groundwater until the chlordane cleanup goal is 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 groundwater extraction and treatment system provided under this alternative is designed to remove and treat approximately 1.6 pounds of chlordane over its operating life. Off-site disposal of the spent GAC would ensure that the reduction in contaminant toxicity and volume is 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 groundwater extraction wells, construction and operation of the groundwater treatment system, and groundwater

sampling would be minimized by compliance with the requirements of 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 first RAO would be achieved immediately upon implementation of institutional controls and monitoring.

Based upon the results of the conceptual design calculations presented in Appendix B, it is estimated that the groundwater extraction and treatment system of Alternative 3 would achieve the second RAO and reduce the chlordane concentration of the contaminant plume to its cleanup goal of 2.0 µg/L within approximately 38 months.

Implementability

Alternative 3 would be readily implementable.

A groundwater extraction and treatment system could readily be constructed and operated without unduly restricting the ability of Site 21 to function as an active golf course maintenance area. Qualified personnel would be needed to operate and 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 that are required for these activities are readily available.

The surface discharge of the treated water would also be implementable. Ditches and swales carrying storm water are located in the vicinity of Site 21 and would be available for such discharge. In order to discharge treated water to a nearby storm water conveyance, 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 of these would be readily implementable.

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 as follows:

- Capital Cost: $453,000
- 5-Year NPW of O&M Cost: $331,000
- 5-Year NPW: $784,000

A detailed breakdown of the cost estimate for this alternative is provided in Appendix C. The incorporation of a liquid-phase GAC adsorption system is not cost effective since approximately 99.9 percent of GAC usage will be the result of the removal of non-COC organic compounds and other harmless humic materials found in the groundwater rather than chlordane.

Cost

The estimated costs for Alternative 3 are as follows:

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A detailed breakdown of the cost estimate for this alternative is provided in Appendix C. The incorporation of a liquid-phase GAC adsorption system is not cost effective since approximately 99.9 percent of GAC usage will be the result of the removal of non-COC organic compounds and other harmless humic materials found in the groundwater rather than chlordane.

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 are being compared in this section:

- Alternative 1: No Action
- Alternative 2: Natural Attenuation, Institutional Controls, and Monitoring
- Alternative 3: 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 groundwater for drinking purposes and future residential development 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 chlordane in groundwater since no monitoring would occur.

Alternatives 2 and 3 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 because they would reduce exposure to contaminated groundwater by preventing use of the surficial aquifer groundwater at Site 21.

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.

Alternative 2 would be protective of human health and the environment since natural attenuation would reduce the concentration of chlordane to below its cleanup goal within a reasonable time frame.

Alternative 3 would be somewhat more protective than Groundwater Alternative 2 because it would slightly accelerate the natural attenuation of chlordane through extraction and on-site treatment of the 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, neither Alternative 2 nor 3 would comply with chemical-specific ARARs and TBCs but both would eventually achieve compliance as they attain the chlordane cleanup goal through natural attenuation or active remediation or a combination of both. Alternative 3 would be the first to achieve compliance.

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. Since there would be no institutional controls to limit the use of surficial aquifer groundwater or prevent future residential development, the potential would also exist for unacceptable risk to develop due to exposure to contaminated groundwater. Since there would be no monitoring, potential migration of contaminants would remain undetected.

Alternatives 2 and 3 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 chlordane cleanup goal has been achieved.

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.

Alternatives 2 and 3 would both provide long-term effectiveness and permanence since either natural attenuation or extraction and on-site treatment would eventually reduce the concentration of chlordane in groundwater down to its cleanup goal.

5.3.4 Reduction of Toxicity, Mobility, or Volume through Treatment

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

Alternative 3 would remove an estimated 1.6 pounds of chlordane from the contaminant plume through extraction and on-site treatment. The 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 RAOs and, although the chlordane cleanup goal might eventually be attained through natural processes, this could not be verified.

Implementation of Alternative 2 would result in a slight possibility of exposing site workers to contaminated groundwater during the installation of a new monitoring well and during sampling and maintenance of the new and existing monitoring wells. However, use of appropriate PPE and compliance with proper site-specific health and safety procedures would effectively control these risks of exposure. Implementation of Alternative 2 would not adversely impact the surrounding community or environment. Alternative 2 would achieve the first RAO immediately upon implementation of institutional controls and monitoring. According to modeling, the second RAO and the chlordane cleanup goal would be attained within approximately 49 months.

Implementation of Alternative 3 would result in a possibility of exposing construction workers to contaminated groundwater during the installation of the groundwater extraction and on-site treatment system. Implementation of this alternative 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 could be effectively controlled by the implementation of engineering controls, by the wearing of appropriate PPE, and by compliance with applicable OSHA regulations and proper site-specific health and safety procedures. Implementation of Alternative 3 would not adversely impact the surrounding community and environment. Alternative 3 would achieve the first RAO immediately upon implementation of institutional controls and monitoring. According to modeling, the second RAO and the chlordane PRG would be met within approximately 38 months.

5.1.6 Implementability

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

Alternatives 2 and 3 would be technically implementable.

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

The technical implementability of Alternative 3 would be significantly more difficult than that of Alternative 2 since, in addition to institutional controls and monitoring, this alternative would require the installation and O&M of a groundwater extraction and treatment system. Although qualified personnel would be required over the long-term for the operation and maintenance 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 ditches and swales, which could be used for this purpose, are present in the immediate vicinity of Site 21. Construction permits would be required for installation of extraction wells and construction of the on-site treatment system. On-site treatment of groundwater would generate contaminated residues such as clogged filter elements and spent GAC, but disposal and/or regeneration of these materials would be reasonably easy to accomplish.

5.1.7 Cost

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

Alternative	Capital ($)	5-year NPW of O&M ($)	5-year NPW ($)
1	0	0	0
2	26,000	72,000	98,000
3	453,000	331,000	784,000

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 three remedial alternatives.

TABLE 5-1

SUMMARY OF COMPARATIVE EVALUATION OF ALTERNATIVES
OU 10, SITE 21 FEASIBILITY STUDY REPORT
NAS CECIL FIELD
JACKSONVILLE, FLORIDA
PAGE 1 OF 2

Evaluation Criteria	Alternative 1: No Action	Alternative 2: Natural Attenuation, Institutional Controls, and Monitoring	Groundwater 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 chlordane in groundwater through extraction and treatment of the contaminant plume.
Compliance with ARARs and TBCs: Chemical-Specific Location-Specific Action-Specific	 Would not comply Would not comply Not applicable	 Would eventually comply Would comply Would comply	 Would eventually comply Would comply Would comply
Long-Term Effectiveness and Permanence	Would not be effective and permanent in the long term since contaminants would remain on site. Any long-term effectiveness would not be known since monitoring would not occur.	Would be effective and permanent in the long term. Groundwater use restrictions and monitoring would effectively prevent unacceptable risk from exposure to contaminated groundwater.	Would be effective and permanent in the long term. Groundwater use restrictions and monitoring would effectively prevent unacceptable risk from exposure to contaminated groundwater.
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 reduction through natural processes.	Would achieve reduction of contaminant toxicity, mobility, and volume through treatment.

TABLE 5-1

SUMMARY OF COMPARATIVE EVALUATION OF ALTERNATIVES
OU 10, SITE 21 FEASIBILITY STUDY REPORT
NAS CECIL FIELD
JACKSONVILLE, FLORIDA
PAGE 2 OF 2

Evaluation Criteria	Alternative 1: No Action	Alternative 2: Natural Attenuation, Institutional Controls, and Monitoring	Groundwater Alternative 3: Extraction, On-Site Treatment, Surface Discharge, Institutional Controls, and Monitoring
Short-Term Effectiveness	Would not result in short-term risks to site workers or adversely impact the surrounding community but would also not achieve the RAOs.	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. The first RAO would be achieved immediately upon implementation. The second RAO and the chlordane cleanup goal would be attained within approximately 49 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. The first RAO would be achieved immediately upon implementation. The second RAO and the chlordane cleanup goal would be attained within approximately 38 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.	Would be slightly more difficult to implement than Alternative 2 since, in addition to institutional controls and monitoring, 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. A construction permit would be required.
Costs:			
Capital	$0	$26,000	$453,000
NPW of O&M	$0	$72,000	$331,000
NPW	$0	$98,000	$784,000

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APPENDIX A

NATURAL ATTENUATION MODELING

TETRA TECH NUS, INC. **CALCULATION WORKSHEET**

CLIENT SOUTHDIV		JOB NUMBER 0039 DSO 11E 220	
SUBJECT Cecil Field Site 21 FS			
BASED ON		DRAWING NUMBER	
BY RRM	CHECKED BY JPO	APROVED BY	DATE 9/27/02

Objective: To determine the length of time required for natural attenuation to reduce the concentration of chlordane in groundwater to the FDEP GCTL.

Site Data:

Plume diameter = 30 feet
Plume area = 707 sq ft
Plume thickness = 10 feet
Porosity (n) = 0.25
K = 3.3 ft/day
i = 0.017
Aquifer thickness (b) = 95 ft
Infiltration = 1.13 ft/yr
Horizontal seepage velocity (V) = Ki/n

V = 3.3 ft/day(0.017)/0.25 = 0.22 ft/day = 81.9 ft/yr

Contaminant Data:

K_{oc} chlordane = 120,000 L/kg (published value)
f_{oc} = 0.00843 (Site 21 TOC sample)
Initial groundwater concentration of total chlordane = 2.9 ug/L
FDEP GCTL = 2.0 ug/L
Initial soil concentration = 21 ug/kg (post-excavation 95% UCL)
$K_d = K_{oc} \times f_{oc}$ = 120,000 L/kg = 0.00843 = 1,012 L/kg
Half-life = 7.6 years

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

4.1 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 21 Job # 0039 **INVESTIGATOR:** RRM **DATE:** 9/27/2002

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX			
		EXPOSURE POINT: (UNDERS, FL)	UNDERS	LEACHATE CONCENTRATION (YES,NO) ?	NO
CONTAMINANT:	Chlordane	UNDERS: Under source, FL: Fenceline		INPUT SOLID-PHASE CONCENTRATION (MG/KG)	2.100E-02
		WATER CRITERIA (UG/L):	2.00E+00	CONSTANT CONCENTRATION (YES,NO)?	NO
HALF-LIFE (YRS):	7.60E+00			TRY NEW GOAL:	1.45E-02
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):	1.01E+03	LENGTH (FT):	30
		WIDTH (FT):	30
DEPLETING SOURCE:		**IS THERE A CLAY LINER LAYER (YES,NO)?**	NO
WASTE CHARACTERISTICS:			
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	2.10E-02	THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INPUT FOLLOWING PARAMETERS:		HOW MANY SUBLAYERS (1 - 10)?	3
THICKNESS (FT):	5	TOTAL THICKNESS (UP TO 30 FT) (FT):	10
SATURATION RATE:	0.6	SATURATION RATE:	0.95
POROSITY:	0.25	POROSITY:	0.2
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3):	1.78
		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):	81.9	DOWNGRADIENT AREA INFILTRATION RATE, q (FT/YR)	1.13
Kd (L/KG):	1.01E+03	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.25	MIXING DEPTH, H (FT):	10.0
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):	2.9	DISTANCE TO F.L.:	50

PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)
SATURATED LAYER CONCENTRATION:	2.90E+00 (UG/L)	0
FENCE LINE CONCENTRATION:	0.00E+00 (UG/L)	5

an 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:**	**Chlordane**
		HALF-LIFE (YRS):	
		LAYER 2:	7.60E+00
INVESTIGATOR:	RRM	**SATURATED LAYER**	7.60E+00
DATE:	9/27/2002	**DOWNGRADIENT**	7.60E+00
		INITIAL CONC. (ug/L):	2.90E+00

SATURATED LAYER

INFILT (FT/YR):	1.13					B (FT):	95	Vzo (FT/YR):	2.1
LENGTH (FT):	30					GW Q3 (L/DAY):	5.55E+02		
WIDTH (FT):	30		Kd (L/KG):	1.01E+03		GW V. (FT/YR):	81.90	Kd (L/KG):	1012
POROSITY 2:	0.3		SATURATION:	1.00		H (FT):	10.0000	RETARDATION:	6073
POROSITY SAT. LAYER:	0.25		THICKNESS (FT):	10.00		EFF. POROSITY:	0.25	q (FT/YR) :	1.13
DENSITY 2 (G/CM3):	1.5		DECAY (1/DAY):	2.50E-04		DISPERSIVITY:		DECAY (1/YR):	1.4E-01
DENSITY GMA (G/CM3):	1.50		CBo (PPB):	2.90E+00		Az (FT):	0.17		
			CU2 (PPB):	0.00E+00		Ax (FT):	5.00	P&T (YEARS):	0
AGE (YEARS):	0	Q1 (L/DAY): 7.89E+01	Q2 (L/DAY):	4.77E+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	2.08E-02	2.90E+00	0.00E+00
0.1	2.06E-02	2.87E+00	0.00E+00
0.2	2.04E-02	2.85E+00	0.00E+00
0.3	2.02E-02	2.82E+00	0.00E+00
0.4	2.00E-02	2.80E+00	0.00E+00
0.5	1.98E-02	2.77E+00	0.00E+00
0.6	1.96E-02	2.74E+00	0.00E+00
0.7	1.95E-02	2.72E+00	0.00E+00
0.8	1.93E-02	2.69E+00	0.00E+00
0.9	1.91E-02	2.67E+00	0.00E+00
1	1.89E-02	2.65E+00	0.00E+00
1.1	1.88E-02	2.62E+00	0.00E+00
1.2	1.86E-02	2.60E+00	0.00E+00
1.3	1.84E-02	2.57E+00	0.00E+00
1.4	1.83E-02	2.55E+00	0.00E+00
1.5	1.81E-02	2.53E+00	0.00E+00
1.6	1.79E-02	2.50E+00	0.00E+00
1.7	1.78E-02	2.48E+00	0.00E+00
1.8	1.76E-02	2.46E+00	0.00E+00
1.9	1.74E-02	2.44E+00	0.00E+00
2	1.73E-02	2.41E+00	0.00E+00
2.1	1.71E-02	2.39E+00	0.00E+00
2.2	1.70E-02	2.37E+00	0.00E+00
2.3	1.68E-02	2.35E+00	0.00E+00
2.4	1.67E-02	2.33E+00	0.00E+00
2.5	1.65E-02	2.31E+00	0.00E+00
2.6	1.64E-02	2.28E+00	0.00E+00
2.7	1.62E-02	2.26E+00	0.00E+00
2.8	1.61E-02	2.24E+00	0.00E+00
2.9	1.59E-02	2.22E+00	0.00E+00
3	1.58E-02	2.20E+00	0.00E+00
3.1	1.56E-02	2.18E+00	0.00E+00
3.2	1.55E-02	2.16E+00	0.00E+00
3.3	1.54E-02	2.14E+00	0.00E+00
3.4	1.52E-02	2.12E+00	0.00E+00
3.5	1.51E-02	2.10E+00	0.00E+00
3.6	1.49E-02	2.08E+00	0.00E+00
3.7	1.48E-02	2.07E+00	0.00E+00
3.8	1.47E-02	2.05E+00	0.00E+00
3.9	1.45E-02	2.03E+00	0.00E+00
4	1.44E-02	2.01E+00	0.00E+00
4.1	1.43E-02	1.99E+00	0.00E+00
4.2	1.41E-02	1.97E+00	0.00E+00
4.3	1.40E-02	1.95E+00	0.00E+00
4.4	1.39E-02	1.94E+00	0.00E+00
4.5	1.38E-02	1.92E+00	0.00E+00
4.6	1.36E-02	1.90E+00	0.00E+00
4.7	1.35E-02	1.88E+00	0.00E+00
4.8	1.34E-02	1.87E+00	0.00E+00
4.9	1.33E-02	1.85E+00	0.00E+00
5	1.31E-02	1.83E+00	0.00E+00
MAXIMUM:	2.08E-02	2.90E+00	0.00E+00

APPENDIX B

CONCEPTUAL DESIGN CALCULATIONS

B.1 GROUNDWATER EXTRACTION SYSTEM DESIGN

B.2 GROUNDWATER TREATMENT SYSTEM DESIGN

B.1 GROUNDWATER EXTRACTION SYSTEM DESIGN

Project:	**Cecil Field**	**Project No.:**	**0039 DSO 11E220**
Subject:	**Site 21 Groundwater Extraction System FS Design**		
By:	JPO	**Date:**	3/28/2001
Checked:	RM	**Date:**	9/27/02

Project/Design Objective:

Design a groundwater extraction system for cleanup of chlordane 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):	30	ft.
Plume Thickness:	10	ft.
Plume Area:	707	ft^2
Plume Volume:	1767	ft^3

Aquifer Characteristics

Thickness (B):	95	ft.
Hydraulic Conductivity (K):	3.3	ft/day
Transmissivity (T):	313.5	ft^2/day
Porosity (n):	0.25	
Storativity (S):	0.25	
Fractional organic carbon content (foc):	0.00843	
Flow Gradient (i):	0.017	

Contaminant Characteristics

Contaminant A representative gw conc.:	Chlordane	2.9	ug/L
Contaminant B representative gw conc.:			
Koc, Contaminant A:		120,000	
Koc, Contaminant B:			
Kd, Contaminant A:		1011.6	
Kd, Contaminant B:		0	
Half-life, Contaminant A:		7.6	years
Half-life, Contaminant B:			
Target Cleanup Level, Contaminant A:		2	ug/L
Target Cleanup Level, Contaminant B:			

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 = 159.89 ft^3/day x 2, or 0.83 gpm x 2

Qt = 319.77 ft^3/day, or 1.66 gpm

Maximum Achievable Pumping Rate in a Single Well (Qa)

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

Qa = 838.03 ft^3/day, or 4.35 gpm

Minimum Number of Extraction Wells Required

= Qt/Qa

= 0.38 wells

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

At	2.00	gpm,	3.9	years
At	4.00	gpm,	3.7	years
At	10.00	gpm,	3.2	years
At natural GW flow rate:	0.83	gpm,	4	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:	3		
Per-well Pumping Rate (Qw):	3.33	gpm, or	641.06 ft^3/day
Total System Pumping Rate (Qes):	10	gpm, or	1925.10 ft^3/day

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

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

WSp = 38.29 ft

or

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

WSp = 48.24 ft

or

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

WSp = 45.95 ft

Downgradient Stagnation Point (SPd) Approximation

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

SPd = 57.49 ft

Alternate Layout of Extraction Well System (I.e., parallel to GW flow direction):

Install three extraction wells within the plume interior, positioned within chlordane hot spot areas to miximize 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:

Three 6-inch diameter extraction wells, screened from 5 to 15 feet below ground, installed within the plume interior at chlordane hot spot locations. Each well will pump at an approximate rate of 3.33 gpm, for a total extraction system pumping rate of 10 gpm and projected cleanup time of approximately 3.2 years.

Pore Volume Contaminant Concentration Calculations

Project:	**Cecil Field Site 21**	**Proj. No.:**	**0039.DSO.11E220**
Chemical :	**Chlordane**	**Koc (Kd*) :**	**120000**
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}	2.900	Cw_{0U2}	2.900	Cw_{0U3}	2.900
n	0.250	n	0.250	n	0.250
SG	2.650	SG	2.650	SG	2.650
foc*	0.0084	foc*	0.0084	foc*	0.0084
Kd	1011.600	Kd	1011.600	Kd	1011.600
Mw	0.725	Mw	0.725	Mw	0.725
Cs	2933.640	Cs	2933.640	Cs	2933.640
Ms	5830.610	Ms	5830.610	Ms	5830.610
Mt	5831.335	Mt	5831.335	Mt	5831.335
Ms/Mt	0.9999	Ms/Mt	0.9999	Ms/Mt	0.9999

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

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
$\mathbf{Cw_{n+1}} = [Cw_n](Ms_n/Mt_n)$

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
0.83	159.79	3,534	53.26	53.26	53.26	1176.822	1176.822	1176.822	22.09	22.09	22.09

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):	2776	1st order decay coef. (k):	0.000250

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	22.09	2.884	2.881	0.06
2	44.19	2.867	2.865	0.12
3	66.28	2.851	2.848	0.18
5	110.47	2.819	2.817	0.30
7	154.66	2.788	2.785	0.42
9	198.85	2.756	2.754	0.54
12	265.14	2.710	2.708	0.73
15	331.42	2.665	2.662	0.91
20	441.90	2.591	2.588	1.21
25	552.37	2.519	2.516	1.51
30	662.85	2.449	2.446	1.81
40	883.80	2.314	2.312	2.42
50	1104.75	2.187	2.185	3.02
70	1546.65	1.954	1.952	4.23
90	1988.55	1.746	1.744	5.44
120	2651.39	1.474	1.473	7.26
150	3314.24	1.245	1.243	9.07
180	3977.09	1.051	1.050	10.89
210	4639.94	0.887	0.886	12.70
250	5523.74	0.708	0.707	15.12
60	1325.70	2.067	2.065	3.63
65	1436.17	2.010	2.008	3.93
66	1458.27	1.999	1.997	3.99
417	9213.59	0.276	0.276	25.23
357	7887.90	0.387	0.387	21.60

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

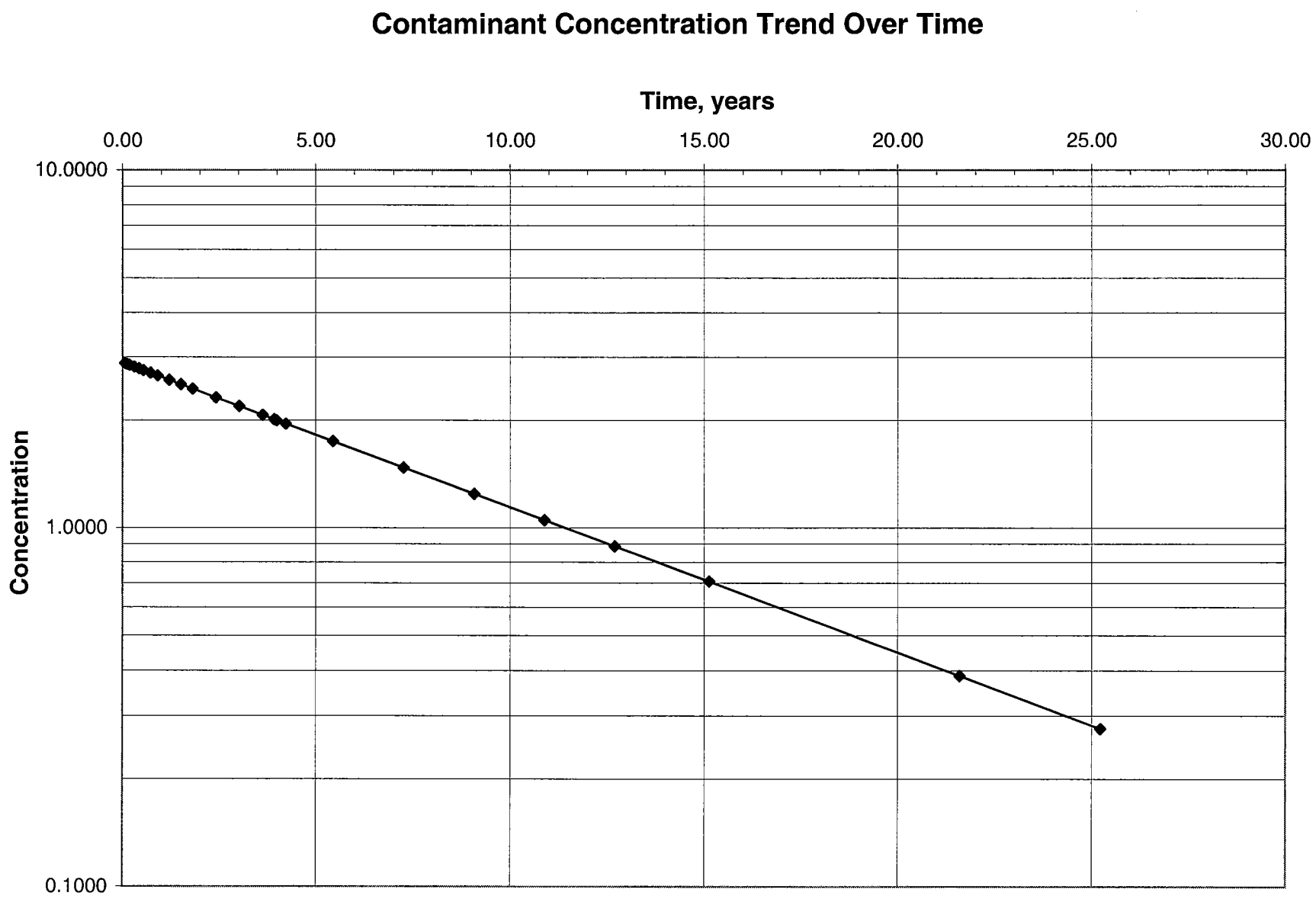
where FQ_{Un} = Fraction of total flow per day, Un unit (volume Un pumped/total volume pumped per day, or volume Un discharged/total volume discharged per day, under natural flushing conditions)

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
10.0000
1.0000
0.1000
Concentration

Pore Volume Contaminant Concentration Calculations

Project:	**Cecil Field Site 21**	**Proj. No.:**	**0039.DSO.11E220**
Chemical :	**Chlordane**	**Koc (Kd*) :**	**120000**
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}	2.900	Cw_{0U2}	2.900	Cw_{0U3}	2.900
n	0.250	n	0.250	n	0.250
SG	2.650	SG	2.650	SG	2.650
foc*	0.0084	foc*	0.0084	foc*	0.0084
Kd	1011.600	Kd	1011.600	Kd	1011.600
Mw	0.725	Mw	0.725	Mw	0.725
Cs	2933.640	Cs	2933.640	Cs	2933.640
Ms	5830.610	Ms	5830.610	Ms	5830.610
Mt	5831.335	Mt	5831.335	Mt	5831.335
Ms/Mt	0.9999	Ms/Mt	0.9999	Ms/Mt	0.9999

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

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
$\mathbf{Cw_{n+1}} = [Cw_n](Ms_n/Mt_n)$

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
2	385.03	3,534	128.34	128.34	128.34	1176.822	1176.822	1176.822	9.17	9.17	9.17

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

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

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

Contaminant Half-Life Data

Does contaminant have a decay half-life (yes/no):	yes	If yes, give half-life (days):	2776	1st order decay coef. (k):	0.000250

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	9.17	2.893	2.890	0.03
2	18.34	2.886	2.883	0.05
3	27.51	2.879	2.876	0.08
5	45.85	2.865	2.862	0.13
7	64.19	2.851	2.849	0.18
9	82.52	2.838	2.835	0.23
12	110.03	2.817	2.814	0.30
15	137.54	2.797	2.794	0.38
20	183.39	2.763	2.761	0.50
25	229.24	2.730	2.727	0.63
30	275.08	2.697	2.695	0.75
40	366.78	2.633	2.631	1.00
50	458.47	2.570	2.568	1.26
70	641.86	2.449	2.447	1.76
90	825.25	2.334	2.332	2.26
120	1100.33	2.171	2.169	3.01
150	1375.41	2.019	2.017	3.77
180	1650.49	1.878	1.876	4.52
210	1925.57	1.747	1.745	5.27
250	2292.35	1.586	1.585	6.28
155	1421.26	1.995	1.993	3.89
154	1412.09	2.000	1.998	3.87
153	1402.92	2.005	2.003	3.84
200	1833.88	1.790	1.788	5.02
100	916.94	2.278	2.276	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)

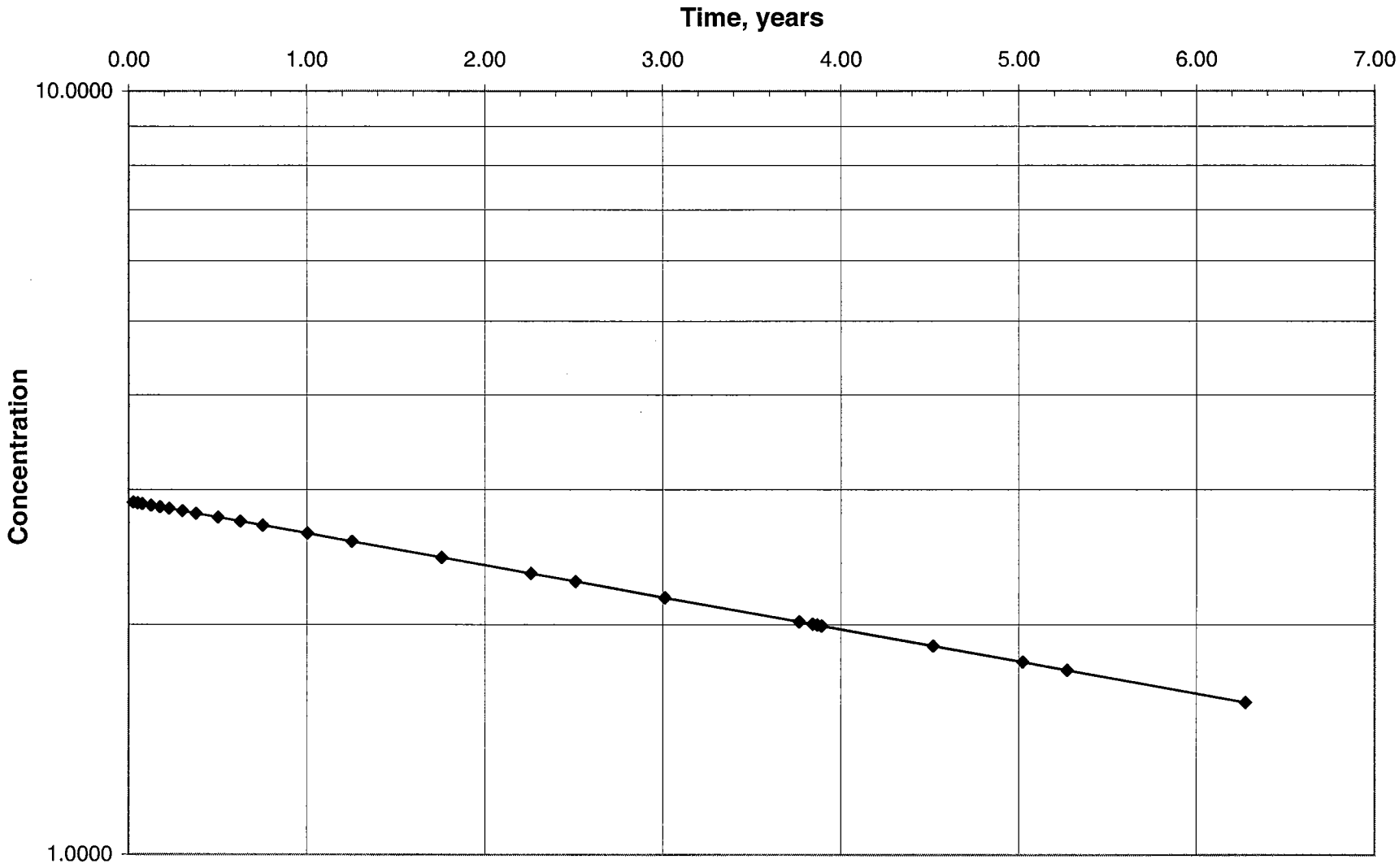
Number of pore volumes (PVs) required to reach target gw concentration Cw_x:

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



Pore Volume Contaminant Concentration Calculations

Project:	**Cecil Field Site 21**	**Proj. No.:**	**0039.DSO.11E220**
Chemical :	**Chlordane**	**Koc (Kd*) :**	**120000**
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}	2.900	Cw_{0U2}	2.900	Cw_{0U3}	2.900
n	0.250	n	0.250	n	0.250
SG	2.650	SG	2.650	SG	2.650
foc*	0.0084	foc*	0.0084	foc*	0.0084
Kd	1011.600	Kd	1011.600	Kd	1011.600
Mw	0.725	Mw	0.725	Mw	0.725
Cs	2933.640	Cs	2933.640	Cs	2933.640
Ms	5830.610	Ms	5830.610	Ms	5830.610
Mt	5831.335	Mt	5831.335	Mt	5831.335
Ms/Mt	0.9999	Ms/Mt	0.9999	Ms/Mt	0.9999

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

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
$\mathbf{Cw_{n+1}} = [Cw_n](Ms_n/Mt_n)$

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
4	770.05	3,534	256.68	256.68	256.68	1176.822	1176.822	1176.822	4.58	4.58	4.58

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):	2776	1st order decay coef. (k):	0.000250

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	4.58	2.896	2.893	0.01
2	9.17	2.893	2.890	0.03
3	13.75	2.889	2.886	0.04
5	22.92	2.882	2.879	0.06
7	32.09	2.874	2.871	0.09
9	41.26	2.867	2.864	0.11
12	55.02	2.856	2.853	0.15
15	68.77	2.845	2.842	0.19
20	91.69	2.827	2.825	0.25
25	114.62	2.809	2.807	0.31
30	137.54	2.792	2.789	0.38
40	183.39	2.756	2.754	0.50
50	229.24	2.722	2.719	0.63
70	320.93	2.654	2.651	0.88
90	412.62	2.587	2.584	1.13
120	550.16	2.490	2.488	1.51
150	687.71	2.397	2.395	1.88
180	825.25	2.308	2.306	2.26
210	962.79	2.222	2.219	2.64
250	1146.18	2.112	2.110	3.14
300	1375.41	1.982	1.980	3.77
290	1329.56	2.007	2.005	3.64
292	1338.73	2.002	2.000	3.67
340	1558.80	1.884	1.882	4.27
380	1742.19	1.791	1.789	4.77

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)

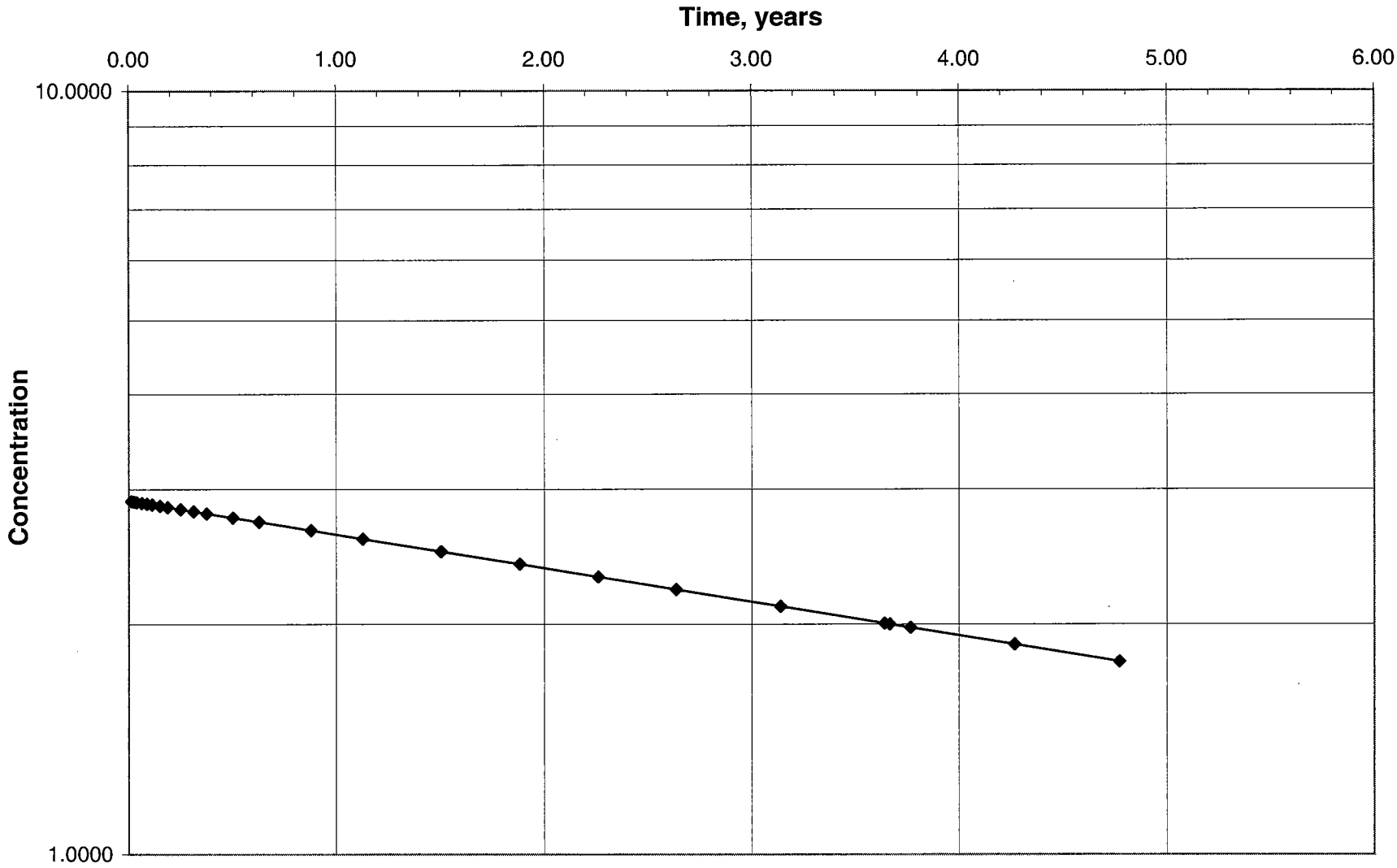
Number of pore volumes (PVs) required to reach target gw concentration Cw_x:

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 21**	**Proj. No.:**	**0039.DSO.11E220**
Chemical :	**Chlordane**	**Koc (Kd*) :**	**120000**
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.

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
$\mathbf{Cw_{n+1}} = [Cw_n](Ms_n/Mt_n)$

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 Physical/Chemical Data

Flow Unit 1 (U1)		Flow Unit 2 (U2)		Flow Unit 3 (U3)	
Cw_{0U1}	2.900	Cw_{0U2}	2.900	Cw_{0U3}	2.900
n	0.250	n	0.250	n	0.250
SG	2.650	SG	2.650	SG	2.650
foc*	0.0084	foc*	0.0084	foc*	0.0084
Kd	1011.600	Kd	1011.600	Kd	1011.600
Mw	0.725	Mw	0.725	Mw	0.725
Cs	2933.640	Cs	2933.640	Cs	2933.640
Ms	5830.610	Ms	5830.610	Ms	5830.610
Mt	5831.335	Mt	5831.335	Mt	5831.335
Ms/Mt	0.9999	Ms/Mt	0.9999	Ms/Mt	0.9999

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

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
6	1155.08	3,534	385.03	385.03	385.03	1176.822	1176.822	1176.822	3.06	3.06	3.06

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):	2776	1st order decay coef. (k):	0.000250

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	3.06	2.897	2.895	0.01
2	6.11	2.895	2.892	0.02
3	9.17	2.892	2.889	0.03
5	15.28	2.887	2.884	0.04
7	21.40	2.882	2.879	0.06
9	27.51	2.877	2.874	0.08
12	36.68	2.869	2.866	0.10
15	45.85	2.862	2.859	0.13
20	61.13	2.849	2.846	0.17
25	76.41	2.836	2.834	0.21
30	91.69	2.824	2.821	0.25
40	122.26	2.799	2.796	0.33
50	152.82	2.774	2.771	0.42
70	213.95	2.725	2.723	0.59
90	275.08	2.677	2.675	0.75
120	366.78	2.607	2.604	1.00
150	458.47	2.539	2.536	1.26
180	550.16	2.472	2.469	1.51
210	641.86	2.407	2.405	1.76
250	764.12	2.323	2.321	2.09
320	978.07	2.183	2.181	2.68
450	1375.41	1.945	1.943	3.77
420	1283.72	1.998	1.996	3.51
418	1277.60	2.001	1.999	3.50
417	1274.55	2.003	2.001	3.49

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)

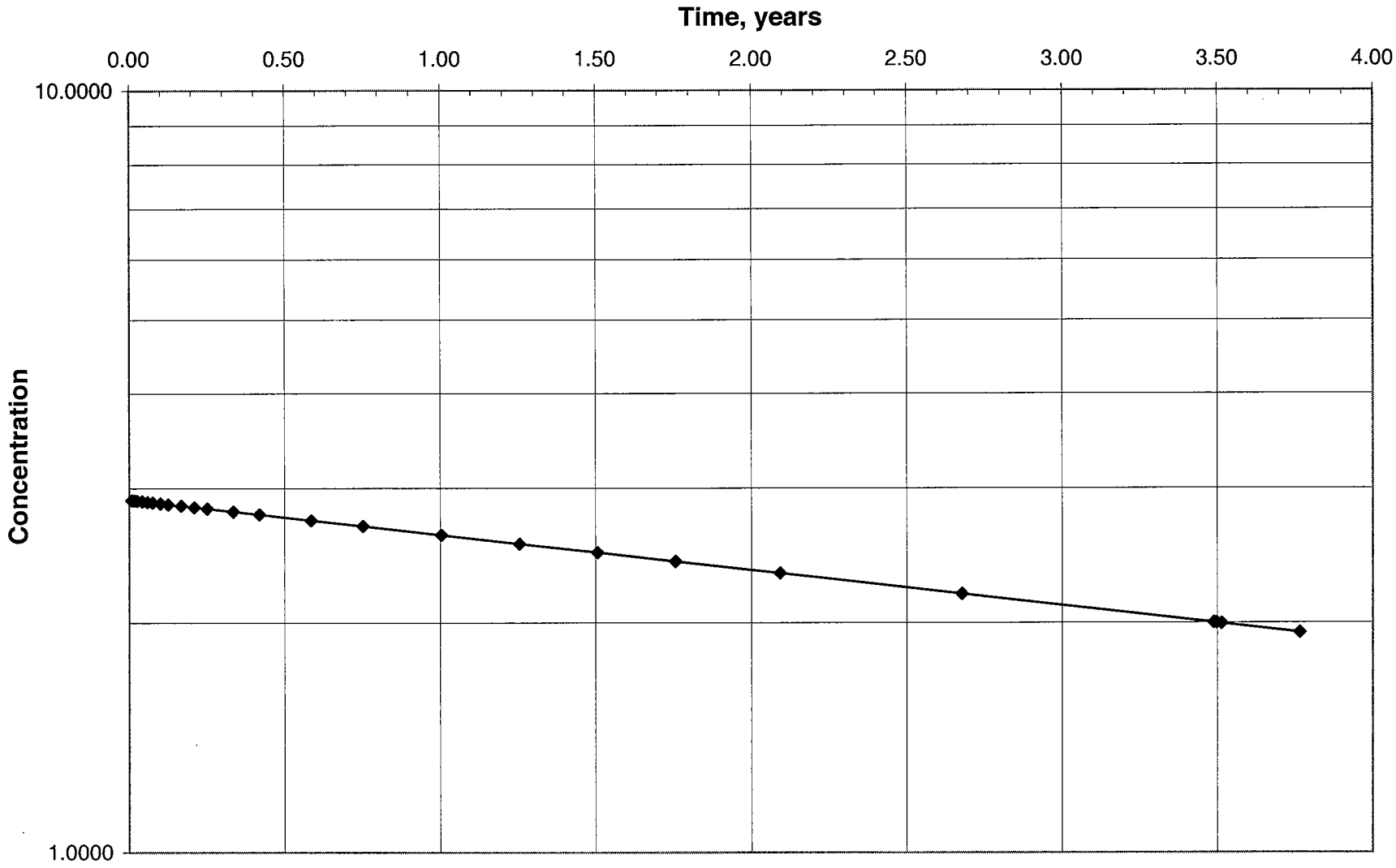
Number of pore volumes (PVs) required to reach target gw concentration Cw_x:

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 21	Proj. No.:	0039.DSO.11E220
Chemical :	Chlordane	Koc (Kd*) :	120000
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}	2.900	Cw_{0U2}	2.900	Cw_{0U3}	2.900
n	0.250	n	0.250	n	0.250
SG	2.650	SG	2.650	SG	2.650
foc*	0.0084	foc*	0.0084	foc*	0.0084
Kd	1011.600	Kd	1011.600	Kd	1011.600
Mw	0.725	Mw	0.725	Mw	0.725
Cs	2933.640	Cs	2933.640	Cs	2933.640
Ms	5830.610	Ms	5830.610	Ms	5830.610
Mt	5831.335	Mt	5831.335	Mt	5831.335
Ms/Mt	0.9999	Ms/Mt	0.9999	Ms/Mt	0.9999

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
$\mathbf{Cw_{n+1}} = [Cw_n](Ms_n/Mt_n)$

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	3,534	641.71	641.71	641.71	1176.822	1176.822	1176.822	1.83	1.83	1.83

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

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

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

Contaminant Half-Life Data

Does contaminant have a decay half-life (yes/no):	yes	If yes, give half-life (days):	2776	1st order decay coef. (k):	0.000250

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	1.83	2.898	2.895	0.01
2	3.67	2.897	2.894	0.01
3	5.50	2.895	2.892	0.02
5	9.17	2.892	2.889	0.03
7	12.84	2.888	2.885	0.04
9	16.50	2.885	2.882	0.05
12	22.01	2.880	2.877	0.06
15	27.51	2.875	2.872	0.08
20	36.68	2.866	2.864	0.10
25	45.85	2.858	2.855	0.13
30	55.02	2.850	2.847	0.15
40	73.36	2.833	2.830	0.20
50	91.69	2.817	2.814	0.25
70	128.37	2.784	2.781	0.35
90	165.05	2.752	2.749	0.45
120	220.07	2.704	2.702	0.60
150	275.08	2.658	2.655	0.75
180	330.10	2.612	2.609	0.90
210	385.11	2.566	2.564	1.05
250	458.47	2.507	2.505	1.26
400	733.55	2.298	2.295	2.01
600	1100.33	2.045	2.043	3.01
750	1375.41	1.874	1.872	3.77
650	1192.02	1.986	1.984	3.26
637	1168.18	2.002	2.000	3.20

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)

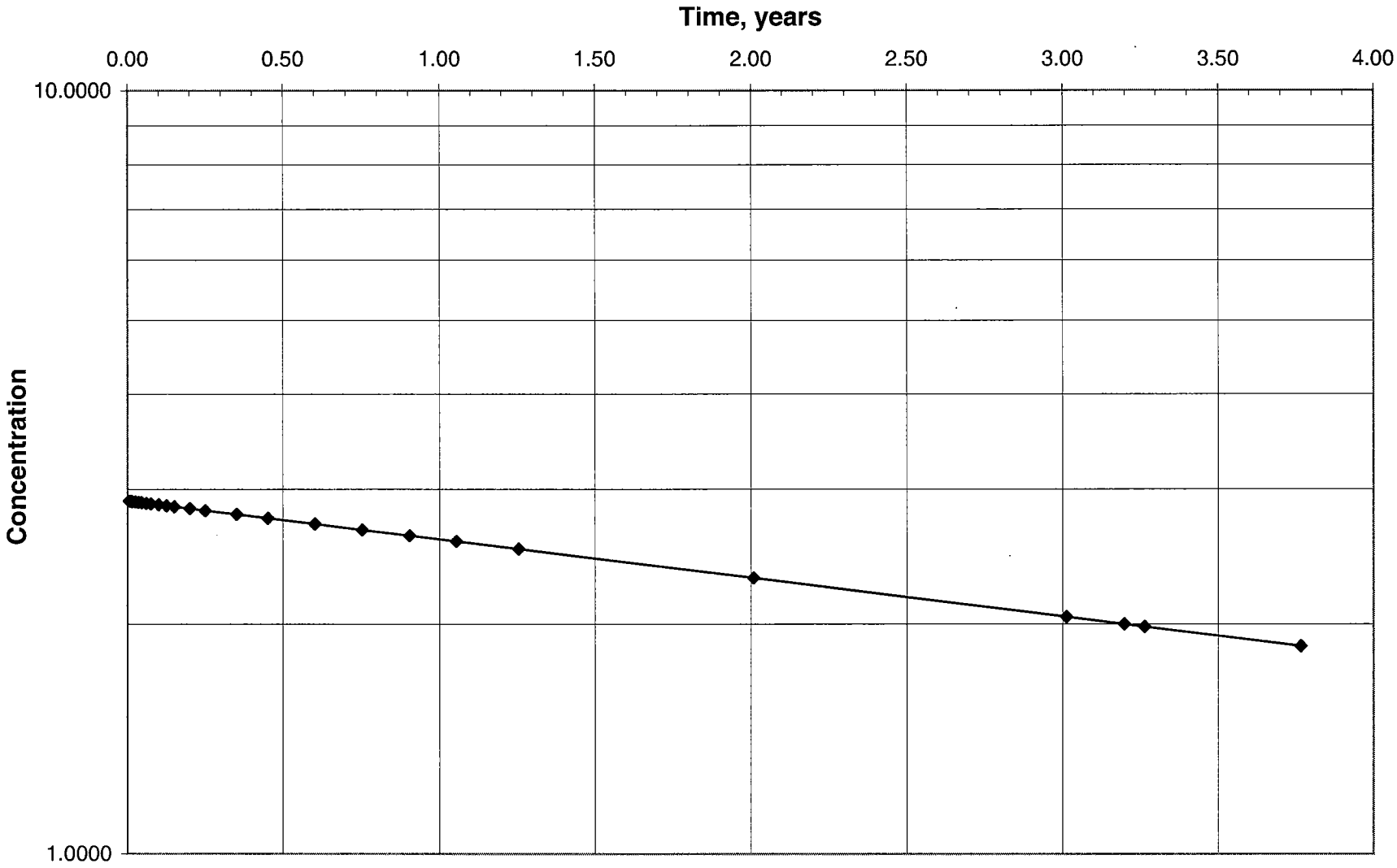
Number of pore volumes (PVs) required to reach target gw concentration Cw_x:

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



B.2 GROUNDWATER TREATMENT SYSTEM DESIGN

Tetra Tech NUS		CALCULATION SHEET	
CLIENT: USN SouthDiv CLEAN	FILE No: 0039-DSO-11E220	BY: GND	PAGE: 1 OF 3
SUBJECT: NAS Cecil Field Site 21 FS Groundwater Alternative 3: Pump-and-Treat		CHECKED BY: JLG	DATE: 2/5/2001

1.0 DESIGN ASSUMPTIONS

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

1 The only COC is total chlordane (sum of α-chlordane and γ-chlordane).
2 The contaminant plume where total chlordane concentrations exceed the PRG (2.0 μg/L) extends in a circular area approximately 30 feet in diameter and centered on well CEF-P21-GW-01S.
3 The depth to which total chlordane concentrations exceed PRGs extends to 15 feet bgs.

2.0 CONTAMINANT PLUME AREA AND VOLUME

Contaminant plume area, as shown on Figure 4-5: $\pi \times [(30)^2/4]$ = **706.87 ft^2**

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

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

$$706.87 \text{ ft}^2 \times 10 \text{ ft} \times 0.25 = 1{,}767 \text{ ft}^3$$

$$1{,}767 \text{ ft}^3 \times 7.48 \text{ gal / ft}^3 = \mathbf{13{,}218 \text{ gallons}}$$

3.0 TREATMENT SCHEME

Alternative 3 would consist of a "pump and treat" system that extracts and treats groundwater from the contaminant plume and features the following elements:

1 Groundwater extraction wells and pumps
2 Equalization
3 Filtration
4 Liquid-phase GAC adsorption
5 Surface Discharge

4.0 GROUNDWATER EXTRACTION WELLS AND PUMPS

As per calculations provided in Appendix A.1, the groundwater extraction system would consist of three wells (EW-1, EW-2, EW-3) screened in the shallow zone of the surficial aquifer (5-15 ft bgs), each pumping at the rate of 3.33 gpm for a total extraction rate of 10 gpm.

The three extraction wells would be located as shown on Figure 4-5. A 3.33 gpm @ 100 ft TDH (0.5 HP motor) multi-stage submersible centrifugal pump would be installed in each well.

5.0 EQUALIZATION

Provide equalization tank to blend groundwater from the three extraction wells. Tank would be equipped with a mixer and would be sized to provide 30 minutes of detention under design flow conditions.

Equalization tank volume: 10 gpm x 30 min = **300 gallons**

>>> Call for a 3.0-ft diameter 6 ft high equalization tank with a working capacity of 300 gallons. Tank to be of open top cylindrical configuration and manufactured of fiberglass with anti-vortex baffles.

Mixer size @ 0.5 HP / 1000 gal: 300 gallons x 0.5 HP / 1000 gal = 0.15, say **0.25 HP**

>>> Call for a rim mounted 0.25 HP high speed propeller-type mixer.

Pumps would be provided to transfer groundwater from the equalization tank to downstream treatment processes. Two transfer pumps should be provided, including an installed spare. Pump operation would be controlled by the liquid level in the equalization tank.

>>> Call for two (one spare) horizontal-centrifugal 10 gpm equalized groundwater transfer pumps (75 ft design TDH - 0.5 HP motor).

6.0 FILTRATION

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

Assuming approximately 5 mg/L of suspended solids in the untreated groundwater and estimating a 90% removal efficiency, particulate matter accumulation in a filter within a week would be:

10 gal/min x 1440 min/day x 7 day/wk x 8.34 lb/gal x (0.9 x 5) mg/L x 10^{-6} = **3.78 lb TSS per week**

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

4 lbs / 1.0 lbs/ft^2 = **4 ft^2**

>>> Call for one 10 gpm multi-bag pressurized filter unit with a total filter area of 4 ft^2

7.0 LIQUID-PHASE GRANULAR ACTIVATED CARBON ADSORPTION

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

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

Required GAC capacity per adsorption unit:

(10 gal/min x 5 min) / 7.48 gal/ft^3 = 6.68 ft^3 of GAC

density of GAC = 35 lb/ft^3, therefore (35 x 6.68) = 250 lb of GAC hydraulically required

Tetra Tech NUS		CALCULATION SHEET	
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The expected duration of each GAC adsorption unit is based on an assumed groundwater SOC concentration of up to 3 mg/L and an adsorption capacity of 0.1 lb of SOC per 1.0 lb of GAC.

Predicted daily GAC use:

(10 gal/min x 1440 min/day x 8.34 lb/gal x 3mg/L SOC x 10^{-6}) / (0.1 lb SOC/1.0 lb GAC) = **3.6 lb GAC/day**

GAC adsorption unit cycle duration = 250 lb GAC / 3.6 lb/day GAC = **69 days - somewhat low**

The next larger commercially available adsorption unit (Carbonair PC-5 or equivalent) holds 575 lbs of GAC

>>> Call for two (in series) adsorption units each holding 575 lb of GAC

Recompute GAC adsorption unit cycle duration = 575 lb GAC / 3.6 lb/day GAC = **160 days OK**

APPENDIX C

DETAILED COST ESTIMATES

C.1 ALTERNATIVE 2

C.2 ALTERNATIVE 3

C.1 ALTERNATIVE 2

NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA
SITE 21
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	
2 MOBILIZATION/DEMOBILIZATION AND FIELD SUPPORT												
2.1 Equipment Mobilization/Demobilization	1	ea			$45.50	$229.00	$0	$0	$46	$229	$275	
2.3 Professional Oversight (1p*1wk)	1	mwk			$1,200.00		$0	$0	$1,200	$0	$1,200	
3 DECONTAMINATION												
3.1 Temporary Decon Pad	1	ls		$500.00	$450.00	$155.00	$0	$500	$450	$155	$1,105	
3.2 PPE (3 p * 2 days)	6	day		$30.00			$0	$180	$0	$0	$180	
3.3 Disposal of Decon Waste (liquid & solid)	1	mo	$4,500.00				$4,500	$0	$0	$0	$4,500	
4 MONITORING WELLS												
4.1 Monitoring Well, 2" dia	15	lf	$30.00				$450	$0	$0	$0	$450	
4.2 Well Development	2	hour	$35.00				$70	$0	$0	$0	$70	
4.3 Collect/Containerize IDW	1	drum	$50.00				$50	$0	$0	$0	$50	
4.4 Transport/Dispose IDW Off Site	1	drum	$150.00				$150	$0	$0	$0	$150	
4.5 Survey Well Location	1	ls	$300.00				$300	$0	$0	$0	$300	
Subtotal							5520	680	5195.5	384	$11,780	
Local Area Adjustments							100.0%	123.0%	88.0%	88.0%		
Subtotal							$5,520	$836	$4,572	$338	$11,266	
Overhead on Labor Cost @ 30%									$1,372		$1,372	
G & A on Labor Cost @ 10%									$457		$457	
G & A on Material Cost @ 10%								$84			$84	
G & A on Subcontract Cost @ 10%							$552				$552	
Total Direct Cost							$6,072	$920	$6,401	$338	$13,731	
Indirects on Total Direct Cost @ 30%											$4,119	
Profit on Total Direct Cost @ 10%											$1,373	
Subtotal											$19,223	
Health & Safety Monitoring @ 2%											$384	
Total Field Cost											$19,608	
Contingency on Total Field Cost @ 20%											$3,922	
Engineering on Total Field Cost @ 15%											$2,941	
TOTAL COST											**$26,470**	

NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA
SITE 21
ALTERNATIVE 2: NATURAL ATTENUATION, INSTITUTIONAL CONTROLS, AND MONITORING
Annual Cost

Item	Item Cost Quarterly (1)	Item Cost Semi-Annually (2)	Item Cost Annually (3)	Item Cost Year 5	Notes
Sampling	$12,000	$6,000	$3,000		Labor, Mobilization/Demobilization, Field Supplies
Analysis/Water	$3,520	$1,760	$880		Analyze samples from 4 wells for pesticides including 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	$31,520	$15,760	$7,880	$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 21
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	$26,470		$26,470	1.000	$26,470
1		$31,520	$31,520	0.935	$29,471
2		$15,760	$15,760	0.873	$13,758
3		$15,760	$15,760	0.816	$12,860
4		$7,880	$7,880	0.763	$6,012
5		$13,380	$13,380	0.713	$9,540
				TOTAL PRESENT WORTH	$98,112

C.2 ALTERNATIVE 3

NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA
SITE 21
ALTERNATIVE 3: 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	51	lf	$35.00				$1,785	$0	$0	$0	$1,785	3 @ 17 ft
4.2 Well Development	18	hour	$35.00				$630	$0	$0	$0	$630	
4.3 Collect/Containerize IDW	9	drum	$50.00				$450	$0	$0	$0	$450	3 drums per well
4.4 Transport/Dispose IDW Off Site	9	drum	$150.00				$1,350	$0	$0	$0	$1,350	
4.5 Survey Well Locations	1	ls	$800.00				$800	$0	$0	$0	$800	
4.6 Extraction Pumps, 3.33 gpm (0.33 HP)	3	ea		$1,682.00	$250.00		$0	$5,046	$750	$0	$5,796	
4.7 Collection Piping, 3/4" PVC, buried	150	lf		$0.82	$9.74	$1.65	$0	$123	$1,461	$248	$1,832	
4.8 Vault Boxes and Misc. Piping/Valves at Well Head	3	ea		$399.50	$299.63		$0	$1,199	$899	$0	$2,097	
4.9 Instruments and Controls	1	ls		$143.00	$480.00		$0	$143	$480	$0	$623	
5 GROUNDWATER TREATMENT SYSTEM												
5.1 Building Foundation	300	sf	$3.89				$1,167	$0	$0	$0	$1,167	
5.2 Treatment System Building	300	sf	$11.03				$3,309	$0	$0	$0	$3,309	
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	
5.5 300 Gallon Fiberglass Equalization Tank	1	ea		$1,056.00	$60.00		$0	$1,056	$60	$0	$1,116	
5.6 Mixer, Propeller-Type (0.25 HP)	1	ea		$1,103.00	$30.00		$0	$1,103	$30	$0	$1,133	
5.7 Centrifugal Transfer Pumps, 10 gpm (0.5 HP)	2	ea		$616.45	$189.21		$0	$1,233	$378	$0	$1,611	
5.8 Bag Filter, 10 gpm dual-element, 25-micron	1	ea		$3,500.00	$800.00		$0	$3,500	$800	$0	$4,300	
5.9 GAC Canister Unit (575 lb each)	2	ea		$4,545.00	$210.35	$70.45	$0	$9,090	$421	$141	$9,652	
5.10 Instruments and Controls	1	ls		$5,000.00	$2,000.00		$0	$5,000	$2,000	$0	$7,000	
5.11 Plumb/Electrify System	1	ls		$500.00	$1,150.00		$0	$500	$1,150	$0	$1,650	1 plumber, 1 electrician
5.12 System Start-up and Testing	1	ls		$50.00	$1,700.00		$0	$50	$1,700	$0	$1,750	
6 SURFACE DISCHARGE												
6.1 Discharge Piping, 2" PVC, buried	200	ft		$1.41	$8.02	$1.50	$0	$282	$1,604	$300	$2,186	
7 INSTITUTIONAL CONTROLS												
7.1 Prepare Deed Restrictions	100	hour			$35.00		$0	$0	$3,500	$0	$3,500	
8 SITE RESTORATION												
8.1 Vegetate Disturbed Areas	1	ls		$250.00	$400.00		$0	$250	$400	$0	$650	
Subtotal							$56,886	$36,074	$99,529	$1,382	$193,871	
Local Area Adjustments							100.0%	123.0%	88.0%	88.0%		
Subtotal							$56,886	$44,372	$87,585	$1,217	$190,059	
Overhead on Labor Cost @ 30%									$26,276		$26,276	
G & A on Labor Cost @ 10%									$8,759		$8,759	
G & A on Material Cost @ 10%								$4,437			$4,437	
G & A on Subcontract Cost @ 10%							$5,689				$5,689	
Total Direct Cost							$62,575	$48,809	$122,619	$1,217	$235,219	
Indirects on Total Direct Cost @ 30%											$70,566	

NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA
SITE 21
ALTERNATIVE 3: 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
Profit on Total Direct Cost @ 10%											$23,522	
Subtotal											$329,306	
Health & Safety Monitoring @ 2%											$6,586	
Total Field Cost											$335,893	
Contingency on Total Field Cost @ 20%											$67,179	
Engineering on Total Field Cost @ 15%											$50,384	
TOTAL COST											**$453,455**	

NAVAL AIR STATION CECIL FIELD
JACKSONVILLE, FLORIDA
SITE 21
ALTERNATIVE 3: 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	27,765	kWh	$0.06	$1,666	
2	Maintenance	1	ls	$1,757.99	$1,758	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				$76,434	

* Operate and maintain system for 4 years

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JACKSONVILLE, FLORIDA
SITE 21
ALTERNATIVE 3: 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 Year 5	Notes
Sampling	$12,000	$6,000	$3,000		Labor, Mobilization/Demobilization, Field Supplies
Analysis/Water	$3,520	$1,760	$880		Analyze samples from 4 wells for pesticides including 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	$31,520	$15,760	$7,880	$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.

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Present Worth Analysis

Year	Capital Cost	Operation and Maintenance Cost	Annual Cost	Total Year Cost	Annual Discount Rate at 7%	Present Worth
0	$453,455			$453,455	1.000	$453,455
1		$76,434	$31,520	$107,954	0.935	$100,937
2		$76,434	$15,760	$92,194	0.873	$80,485
3		$76,434	$15,760	$92,194	0.816	$75,230
4		$76,434	$7,880	$84,314	0.763	$64,331
5		$0	$13,380	$13,380	0.713	$9,540
					TOTAL PRESENT WORTH	$783,979