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FEASIBILITY STUDY REPORT
OPERABLE UNIT 2
NAS PENSACOLA
PENSACOLA, FLORIDA

SOUTHNAVFACENGCOM
Contract Number: N62467-89-D-0318
CTO-059

VOLUME 1 OF 2
SECTIONS 1 - 6

Prepared for:

Comprehensive Long-Term Environmental Action Navy (CLEAN)
Naval Air Station Pensacola
Pensacola, Florida

Prepared by:

EnSafe Inc.
5724 Summer Trees Drive
Memphis, Tennessee 38134
(901) 372-7962
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December 14, 2005

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Naval Facilities Engineering Command
SOUTHERN DIVISION

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The Contractor, EnSafe Inc., hereby certifies that, to the best of its knowledge and belief, the technical data delivered herewith under Contract No. N62467-89-D-0318 are complete, accurate, and complies with all requirements of the contract.

Date:	December 14, 2005
Signature:	Allison Harris
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EXECUTIVE SUMMARY
FEASIBILITY STUDY FOR OPERABLE UNIT 2

This Feasibility Study (FS) develops, evaluates, and compares remedial action alternatives (RAAs) that may be used to mitigate hazards and threats to human health and the environment resulting from soil and groundwater contamination at Operable Unit 2 (OU 2) at Naval Air Station (NAS) Pensacola. OU 2 is comprised of Sites 11, 12, 25, 26, 27, and 30. Remedial investigations of OU 2 are reported in the *Remedial Investigation Report* (EnSafe, 1997) and the *Remedial Investigation Report Addendum* (EnSafe, 2003). An initial FS was prepared based on the results of the initial remedial investigation (RI) and is reported in the *Feasibility Study Report* (EnSafe, 1999). This FS is prepared to revise the 1999 FS considering additional information reported in the 2003 RI Addendum and revised remedial standards.

The nature and extent of contamination at OU 2 is defined by the remedial goals for the site, which are defined by Chapter 62-777, FAC (Contaminant Cleanup Target Levels). The characterized media includes surface soil (0 to 2 ft below grade level [bgl]), subsurface soil (2 ft bgl to water table), groundwater, and groundwater discharging to surface water. RI data were initially collected in 1993 and supplemental groundwater data was collected 1995. In 2003, the subsurface soil and groundwater were comprehensively assessed to determine the current status of contamination. Therefore, 1993 data were used to define the nature and extent of surface soil contamination, whereas 2003 data were used to define the nature and extent of subsurface soil and groundwater contamination. The media-specific and contaminant-specific remedial volumes are calculated based on the cleanup target level (CTL) exceedances.

Media-specific RAAs are developed on a site-wide basis for OU 2. Although there is presumptive interaction between the soil and groundwater media, separate media-specific RAAs are developed because they principally address different receptors. Site-wide RAAs are developed because remedial actions would presumably be performed concurrently for Sites 11, 12, 25, 26, 27, and 30, and contamination is similar. The assembled alternatives may contain multiple treatment technologies. As stated in OSWER Directive 9355.3-01, the assembled alternatives should preferably include a no-action alternative, one or more containment alternatives, one or more treatment alternatives, and a removal alternative.

The RAAs developed for soil contamination include:

- No Action
- Land Use Controls

- Soil and Asphalt Capping
- Phytoremediation Covers and Asphalt Capping
- Excavation and Offsite Disposal

The RAAs developed for groundwater contamination include:

- No Action
- Land Use Controls
- Monitored Natural Attenuation
- Riparian Corridors
- Permeable Reactive Barrier and Riparian Corridors
- Groundwater Pumping and Discharge to FOTW
- Groundwater, Pumping, Treatment, and Discharge to Wetlands

A detailed analysis was performed by evaluating the RAAs using the nine criteria stipulated in the NCP (40 CFR §300.430) and OSWER Directive Number 9355.3-01. The detailed analysis and presentation of pertinent information permits decision-makers to adequately compare the alternatives, select an appropriate site remedy, and satisfy the CERCLA remedy selection requirements in the Record of Decision. The comparative analyses of the media-specific RAAs are summarized in Tables 8-1 and 8-2 of this report.

List of Abbreviations

µg/L	micrograms per liter
µg/kg	micrograms per kilogram
1,2-DCA	1,2-dichloroethane
1,2-DCE	1,2-dichloroethene, 1,2-dichloroethylene
ABB	ABB Environmental Services, Inc.
ACL	alternate concentration level
ARAR	applicable or relevant and appropriate requirement
BEHP	bis(2-ethylhexyl)phthalate
BEQ	benzo(a)pyrene equivalent
bgl	below grade level
BRA	baseline risk assessment
BRAC	base realignment and closure
BTEX	benzene, toluene, ethylbenzene, and xylene
CAMU	corrective action management unit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
CG	cleanup goal
C/I	commercial/industrial
CLEAN	Comprehensive Long-Term Environmental Action Navy
CLP	Contract Laboratory Program
cm/sec	centimeter per second
COPC	chemical of potential concern
Cr(VI)	hexavalent chromium
CTL	cleanup target level
CWA	Clean Water Act
CY	cubic yard
DRMO	Defense Reutilization and Marketing Office
E/A&H	EnSafe/Allen & Hoshall
E&E	Ecology & Environment
FS	feasibility study
FAC	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FGGC	Florida groundwater guidance concentration
FOTW	federally owned treatment works
FPDWS	Florida primary drinking water standard
FR	Federal Register
FSDWS	Florida secondary drinking water standard
FSWQ	freshwater surface water quality criteria
ft^2	square feet
ft/day	feet per day

GAC	granular activated carbon
GCTL	groundwater cleanup target level
G&M	Geraghty & Miller, Inc.
gpd	gallon per day
gpm	gallon per minute
HDPE	high density polyethylene
IAS	initial assessment study
IRP	Installation Restoration Program
ISCTL	industrial soil cleanup target level
IWTP	industrial wastewater treatment plant
LDR	land disposal restriction
LUCA	land use control agreement
MCLG	maximum contaminant level goal
MCL	maximum contaminant level
MEK	methyl ethyl ketone
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MNA	monitored natural attenuation
msl	mean sea level
MSWQ	marine surface water quality criteria
NADEP	Naval Aviation Depot
NAS	Naval Air Station
NCP	National Oil and Hazardous Substances Contingency Plan
NEESA	Naval Environmental and Engineering Support Activity
NFESC	Naval Facilities Engineering Service Center
NPDES	National Pollutant Discharge Elimination System
O&M	operation & maintenance
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
OU 2	Operable Unit 2 (Sites 11, 12, 25, 26, 27, and 30)
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethene, tetrachloroethylene
PPE	personal protective equipment
ppm	parts per million
PQG	poor quality groundwater
PRB	permeable reactive barrier
PRG	preliminary remediation goal
PWC	Public Works Center
RAA	remedial action alternative
RACER	Remedial Action Cost Engineering and Requirements system software

RAO	remedial action objective
RASO	Radiological Affairs Support Office
RBC	risk based criteria
RCRA	Resource Conservation and Recovery Act
RC	reference concentration
RD	Remedial design
RG	remedial goal
RI	remedial investigation
ROD	Record of Decision
RSCTL	residential soil cleanup target level
SARA	Superfund Amendments and Reauthorization Act
SCTL	soil cleanup target level
SDWA	Safe Drinking Water Act
SEGS	Southeastern Geological Society
SL-PQG	soil leaching criteria protective of poor quality groundwater
SL-SW	soil leaching criteria protective of surface water
SMCL	secondary maximum contaminant level
SQAG	sediment quality assessment guideline
S/S	solidification/stabilization
SSL	soil screening level
SSV	sediment screening value
SVE	soil vapor extraction
SVOC	semivolatile organic compound
TAL	target analyte list
TCE	trichloroethene, trichloroethylene
TCLP	toxicity characteristic leaching procedure
TEL	threshold effect level
TRPH	total recoverable petroleum hydrocarbons
UIC	underground injection control
UPB	unit price book
USDOT	U.S. Department of Transportation
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UST	underground storage tank
UTS	universal treatment standard
VC	vinyl chloride
VOC	volatile organic compound
yd^2	square yard
ZVI	zero-valent iron

1.0 INTRODUCTION

1.1 Report Purpose

This feasibility study (FS) develops, evaluates, and compares remedial action alternatives (RAAs) that may be used to mitigate hazards and threats to human health and the environment resulting from soil and groundwater contamination at Operable Unit 2 (OU 2) at Naval Air Station (NAS) Pensacola. OU 2 is comprised of Sites 11, 12, 25, 26, 27, and 30. Remedial investigations of OU 2 are reported in the *Remedial Investigation Report Operable Unit 2* (EnSafe, 1997) and the *Remedial Investigation Report Addendum Operable Unit 2* (EnSafe, 2004).

1.2 Report Organization

This FS is prepared pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and the Superfund Amendments and Reauthorization Act (SARA) of 1986. This report is organized as outlined in the Office of Solid Waste and Emergency Response (OSWER) Directive 9355.3-01, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA, October 1988). The FS is organized as follows:

- **Section 1 — Introduction:** Discusses the purpose and organization of the FS.

- **Section 2 — Site Description:** Describes OU 2 sites and discusses their operational and investigative history, and summarizes the nature and extent of contamination.

- **Section 3 — Feasibility Study Process:** Describes the regulatory process for conducting an FS. Remedial action objectives (RAOs) are developed using characterization and assessments made in the RI and by considering applicable or relevant and appropriate requirements (ARARs), which are presented in Appendix A.

- **Section 4 — Nature and Extent of Contamination:** Identifies the areas requiring analysis, based on the RAOs. Media-specific remedial goal exceedances are identified and the volumes and/or areas requiring remedial action are estimated.

- **Section 5 — Technology Screening:** Identifies potential remedial technologies and provides a cursory evaluation based on the criteria of effectiveness, implementability, and cost. Inappropriate technologies are removed from further consideration, and several technologies are retained for the assembly of RAAs.

- **Section 6 — Assembly of Alternatives:** Assembles the retained technologies into media-specific RAAs for OU 2. RAAs are evaluated on the criteria of implementability, effectiveness, and cost.

- **Section 7 — Detailed Analysis of Alternatives:** Evaluates the individual alternatives according to the nine evaluation criteria identified in OSWER Directive 9355.3-01 (USEPA, October 1988).

- **Section 8 — Comparative Analysis of Alternatives:** Compares performance of alternatives, presenting strengths and weaknesses to prioritize the alternatives according to the nine evaluation criteria.

2.0 SITE DESCRIPTION

The *Remedial Investigation Report Operable Unit 2* (EnSafe, 1997) and *Remedial Investigation Report Addendum Operable Unit 2* (EnSafe, 2004) provide a comprehensive description, the site characterization, and the baseline risk assessment (BRA) of OU 2. In this FS, this section summarizes the OU 2 site descriptions, investigative history, nature and extent of contamination, and BRA. In Section 4, the nature and extent of contamination is defined in terms of the remedial goals.

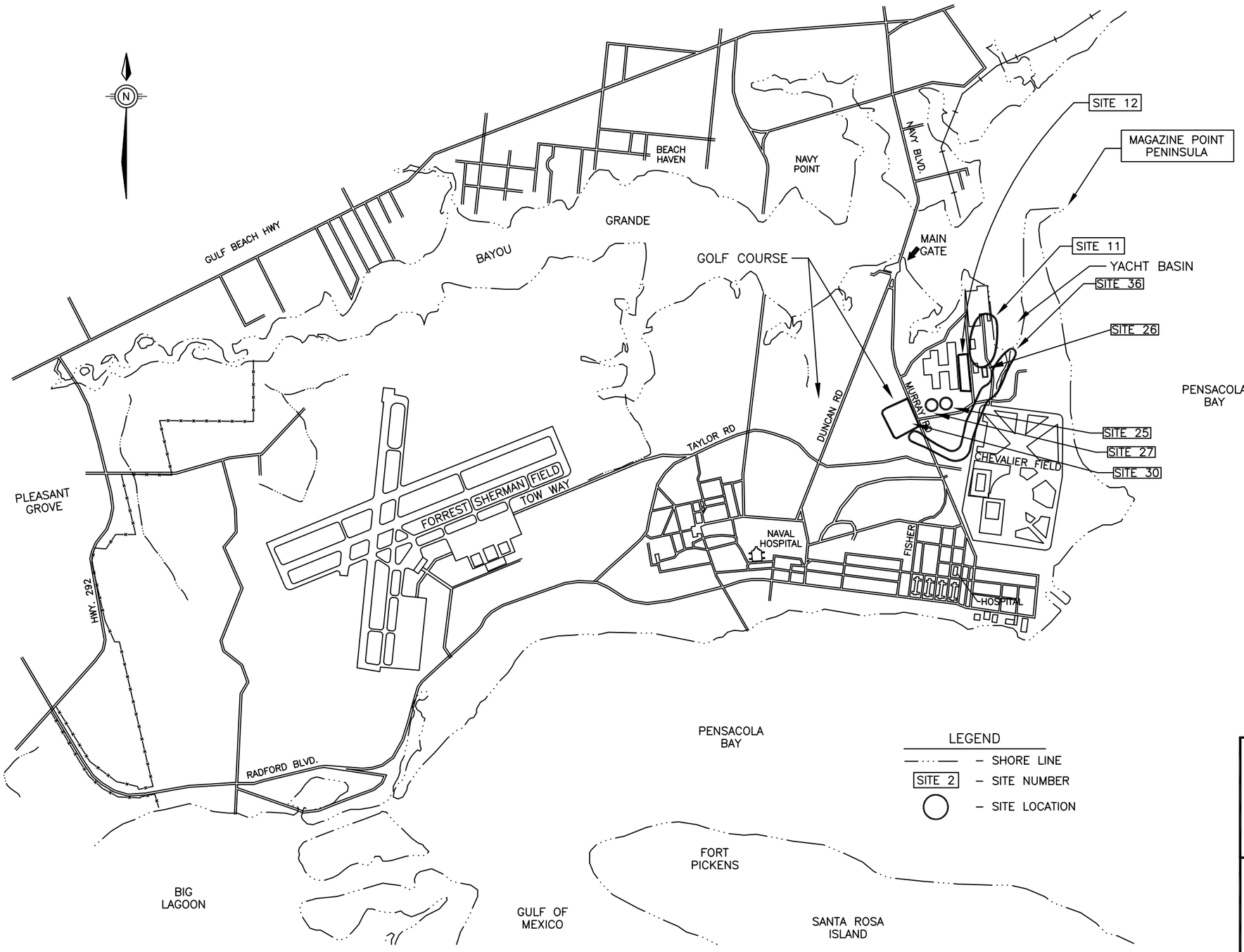
2.1 Site Descriptions and History

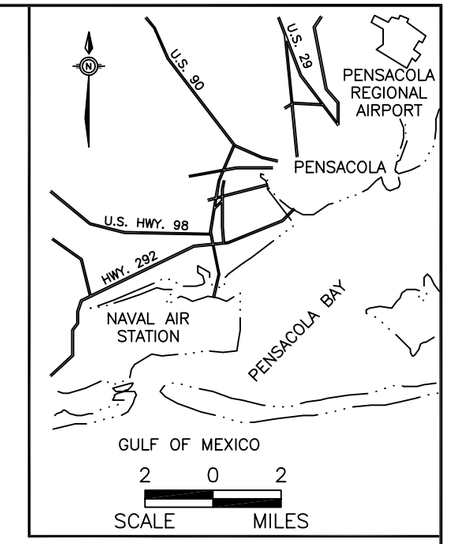
OU 2 (Sites 11, 12, 25, 26, 27, and 30) is in the northeast portion of NAS Pensacola as shown in Figure 2-1 and Figure 2-2. These sites were grouped together as an operable unit because they are near each other within the same watershed. OU 2 extends from the western edge of the golf course east to the Yacht Basin.

2.1.1 Site 11 — North Chevalier Field Disposal Area

The North Chavalier Field Disposal Area, Site 11, is a former landfill where industrial and municipal wastes were disposed and burned from the late 1930s to the mid-1940s. The area occupies approximately 20 acres southwest of an extension of Bayou Grande called the Yacht Basin. Surface elevations on the site are approximately 5 feet above mean sea level (msl), and topography slopes gently eastward toward Bayou Grande. Two prefabricated buildings — Buildings 3627 and 3628 — are near the center of the site. Building 3445, at the site's southeastern corner, is used to store outdated office equipment. A fenced area north and south of Buildings 3445 is used for outside storage of boats, trucks, and heavy equipment. Pat Bellinger Road runs north-south through the center of Site 11.

According to the initial assessment study (IAS) conducted by the Naval Facilities Engineering Service Center (NFESC), this landfill was used to burn refuse through the mid-1940s. During this time, it received combustibles such as fuels, solvents, and waste oil from aircraft engine overhauls. During landfill operations from the early 1930s to the 1940s, approximately 24 cubic yards (CYs) of material





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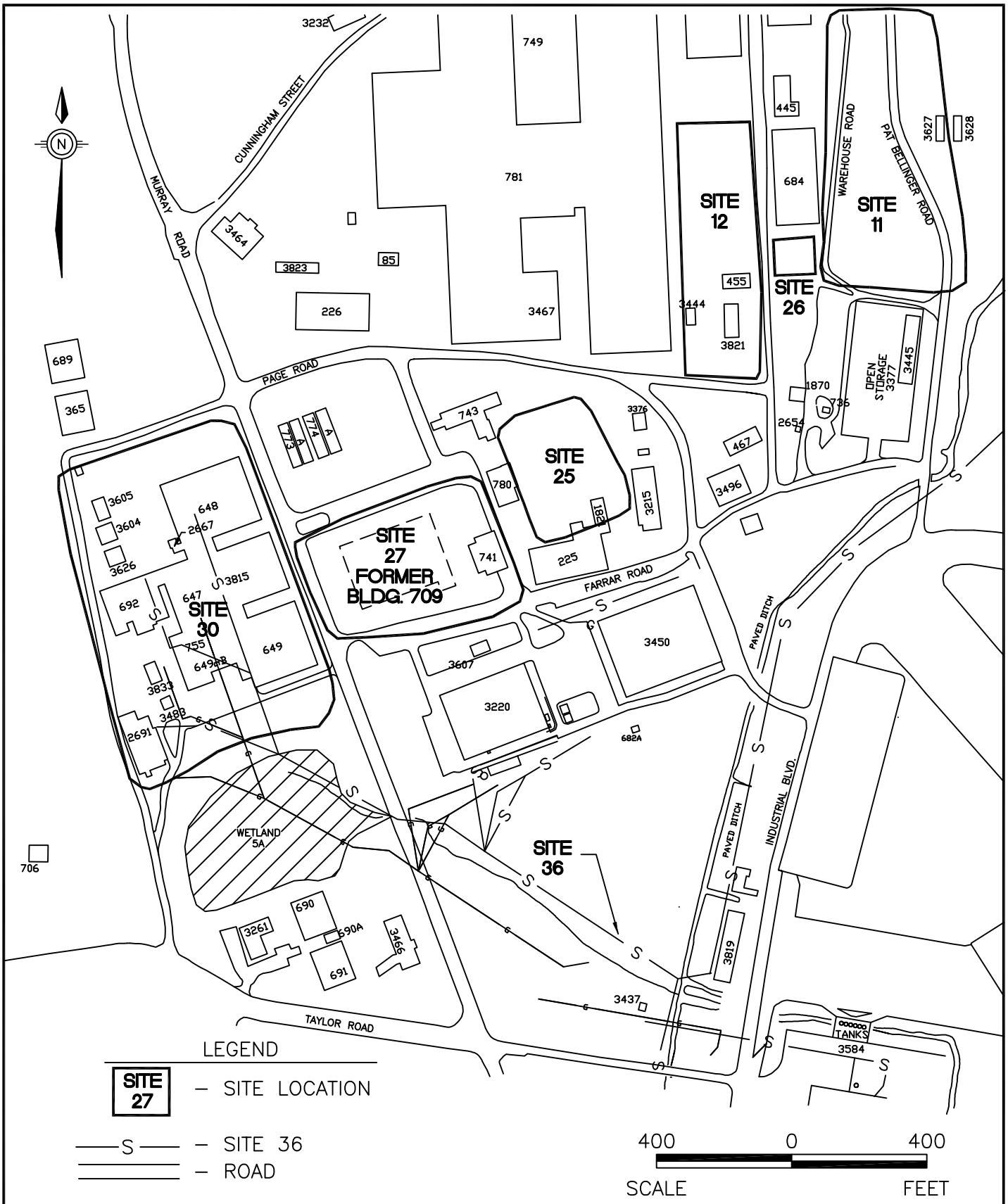
FEASIBILITY STUDY
OPERABLE UNIT 2
NAS PENSACOLA
PENSACOLA, FLORIDA

FIGURE 2–1
SITE LOCATION MAP

DWG DATE: 11/19/04 | NAME: 0059001W089



LEGEND

SITE 27 – SITE LOCATION

—S— – SITE 36

– ROAD

400 0 400

SCALE FEET

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PENSACOLA, FLORIDA

FIGURE 2–2
SITE AREA MAP

DWG DATE: 11/18/04 | NAME: 0059001W088

were disposed of daily from several NAS Pensacola locations. During this time, an unknown number of 55-gallon drums of unknown contents was observed. Until the 1950s, oil slicks were noted during heavy rains in the Yacht Basin (Naval Environmental and Engineering Support Activity, [NEESA], 1983).

2.1.2 Site 12 — Scrap Bins

Site 12 is currently referred to as the Defense Reutilization and Marketing Office (DRMO) Recyclable Materials Center and used to store scrap metal. The site is approximately 800 feet northwest of former Chevalier Field and immediately west and upgradient of Site 26. Most of the site area is enclosed by a chain-link fence and covered with a large concrete pad where heavy equipment is stored. Surface elevations average 15 to 18 feet above msl, and the terrain is relatively flat. The limited exposed surface soil is sandy and well drained. Buildings 455 and 3821 are in the southern portion of the site. Building 455 houses an office, break area, and storage warehouse, whereas Building 3821 is a storage warehouse.

From the early 1930s to the 1940s, garbage was stored at Site 12 in an area known as "Pig Sty Hill" near Building 455. Approximately 16 CYs (two truckloads) per day of wet garbage were stored here before being hauled off for livestock feed. The site has since been used as a scrap metals storage area (NEESA, 1983).

2.1.3 Site 25 — Radium Spill Area

The approximately 50-foot x 50-foot concrete-paved area is on the eastern portion of NAS Pensacola, immediately east of Murray Road and north of Farrar Road. The site includes an area east of the radium decontamination building (Building 780) where the radium spill is reported to have occurred. A former helicopter scrap yard approximately 25 feet east of Building 780 is currently used as a parking area for Navy Exchange semi-trailers. The fenced yard is unpaved and covered with interlocking, perforated metal sheets. Building 780 currently houses the Joint Oil Analysis Laboratory, which is used for quality assurance analysis of oil from aircraft and vehicles. The site is flat with land surface elevations averaging approximately 22 to 25 feet above msl. Where exposed, site surface soil is sandy and well drained.

Building 780 was constructed in 1951 to house the oxygen and carbon dioxide shops. In approximately 1975, a radium decontamination operation was added. Radium wastes from this operation were stored in a drum onsite before being disposed. In 1978 a spill occurred in the storage area between Building 780 and the scrap yard. Approximately 25 gallons of low-level radium paint waste spilled from a ruptured, eroded drum onto the underlying concrete floor (NEESA, 1983). The waste was reportedly cleaned up, placed in a secure container, and sent to a proper disposal site. The exact location of the spill, the details of the cleanup operation, and whether the waste reached unpaved soil were not determined from the existing records (Ecology and Environment [E&E], 1992a).

2.1.4 Site 26 — Supply Department Outside Storage Area

The Supply Department Outside Storage Area, Site 26, is northwest of former Chevalier Field and immediately south of Building 684. The approximately 150-foot x 200-foot area houses an open metal shed near a former chemical storage building. DRMO uses this area to store paints, fuels, and solvents. Site access is limited by an 8-foot chain-link fence surrounding the storage area. The concrete pavement inside the fence is bordered by sandy soil and mowed grass. Site 26 is bounded on the west by a paved road and on the east by a wooded area (Site 11). The site gently slopes eastward to a topographic break where elevations abruptly drop to approximately 5 feet above msl.

From 1956 until 1964, the supply department used Site 26 to store incoming paint strippers and acids. Containers of these materials placed outside on steel matting sometimes leaked, discharging the materials onto the ground (Geraghty & Miller [G&M], 1984).

2.1.5 Site 27 — Radium Dial Shop Sewer

The Radium Dial Shop Sewer extends through the remaining concrete foundation of Building 709, which is currently a parking lot. The building foundation is 2 to 4 feet above the surrounding area. Beyond the building formation, the sewer easement is unpaved. The site is approximately 150 feet west of Building 780 (Site 25) and bounded by Farrar and Murray roads on the south and west, respectively. An adjacent parking lot north of the building foundation is asphalt paved, and a gravel and shell parking lot is northeast of the foundation. All area roads are paved with either concrete or asphalt. Originally, the site consisted of a small radium dial shop in former Building 709 with a

connection to the sanitary sewer. However, recent investigations have associated additional areas of contamination with the site, expanding the area of investigation to approximately 6 acres.

Building 709, constructed in 1941, was used for several operations, including carburetor repair, propeller repair, painting and maintenance, various instrument shops (including a radium paint room), and a plating shop (E&E, 1992b). In 1949, a small shop in Building 709 was used to rework luminous instrument dials. Worn and damaged instruments were returned to this shop to be stripped and repainted. From 1941 to 1965, the stripping procedure required soaking the instruments in benzene, scraping them in a benzene or water bath, or dry scraping and painting them under a ventilation hood. After 1965, the procedure switched to scanning the instruments for radium, then stripping them with paint stripper and a lye-nitric acid solution. Contaminated instrument cases were soaked in another acid solution called "Turco" then scrubbed with a wire brush (NEESA, 1983).

Building 709 also housed a large plating operation from 1941 to approximately 1970. The operation involved the use of 50 solution tanks ranging from 50 to 3,865 gallons in capacity (E&E, 1992b).

A routine disposal operation in Building 709 involved washing spent cleaning solutions and luminous paint down the drains into the sanitary sewer. The disposed wastes from this location included cleaning solutions containing benzene, white pigments, phosphorus, radium, and small amounts of acidic or caustic solutions. Plating wastes from Building 709 and shops in Building 604 and 649/755 were periodically dumped through drains into the sanitary sewer. Most of the building drains connected to a single line draining into the sanitary sewer line. From 1941 to 1948, all wastes from Building 709 were discharged directly into Pensacola Bay. From 1941 to 1962, concentrated cyanide wastes from Building 709 were periodically dumped into the sanitary sewer. After 1962, the cyanide was drummed and disposed 15 miles offshore in the Gulf of Mexico although small quantities of cyanide continued to be discharged into the sewer. Plating operations ceased in Building 709 in 1970 or 1973 (NEESA, 1983). Building 709 has been removed, and the old building floor is used as a parking lot.

2.1.6 Site 30 — Complex of Industrial Buildings and IWTP Sewer Line

The approximate 35-acre site houses a complex of industrial buildings — known as the Building 649 complex (interconnected Buildings 647, 648, 649, 692, 755, 3815, and several smaller separate, associated buildings). Housing the Dynamic Component Division of the former Naval Aviation Depot (NADEP), several aircraft component repair functions were carried out here. Operations in this complex began in the 1940s and continued until NADEP closed. Also included in the Site 30 investigation were the areas surrounding Buildings 3220 and 3450, former NADEP buildings where aircraft electronics were repaired. The Site 30 investigation also included a portion of the industrial wastewater treatment plant (IWTP) sewer line from the Building 649 complex to the wastewater treatment plant. The portions of the sewer investigated with Site 30 include those associated with Sites 25, 27, and 30, and downstream segments. The portions include the segment extending from the Building 649 complex, the feeder line from Building 3220, and the main line running to the IWTP.

Aircraft and parts were painted in booths in the Building 649 complex beginning in 1940. The paints used at NAS Pensacola were cellulose nitrate lacquer, zinc chromate, nitrate dope, acetate dope, "day glow," epoxy, and enamel. Thinners used were lacquer thinner, toluene, and M-T-6096 (NEESA, 1983).

A tin-cadmium plating shop operated in the Building 649 complex from the mid-1940s to the early 1960s. At this time, it was replaced by a magnesium treatment line, which operated until the early 1970s. Near Building 649, 15 tanks ranging in capacity from 200 to 500 gallons contained solutions of tin, cadmium, and cyanide. Additionally, a 250-gallon tank stored trichloroethene (TCE) (NEESA, 1983), and a 500-gallon underground storage tank (UST) on Building 649's north end stored waste oil (Graham, 1993, personal communication). The contents were drained periodically into a "ditch" east of the buildings. Based on current topography and historical data, this "ditch" was either Wetland 5A or a topographical low draining into it. When the tin-cadmium operation was replaced by a magnesium treatment line in the early 1970s, the 15 tanks near Building 649 were then used to store acids, caustics, degreasers, chromate solutions, and potassium permanganate (NEESA, 1983).

In the summer of 1994 as part of an interim removal action, the Public Works Center (PWC) removed an aircraft engine shipping container from Wetland 5A immediately southeast of Building 649. The shipping container had been used as an oil-water separator. Wetland 5A was sampled under the Site 41 investigation. A second plating shop in Building 755 was used from the early 1960s until the early 1970s. Fifty tanks ranging in capacity from 50 to 200 gallons contained metal plating solutions, including nickel, chromium, silver, lead, and tin (NEESA, 1983).

Concentrated cyanide wastes generated in Buildings 649 and 755 were disposed in the same manner as Building 709's cyanide waste. Disposal involved discharging the wastes down the sewer from 1941 to 1962, discarding drummed waste in the gulf after 1962. Overflow discharged into the sewer (NEESA, 1983).

An empty fiberglass UST mounted in concrete is still near Building 692's southeast corner. Installed in 1986, this tank stored JP-1/JP-5 (jet fuel) calibration fluid for use in Building 692. The fiberglass tank replaced an older steel tank also used to store calibration fluid. The older tank had at least one undocumented spill. A UST along the west side of Building 692 supplied Building 755 with methyl ethyl ketone (MEK) via underground pipes. Several other USTs were along the entire north side of Building 692; their exact contents are unknown. Some of the storage tanks may have contained chromium wastes (Graham, 1993, personal communication).

In 1973, minor painting operations began in Building 3450 (NEESA, 1983). Several 1,000-gallon USTs along the south wall of Building 3450 were reportedly used to store gasoline (ABB Environmental Services, Inc. [ABB], 1993).

Several tanks near Building 3220 included a diesel UST near the southeast corner, a waste oil UST on the south wall, and a series of USTs approximately 50 feet south of the waste oil tank (ABB, 1993).

The wastewater treatment plant, originally built in 1948, was replaced in 1971 with a modern plant that could accept industrial wastes. Most facilities discharging to the sewer did so without any pretreatment or waste segregation. The waste stream has included paint strippers, heavy metals, pesticides, radioactive wastes, fuels, cyanide waste, and waste oil (NEESA, 1983).

Beginning in 1973, the Naval Air Rework Facility operations discharged to the sewer instead of to Pensacola Bay. The IWTP sewer line consisted of vitreous clay and cast-iron piping installed both before and after 1971.

2.2 Previous Investigations

The section summarizes events and investigations relevant for the OU 2 sites.

1976 — Radiation Survey/Removal: According to NEESA accounts, the Radiological Affairs Support Office (RASO) conducted an investigation of radium contamination in the drain lines at the demolished Building 709 area (Site 27). Portions of the drain pipe, linoleum floor, walls, and wood flooring within the dial plating shop were identified as radioactive. The contaminated drain pipe was excavated to a depth of 18 inches, and the remaining area was capped and abandoned.

1983 — Initial Assessment Study: The IAS involved review of historical documents and aerial photographs, interviews, and site inspections. Although 29 sites were identified as having possible contamination, none were thought to have an immediate risk to human health or the environment. Sediment samples were taken from Bayou Grande near Site 11, and metals were detected above toxicity levels. The IAS recommended seven sites, including Sites 11 and 27, for a confirmation study of the suspected contaminants (NEESA, 1983).

1984 — Verification Study: As a follow-up to NEESA's report, G&M installed several monitoring wells and piezometers throughout NAS Pensacola, involving all the OU 2 sites except for Sites 12 and 25. At Site 11, volatile organic compounds (VOCs) were detected and additional wells were recommended. Samples from one drilled well at Site 27 detected gross alpha below drinking standards and chlorinated hydrocarbons. Additional wells were recommended. A well was drilled north of Building 648, next to Site 30 at former Site 31. Low concentrations of VOCs were detected. Sediment samples collected from a presumed "ditch" at Site 30 contained concentrations of cadmium, magnesium, and copper (G&M, 1984).

1986 — Characterization Study: Several sites were investigated in this study. VOCs were detected in wells northwest of former Chevalier Field (Site 11). VOCs were not detected in a deep well at Site 27. No further action was recommended for Sites 27 and 30. Lead, mercury, and VOCs were detected at Site 11. Two zones of contamination were identified at Site 11, and additional work was recommended (G&M, 1986).

1991 — Site Investigation: VOCs and radioactive contamination were evaluated in soil at Sites 25 and 27, and all parameters were at or near background levels (ABB, 1991).

1991, 1992 — Contamination Assessment/Remedial Activities Investigations: As part of the Navy's Installation Restoration Program (IRP), E&E conducted Phase I contamination assessments for 22 sites to identify principal areas and primary chemicals of potential concern (COPCs) and to recommend subsequent investigations. Fieldwork included site reconnaissance, surface emission surveys, particulate air screening, utilities surveys, soil and groundwater sampling, and hydrologic assessments. Laboratory screening analyses were deficient in their lack of reproducibility. Groundwater samples, which were sampled with bailers and were analyzed unfiltered, were characterized by high turbidity resulting in high metal results. The findings were reported in interim data reports for each site:

- **Site 11** — Metals, totals recoverable petroleum hydrocarbons (TRPHs), VOCs, polycyclic aromatic hydrocarbons (PAHs), and phenol were present in unsaturated soils over a large area of the site. The soil contamination was attributed to past waste disposal and burning activities at the site. Groundwater was contaminated with metals at concentrations exceeding primary drinking water standards. TRPHs, VOCs, PAHs, and phenols were also present in groundwater. Some wells contained floating petroleum product. Potential impacts to Bayou Grande from soil and groundwater contamination at Site 11 were noted (E&E, 1991a).

- **Site 12** — Contamination was detected in sediment, soil, and groundwater. Metals, TRPHs, VOCs, PAHs, phenols, and polychlorinated biphenyls (PCBs) were the primary contaminants.

A potential source of radiation was documented to be in the southeast area of the site. Further investigation was recommended (E&E, 1991b).

- **Site 26** — The Site 26 investigation conclusions stated that limited soil and groundwater contamination was present. Metals (arsenic, cadmium, and chromium), TRPHs, VOCs, and PAHs were the primary contaminants. Further investigation was recommended (E&E, 1991c).

- **Site 25 and 27** — This investigation involved a screening surface radiation survey, a soil head-space survey, and soil and groundwater sampling. At Site 25, analyses showed isolated areas of TRPH, PCBs, metals, and radium-226 contamination in soil, and metals and radium-226 in groundwater. All wells contained concentrations of radium-226 near or above primary drinking water standards (E&E, 1992a). At Site 27, metals were observed in soil near the drain and sewer lines at the former Building 709 location. Metals and radium-226 were detected where the apparent surface spills occurred south of the building. VOCs, PAHs, and phenols were detected on the north side of the building. Groundwater results showed metals and radium-226 near the spill locations and radium-226 at the drain and sewer lines. Arsenic, lead, TRPHs, phenols, and xylene were detected in groundwater at the north side of the former building (E&E, 1992b).

- **Site 30** — Metals, TRPHs, PAHs, phenols, and VOCs were detected in surface water, groundwater, and soil. The most contaminated areas were near the Building 648 complex and next to Site 11. Further assessment was recommended (E&E, 1991c). Although metals, TRPH, VOC, and PAH contamination were identified near the IWTP sewer, the IWTP sewer was not identified as the source (E&E, 1992c).

1992 — Site Inspection Report: Site 25 and 27 surface soil samples were analyzed for target analyte list (TAL) metals, Resource Conservation and Recovery Act (RCRA) toxicity characteristic leaching procedure (TCLP) metals, and limited semivolatile organic compounds (SVOCs). Instead of studying source areas, the investigations focused on adjacent areas.

TCLP metals and SVOCs were not detected at concentrations exceeding background. The report concluded that soil in the area sampled would be classified as nonhazardous if removed during the construction of a proposed cold storage facility (ABB, 1991).

1992 — Naval Aviation Depot Installation Restoration Conference: ABB presented results from 18 UST investigations at NAS Pensacola. Groundwater data were presented from one UST near Building 709, four USTs in the Building 648/649 complex, and five USTs near Buildings 3220 and 3450. Most USTs showed petroleum and solvent contamination. The study documented contaminants and presented isoconcentration-contoured plots for some parameters. This presentation was not formally published. This presentation resulted in the transfer of solvent contaminated UST sites to the IRP.

1992 — USEPA Field Investigation for Sites 1, 11, and 30: The U.S. Environmental Protection Agency (USEPA) sampled surface water, sediment, and four wells near Site 11, along with the wetlands associated with Site 30. Metals were detected in sediment at Bayou Grande next to Site 11 and in the wetlands south of the Building 648 complex. Recommendations included additional sampling in Bayou Grande, the removal of the waste receiving structure in Wetland 5A, and follow-up sampling (USEPA, 1992).

1993 — Contamination Assessment Report, South of Building 3450: The investigation identified TRPH contamination in soils and chlorinated contaminants in groundwater near a former UST site in Site 30 (ABB, 1993).

1994 — Wetland 5A Removal Action South of Buildings 649 and 755 in Site 30: The Navy PWC removed and properly disposed of a waste-receiving structure and its contents, along with all sediment that exceeded photoionization detector measurements of 10 parts per million (ppm). The waste receiving structure was sent to DRMO for recycling. The sludge and other contents were classified and disposed as nonhazardous waste.

Silt fencing was used during the project and precautions were taken to reduce the impact of the removal action to the downgradient wetlands. Three surface water samples were collected from a downgradient location before, during, and after the removal action to assess the impacts to the downgradient Wetland 5B. The highest concentrations were found in the sample collected before removal, which indicates that the removal action did affect Wetland 5B. Sediment samples were collected from beneath the waste-receiving structure and oil/water separator immediately after their removal. Both sediment samples exceeded the Florida Department of Environmental Protection (FDEP) sediment quality assessment guidelines for a variety of constituents. Wetland 5A contamination is addressed in the Site 41 RI (EnSafe, *in press*).

1995 — Base Realignment and Closure (BRAC); Remodeling at Buildings 3220 and 3450: Buildings 3220 and 3450, which are southeast of Sites 25, 27, and 30, were remodeled as part of the BRAC construction for the Naval Training Center. Construction alteration to the site included repaving parking lots, new electrical corridors, and a radar tower. A few monitoring wells were damaged during construction activities. The construction was complete and available for student occupancy in spring of 1996.

1997 — Remedial Investigation: The RI field investigation for OU 2 was conducted between July 1993 and December 1995. Shallow (0 to 1 foot) and subsurface (1 foot to the water table in 2-foot increments) soil samples were collected using hollow stem auger drilling techniques and trenches. Groundwater samples were collected in two phases. The Phase I groundwater sample locations were based on previous investigations and a preliminary soil gas survey, whereas Phase II locations were determined by consensus at the January 1995 Tier I Partnering meeting. Phase I samples were collected using a Grundfos pump or with bailers, and Phase II samples were collected with a peristaltic pump using a low-flow sampling protocol. Thus, the Phase II groundwater samples had a lower turbidity and lower concentrations of metals and sorbed species. The RI investigation also included radium-226 screening at Sites 12, 25, 26, and 27; a contaminant source survey; a habitat and biota survey; and specific capacity testing of constructed monitoring wells.

2004 — Remedial Investigation Addendum: In preparation for the FS, Phase III soil and groundwater samples were collected to assess the conditions of OU 2 in 2003. Twenty-five direct push borings were advanced, and 32 soil samples were collected from the same intervals that leachability-based FDEP soil cleanup target levels were exceeded in the RI. Groundwater samples were collected from 69 strategic locations, which were selected based on previous FDEP groundwater cleanup target level exceedances or in locations in the middle or downgradient of previously identified plumes. The analytical parameters included metals, pesticides/PCBs, SVOCs, VOCs, and monitored natural attenuation (MNA) indicator parameters. The new data were compared to previous analytical data to document changes from the RI and to support this FS.

2.3 Summarized Remedial Investigation Findings

This section briefly summarizes the sources and nature and extent of contamination reported in the RI. In Section 4, the RI and RI addendum data are compared with the remediation goals in order to determine the nature and extent of contamination.

2.3.1 Site 11 — North Chevalier Field Disposal Area

The source of contamination was identified to be a former landfill, where trenching revealed evidence of a "seam" of blackened debris at the water table. This oily material contained finely corroded bits of metal and other debris.

The BRA identified soil inorganic COPCs at Site 11 as arsenic, beryllium, cadmium, chromium, and iron. Soil organic COPCs are Aroclor-1260 and benzo(a)pyrene equivalents (BEQs). Groundwater inorganic COPCs are arsenic and beryllium. Groundwater organic COPCs are 1,2-dichloroethene (1,2-DCE), aldrin, chloroform, 1,2-dichloroethane (1,2-DCA), dieldrin, 1,1,2,2-tetrachloroethane, tetrachloroethene (PCE), TCE, and vinyl chloride (VC).

2.3.2 Site 12 — Scrap Bins

The Site 12 soil contaminants included primary/secondary metals, PCBs, and SVOCs. The storage of scrap metals contributes to metals contamination at this site. Though none were noted during the RI field investigation, past storage of old transformers pending their disposal is a possible

contributor to the PCB contamination at Site 12. Residual fuels and oils from scrapped aircraft and vehicles stored at the site are possible sources of SVOCs at Site 12. Radium-226 contamination was found at two locations in the north-central portion of Site 12 and in a 15-foot x 50-foot area near the southeast corner of the site.

The BRA identified soil inorganic COPCs at Site 12 as arsenic, cadmium, and iron. Soil organic COPCs are Aroclor-1260 and BEQs. In addition, soil samples contained radium-226 in amounts equal to four times the standard in 40 Code of Federal Regulations (CFR) 192.12. COPCs identified in groundwater were Aroclor-1260, chloroform, 1,1-DCE, dieldrin, heptachlor epoxide, and PCE.

2.3.3 Site 25 — Radium Spill Area

Soil samples collected behind Building 780 revealed a wide range of primary/secondary metals and SVOC contamination. Shallow wells next to the building contained primary and secondary metals, and an adjacent intermediate depth well contained metals, as well as chlorinated solvents, benzene, and xylene. Improper storage and disposal of materials at Building 780 are possible sources of soil and groundwater contamination. Another location of concern at Site 25 is the storage yard behind Building 225, used as a metal prefabricating shop by the NAS Pensacola PWC. This yard contains racks of metal sheeting, piping, etc. Shallow and intermediate wells located here contained numerous primary and secondary metals exceedances, as well as PCE and TCE. Activities in and around this building are a possible source for contamination in these wells. The loading dock where the radium-paint spill and cleanup occurred was investigated, but no evidence of radium-226 contamination was found.

The BRA identified soil inorganic COPCs at Site 25 as arsenic, beryllium, cadmium, chromium, and iron. Soil organic COPCs are Aroclor-1254, Aroclor-1260, BEQs, and dieldrin. All inorganic COPCs identified in Phase I groundwater samples were eliminated from the risk assessment because inorganic analytes in Phase II groundwater samples did not exceed hazard indices greater than 1. Groundwater organic COPCs are chlorinated VOCs (1,1-DCE, chloroform, PCE, TCE, and VC).

2.3.4 Site 26 — Supply Department Outside Storage Area

No significant contamination was detected at Site 26. No inorganics contributed to risk in Site 26 soil. BEQs in Site 26 soil samples elevate the risk close to the 1E-06 threshold. Groundwater inorganic COPCs are arsenic, beryllium, and cadmium. Groundwater organic COPCs are dieldrin and PCE.

2.3.5 Site 27 — Radium Dial Shop Sewer

Known as the Radium Dial Shop, Site 27 is on the remaining concrete foundation of former Building 709, which is currently a parking lot. At Site 27, SVOC exceedances were noted from wells previously installed by ABB in support of UST removals at this location. The former UST locations are possible contributors of contamination in these wells. The radiological survey revealed a small area south of former Building 709. From the size of the area, the contamination appeared to be a spill adjacent to an old stairway from Building 709. Outside this limited area, no significant soil radiological contamination was found anywhere on these sites.

The BRA identified soil inorganic COPCs at Site 27 as aluminum, arsenic, cadmium, chromium, iron, and mercury. Soil organic COPCs are dieldrin and BEQs. In groundwater, chromium, iron, and manganese contributed to a cumulative hazard index greater than 1. Groundwater organic COPCs are 1,4-dichlorobenzene, 1,1-DCE, 1,2-DCA, dieldrin, chloroform, PCE, and TCE, and have associated risk projections ranging from 1E-06 to 6E-04.

2.3.6 Site 30 — Complex of Industrial Buildings and IWTP Sewer Line

At Site 30, numerous former ABB wells associated with previous UST removals within the Building 649 complex revealed chlorinated solvents and benzene in groundwater exceeding preliminary remediation goals (PRGs). EnSafe/Allen & Hoshall (E/A&H) wells installed on the western side of this complex revealed SVOC and VOC exceedances in groundwater. Aboveground storage tanks at this complex, the former USTs, and associated buried piping are considered sources for this contamination. Several former ABB wells in and around Building 3220 exhibited benzene, chlorinated solvents, and phenol in groundwater exceeding PRGs. Also, former ABB wells south of Building 3450 exhibited phenol in groundwater above PRGs. All of these

ABB wells were associated with former UST removals. A shallow well (30GS154) installed on the north side of Building 3450 exhibited VC and xylene in groundwater above PRGs.

The BRA identified soil inorganic COPCs at Site 30 as arsenic and beryllium. Soil organic COPCs are BEQs and PCBs. Groundwater inorganic COPCs are arsenic, cadmium, and chromium. Groundwater organic COPCs are benzene, chloroform, 1,1-DCE, 1,4-dichlorobenzene, PCE, and 1,1,1-trichlorethane. In addition to noting the risk associated in and around previous UST removals in the Site 30 area of investigation, the BRA noted that groundwater concentrations of VC contribute significantly to elevated risk at locations represented by monitoring well 30GS154.

Site 30 also includes a portion of the IWTP sewer line. The intermediate well (30GI111) adjacent the southwest corner of Building 3189 exhibited chlorinated VOCs, benzene, iron, manganese, and sodium above PRGs for groundwater. Activities at the former hazardous materials accumulation area likely contributed to this contamination. Samples from well 30GS103 installed in a fenced storage yard directly north of Building 3644 (a former NADEP building), contained primary/secondary metals contamination, as well as chlorobenzene. Nearby well 30GS101 contained xylene and benzene. The contamination in 30GS103 is likely attributable to NADEP activities at Building 3644. Well 30GS101 is adjacent the IWTP and may be impacted from IWTP activities. Chlorobenzene and toxaphene were detected at well 30GS123 near a lift station for the IWTP sewer line. Past spills from this lift station are the suspected contributors of this contamination. The BRA found that groundwater concentrations of arsenic, benzene, 1,4-dichlorobenzene, and VC contribute significantly to elevated risk while chlorobenzene and iron contribute significantly to elevated hazard indices at the location represented by monitoring well pair 30GS111 and 30GI111. Other than 30GI111 for Site 36, the BRA only addressed soil boring 30S102, north of the Building 3644 complex, reporting elevated risk concentrations for BEQs.

2.4 Potential Receptors

OU 2 has been an industrial area supporting supply, maintenance, and disposal activities for more than 40 years. The contaminants within OU 2 appear to be limited to the surface and subsurface soils, the surficial aquifer, groundwater to surface water discharge, and areas where point source or

non-point source storm water discharges occur (e.g., wetlands). Current and potential receptors include the following:

- The surficial zone of the sand-and-gravel aquifer, which is not used as a potable water source due to taste and odor characteristics.

- The main producing zone of the sand-and-gravel aquifer, which is used as a potable water source in Escambia County and underlies the surficial zone but is separated by a confining clay unit.

- NAS Pensacola Wetland 5A, which receives runoff from the southwestern portion of the OU 2 area (Site 30).

- NAS Pensacola Wetland 5B, which drains Wetland 5A to Wetland 6 (Sites 36, 25, and 27).

- The concrete-lined drainage ditch, also known as NAS Pensacola Wetland 6.

- The Yacht Basin, an arm of Bayou Grande, which receives runoff and groundwater flow from the areas of Sites 11, 12, 25, and 26.

The low permeability clay layer between the surficial and main producing zones may inhibit any downward contaminant migration into the deeper groundwater below the clay. The coastal waters of surrounding NAS Pensacola have been classified by the FDEP as Class III surface water, which indicates their use for recreation and maintenance of a well-balanced fish and wildlife population. Potential ecological impacts on wetland areas adjacent OU 2 and Bayou Grande are addressed in separate RI/FSs for Bayou Grande (Site 40) and the NAS Pensacola Wetlands (Site 41).

3.0 FEASIBILITY STUDY PROCESS

The overall objective of the CERCLA remedy selection process is to select remedies that are protective of human health and the environment, that maintain protection over time, and that minimize untreated waste. The RI is used to assess site conditions and the risk assessment process is used to assess risk and hazard based on RI findings. These data are used to gauge the magnitude of site risk and identify possible areas requiring FS. At OU 2, Sites 11, 12, 25, 27, and 30 were recommended for FS.

The FS comprises the following elements:

- **Development of Remedial Action Objectives** — This includes the definition of ARARs, the development of RAOs, the delineation of areas that exceed remedial goals (RGs) and require feasibility analysis, and the estimation of associated impacted volumes.

- **Technology Screening** — This includes the identification of remedial process options that address site contaminants, the evaluation of these technologies using implementability, effectiveness, and cost criteria, and the screening of these technologies.

- **Assembly of Alternatives** — Suitable technologies, which are retained based on engineering judgment, are assembled into viable RAAs. A conceptual design is developed and evaluated using implementability, effectiveness, and cost criteria. This second screening process identifies advantages and disadvantages of each remedial approach.

- **Detailed Analysis of Alternatives** — The assembled alternatives are evaluated using the nine criteria specified in 40 CFR §430(e)(9)(iii) (the National Oil and Hazardous Substances Contingency Plan [NCP]). The nine criteria are used to evaluate each alternative's overall protection of human health and the environment and compliance with statutory requirements.

- **Comparative Analysis of Alternatives** — The RAAs are comparatively evaluated using the nine NCP criteria.

3.1 Development of Remedial Action Objectives

The RAA selection process begins during RI planning, when PRGs are set based on readily available information such as presence of chemical-specific ARARs. As the RI/FS proceeds, goals are modified as needed to reflect understanding of the site and its ARARs. Final RGs are established when the remedy is selected. The goals must consider ARARs and must establish acceptable exposure levels that are protective of human health and the environment.

In developing RAOs for the FS, four issues were addressed:

- PRGs based on chemical-specific ARARs.
- Spatial distribution of contamination in the media of concern, as determined by the RI.
- Human health and ecological assessments, including exposure pathways, addressed in the BRA.
- Potential groundwater contamination by contaminant residuals in site soil.

3.1.1 Chemical-Specific Applicable or Relevant and Appropriate Requirements and To-Be-Considered Criteria

As per the NCP, RGs shall establish acceptable exposure levels that are protective of human health and the environment and are developed by considering the following:

- ARARs under federal environmental or state environmental or facility sitting laws, if available, and the following factors:
    - For systemic toxicants, acceptable exposure levels shall represent concentration levels to which the human population, including sensitive subgroups, may be exposed without adverse effects during a lifetime or part of a lifetime, incorporating an adequate margin of safety.

— For known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk of between 1E-06 and 1E-04. The 1E-06 risk level shall be used as the point of departure for determining RGs for alternatives when ARARs are not available or are not significantly protective due to the presence of multiple contaminants or exposure pathways.

— Technical limitations, quantitative limits, uncertainties, etc.

- Non-zero maximum contaminant level goals (MCLGs), established under the Safe Drinking Water Act (SDWA), are relevant and appropriate for ground or surface waters that are current or potential drinking water sources. When MCLGs are set at zero, the maximum contaminant levels (MCLs) shall be attained when relevant and appropriate to the circumstances of the release.

- In cases involving multiple contaminants or pathways where attainment of chemical-specific ARARs will result in cumulative risk in excess of 1E-04, risk- or technology-based goals may be developed.

- Water quality criteria established under the Clean Water Act (CWA) shall be attained where relevant and appropriate.

- Alternate concentration levels (ACLs) may be established in accordance with CERCLA Section 121(d)(2)(B)(ii).

- Environmental evaluations shall be performed to assess threats to the environment.

Chemical-specific ARARs will be considered in developing RAOs for the site.

A review of potential ARARs, shown in Appendix A, identified potential RGs for OU 2. Proposed Rule 62-780, Florida Administrative Code (FAC), stipulates the cleanup criteria for OU 2.

Proposed Rule 62-780 addresses contaminated site cleanup criteria and references contaminant cleanup target levels in Rule 62-777, FAC. As discussed in Rule 62-777, FAC, the RGs for soil may include the following:

- Residential soil cleanup target levels (SCTLs), which do not require land use restrictions.
- Commercial/industrial SCTLs, which require land use restrictions.
- Leachability SCTLs based on groundwater criteria.
- Leachability SCTLs based on surface water (marine or freshwater as appropriate).

Because NAS Pensacola is not proposed for realignment and closure, it is reasonable for the base to be evaluated using commercial/industrial (C/I) decision criteria. As discussed in Rule 62-777, FAC, the RGs for groundwater may include the following:

- Primary and secondary drinking water standards, as defined in 62-550, FAC.
- Groundwater cleanup target levels (GCTLs).
- Surface water CTLs for marine and freshwater, as appropriate.

Surface water CTLs are only applicable for groundwater discharging to surface water.

3.1.2 Definition of Remedial Action Objectives and Remedial Goals

RAOs are typically defined once the nature of site contaminants is known. In addition, current and future land use, adjacent property conditions, human health and ecological risk assessments, and other factors may be considered to identify a "reasonable future use" scenario. The identification of site COPCs, as well as the future use scenario, enables decision makers to develop site-specific RGs that are protective of human health and the environment, but which are not overly conservative given probable exposure scenarios.

Proposed Rule 62-780, FAC, provides three risk management options to be pursued. The risk management options are described as follows:

- Level I — No further action without institutional or engineering controls, 62-780.680(1), FAC.

- Level II — No further action with institutional controls and, if appropriate, engineering controls that are agreed to by the real property owners of the source property, 62-780.680(2), FAC.

- Level III — No further action with institutional controls and, if appropriate, engineering controls that are agreed to by the real property owners of all properties subject to the institutional or engineering controls, 62-780.680(3), FAC.

In this FS, remedies will be identified and evaluated that meet the RAOs defined by Risk Management Option Level II and one groundwater alternative is pursuant to Risk Management Option III.

3.1.3 Delineation of Areas Exceeding Remedial Goals

Once RAOs and RGs are defined, media exceeding RGs can be identified. At OU 2, the environmental media exceeding RGs are soil and groundwater. FDEP has required point-by-point compound-specific compliance with RGs; therefore, constituents in each soil boring and each groundwater monitoring well are compared with RGs. The soil and groundwater exceedances of the CTLs are discussed in Section 4 and summarized in Appendix B.

3.1.4 Environmental Media Volumes Exceeding Remedial Goals

The volumes of environmental media that exceed CTLs are estimated from data reported in the *Remedial Investigation Report* (EnSafe, 1997) and the *Remedial Investigation Report Addendum Operable Unit 2* (EnSafe, 2004). The estimated volumes of environmental media requiring remedial action are necessary to select appropriate remedial alternatives and develop the cost estimates for these remedies.

3.2 Technology Screening

After impacted media volumes are defined, the next step in the FS process is identification of technologies applicable to site contaminants. Once technologies are identified, they are reviewed for effectiveness, implementability, and cost. Technologies are either eliminated or retained for further consideration. The screening is done on a media-specific basis and site-by-site basis for OU 2 because of the various contaminants identified and ongoing use requirements at the base.

3.2.1 CERCLA Response Actions

The NCP provides guidance for conducting the RI/FS and the process for remedy selection. The stated purpose of the selection process is to assure that implemented remedies protect human health and the environment by eliminating, reducing, and/or controlling risks posed through each pathway. The goal of the FS process is to select remedies based on fundamental criteria, including the following:

- Protection of human health and the environment
- Compliance with ARARs
- Minimization of untreated hazardous waste

3.2.2 Program Management Principles

Sites should be remediated in OUs when 1) reduction of significant risk must be accomplished quickly, 2) a phased analysis and response is necessary or appropriate given the size or complexity of the site, or 3) when the expected final remedy must be expedited. Interim responses should not be inconsistent with implementation of the expected final remedy, nor should they preclude it. Site-specific data needs, alternative evaluation, and documentation of the selected remedy should reflect the scope and complexity of site problems being addressed.

3.2.3 Expectations

In the NCP, USEPA broadly categorizes remedial action alternatives into general response actions for consideration in the FS. Remedial action categories include the following:

- **Treatment** — Use treatment to address the principal threats posed by a site, where practical.

- **Containment** — Use engineering controls such as containment for waste that poses a relatively low long-term threat or where treatment is impractical.

- **Combination** — Combine appropriate methods to protect human health and the environment.

- **Institutional Controls** — Use institutional controls such as water and deed restrictions to supplement engineering controls as appropriate for short- or long-term management to prevent or limit exposure to hazardous substances, pollutants, or contaminants. Institutional controls will not be substituted for active response measures as the sole remedy unless such active measures are determined to be impractical based on the balance of tradeoffs among alternatives determined during remedy selection.

- **Innovative Technology** — Consider an innovative technology when it offers the potential for comparable or better treatment, performance, or ease of implementation, less adverse impacts, or lower costs than demonstrated technologies.

- **Groundwater Restoration** — Restore usable groundwater to its beneficial uses whenever practical in a reasonable amount of time. Where this cannot be accomplished, USEPA expects to prevent further migration of the plume, prevent exposure to contaminated groundwater, and evaluate further risk reduction.

3.2.4 General Response Actions

General response actions are media-specific actions that can achieve RAOs alone or in combination with other actions. Response action alternative types include the following:

- **Source Control Actions** — Source control actions are a range of alternatives in which treatment is used to reduce the toxicity, mobility, or volume of hazardous substances, pollutants, or contaminants. The range considered in an FS should include an alternative that removes or destroys these constituents of concern to the maximum extent feasible, eliminating or minimizing the need for long-term management. In addition, alternatives are to be considered that treat the principal threats posed by the site but vary in the degree of treatment and the amount and characteristics of residuals and untreated waste that must be managed.

- **Containment Actions** — One or more alternatives should be considered that protect human health and the environment primarily by preventing or controlling exposure to site contaminants through engineering or institutional controls. Examples include engineering controls such as extraction or injection wells and institutional controls such as deed or access restrictions.

- **Groundwater Response Actions** — A limited number of groundwater remediation actions should be assessed that attain site-specific goals within different restoration time periods. These alternatives should use one or more methods such as groundwater extraction, treatment, and in situ actions.

3.2.5 Identification of Technologies

This section provides general descriptions of technology types that may be applied to meet the response actions described above.

No Action/Limited Action — The NCP requires evaluation of a no-action alternative as a basis of comparison with other RAAs. Because no action may result in contaminants remaining onsite, CERCLA requires a review and evaluation of site conditions every 5 years if this alternative is selected.

Natural Attenuation — Natural attenuation refers to dilution, dispersion, advection, and biotic degradation of contaminants in the environment. Consideration of this option requires modeling and evaluation of contaminant degradation rates and transport during remedial design. Sampling and sample analysis must be conducted throughout the process to confirm that attenuation is proceeding at rates that meet remediation objectives and to ensure that receptors are not threatened.

Institutional Controls — Institutional controls reduce potential hazards by limiting public exposure, as opposed to reducing volume, mobility, or toxicity of hazardous substances. Examples of institutional controls include:

- Site access controls
- Public awareness and education
- Groundwater use restrictions
- Long-term monitoring
- Deed restrictions
- Warning against excavation and soil use

Removal/Excavation — Removal/excavation provides complete removal of contaminated media. Examples include the excavation of soil with heavy equipment and the removal of groundwater via groundwater extraction wells and subsurface drains.

Containment — Groundwater is contained by installing a network of extraction wells or subsurface drains to produce a hydraulic barrier and eliminate or reduce the migration of groundwater. Vertical barriers such as slurry walls, high-density polyethylene (HDPE) sheeting, or sheet piling may also be used to reduce horizontal contaminant transport in groundwater from contaminated soil zones. A surface cap of asphalt, concrete, soil barriers, or synthetic membranes indirectly provides containment by reducing contaminant transport through soil by minimizing the percolation of water through soils. These containment options can be used alone or together to isolate contaminated soil and/or groundwater.

Ex situ Treatment — Ex situ groundwater treatment technologies include groundwater extraction, air stripping, bioreactor, carbon absorption, and precipitation. Soil may be treated ex situ by multiple technologies such as excavation and offsite disposal, soil washing, landfarming, thermal desorption, and solidification and stabilization.

In situ Treatment — In situ groundwater treatment technologies include air sparging, vertical barriers, treatment walls, geochemical fixation, cosolvent/surfactant flushing, electrokenetic remediation, and enhanced bioremediation. Soil may be treated in situ by multiple technologies, including vitrification, bionutrification, solidification and stabilization, and thermal extraction.

Discharge/Disposal — Groundwater may be treated and discharged to the federally owned treatment works (FOTW), treated and discharged to surface water, or reinjected into the aquifer. Excavated soil may be disposed offsite at a hazardous or nonhazardous waste landfill, used as site fill material, or isolated in an onsite containment unit.

3.2.6 Preliminary Technology Screening

Once the treatment technologies are identified, they are screened on a site-specific basis using the criteria implementability, effectiveness, and cost.

Implementability — Encompasses a technology's technical and administrative feasibility. Technical implementability is used to eliminate technology types and process options that are clearly ineffective or unworkable. Information from RI site characterization is used to screen out technologies and process options. Administrative implementability emphasizes institutional aspects such as the ability to obtain necessary permits for offsite actions; the availability of treatment, storage, and disposal services (including capacity); and the availability of necessary equipment and skilled workers to implement the technology.

Effectiveness — Screening is based on how effective each technology would be in protecting human health and the environment. Each technology should be evaluated with regard to its effectiveness in providing protection and reducing the toxicity, mobility, or volume of contamination. Both short- and long-term effectiveness should be evaluated. Short term refers to

construction and implementation, whereas long term refers to the period after the remedial action is complete.

Cost — Plays a limited role in the screening process. Relative capital and operation and maintenance (O&M) costs are used rather than detailed estimates. At this stage in the process, the cost analysis is based on engineering judgment, and each process is evaluated based on whether costs are high, low, or medium relative to other process options.

3.3 Assembly of Alternatives

Following the identification and screening of technologies, general response actions and process options are combined to form alternatives that address the entire site. These process options were chosen as representatives of technology types. In assembly alternatives, the NCP goal of evaluating a range of alternatives was considered. Where possible given the size of the site and the extent of RG exceedances, the alternatives vary in level of effort, balance of containment versus treatment measures, cost, and remediation time frame. Alternatives have been developed to respond separately to remedial needs for groundwater and soil.

Definitions of each alternative should provide sufficient information to distinguish the alternatives with respect to effectiveness, implementability, and cost. The following information should be included in each definition:

- Locations of areas to be excavated or contained.
- Approximate volumes of soil and/or groundwater to be managed.
- Size and configuration of onsite excavation and treatment systems or containment structures.
- Approximate locations of wells, trenches, treatment systems, etc.
- Management options for treatment residuals.

- For media with several hazardous constituents, it may be necessary to identify which contaminant(s) impose the greatest treatment requirements.
- Remediation time frame.
- Rates or flows of treatment.
- Spatial requirements for treatment or containment actions.
- Distances for disposal actions.
- Required permits for offsite actions and imposed limitations.

In short, the alternative description should include enough information to adequately explain the alternative and document the logic behind the proposed action.

After development, each alternative is screened again using the three general criteria of implementability, effectiveness, and cost.

Implementability — Measures both the technical and administrative feasibility of constructing, operating, and maintaining an alternative. Technical feasibility refers to the ability to construct, operate, and meet ARARs and includes an assessment of O&M and monitoring. Administrative feasibility refers to interactions with other agencies, availability of treatment, and any specific or unusual requirements.

Effectiveness — Is evaluated through an assessment of how each alternative provides protection and the degree to which it reduces toxicity, mobility, or volume. Short-term effectiveness is evaluated according to the implementation period; long-term effectiveness assesses conditions after the remedial action is completed.

Cost — Is assessed in greater detail at this stage than in the initial technology screening. A variety of cost-estimating data are considered to develop both capital and O&M costs. The cost estimates in this FS were prepared using the Remedial Action Cost Engineering and Requirements (RACER) system, version 2005. RACER is a parametric cost modeling system used to develop costs for environmental projects, technologies, and processes. Costs are primarily derived from the unit price book (UPB), which is developed by the Tri-Services Cost Engineering Group, but also include other specialized assemblies. RACER was submitted for formal validation, verification, and accreditation in accordance with Department of Defense Instruction 5000.61 and was accredited for the following intended use:

> To provide an automated, consistent and repeatable method to estimate and document the program cost for the environmental cleanup of contaminated sites and to provide a reasonable estimate for program funding purposes consistent with the information available at the time of the estimate preparation.

3.4 Detailed Analysis of Alternatives

Once identified, remedial alternatives are evaluated with respect to the requirements stipulated in CERCLA as amended, the NCP (40 CFR §300.430), OSWER Directive 9355.9-19 (USEPA, December 24, 1986), and factors described in OSWER Directive 9355.3-01 (USEPA, October 1988).

The detailed analysis of alternatives provides decision makers with the information needed to select an appropriate site remedy. During the detailed analysis, each alternative is assessed against the evaluation criteria described in the OSWER Directive 9355.3-01 and the other alternatives. Assessment results are arrayed to compare the alternatives and identify key tradeoffs among them. The results of the detailed analysis provide the basis for identifying a preferred alternative and preparing a proposed plan. This approach is designed to provide decision makers with sufficient information to adequately compare the alternatives, select an appropriate remedy for a site, and satisfy CERCLA requirements for selecting the remedial action.

This section summarizes the nine evaluation criteria used to evaluate the remedial alternatives, as defined in 40 CFR §300.430. These criteria have been categorized as threshold criteria,

balancing criteria, and modifying criteria. The remedial alternatives are individually evaluated with these nine criteria in Section 7 and comparatively evaluated in Section 8.

3.4.1 Threshold Criterion — Overall Protection of Human Health and the Environment

Each alternative must satisfy this criterion to be eligible for selection. Analysis in this section should provide a final check to assess whether each alternative adequately protects human health and the environment. The overall assessment of protection draws on the assessments conducted under other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

Evaluation of an alternative's overall protectiveness should focus on whether it achieves adequate protection by eliminating, reducing, or controlling the risks posed through each pathway through treatment, engineering, or institutional controls. This evaluation considers whether an alternative poses any unacceptable short-term risk or cross-media impacts.

3.4.2 Threshold Criterion — Compliance with Applicable or Relevant and Appropriate Requirements

Alternatives must meet this criterion to be considered for selection. Compliance with ARARs is used to determine whether each alternative will meet all the federal and state ARARs identified in previous stages of the remedial process. The detailed analysis should identify which requirements are applicable or relevant and appropriate to an alternative. The actual determination of which requirements are applicable or relevant and appropriate is made by the lead agency (the Navy) in consultation with the support agencies (USEPA and FDEP). Compliance with the following ARARs should be addressed for each alternative during the detailed analysis: chemical-specific, location-specific, and action-specific ARARs.

3.4.3 Balancing Criterion — Long-Term Effectiveness and Permanence

The evaluation of alternatives under this balancing criterion addresses the results of a remedial action in terms of the risk remaining at the site after response objectives have been met. The primary focus of this evaluation is the extent and effectiveness of the controls that may be

required to manage the risk posed by treatment residuals and/or untreated wastes. The following should be addressed for each alternative:

- **Magnitude of Residual Risk** — This factor assesses the residual risk from untreated waste or treatment residuals at the conclusion of remedial activities. This risk may be measured by numerical standards such as cancer risk levels or the volume or concentration of constituents in waste, media, or treatment residuals remaining onsite.

- **Adequacy and Reliability of Controls** — This factor assesses the adequacy and suitability of any controls used to manage treatment residuals or untreated wastes remaining onsite. It may include an assessment of containment systems and institutional controls to determine if they sufficiently ensure that any exposure to human and environmental receptors is within protective levels.

3.4.4 Balancing Criterion — Reduction of Toxicity, Mobility, or Volume Through Treatment

This criterion addresses the statutory preference for remedial actions employing treatment technologies that permanently and significantly reduce the toxicity, mobility, or volume of hazardous substances. This is one of the primary balancing criteria on which the detailed analysis is based. The evaluation should consider the following specific factors:

- The treatment processes, the remedies they will employ, and the materials they will treat.

- The amount of hazardous materials that will be destroyed or treated, including how principal threat(s) will be addressed.

- The degree of expected reduction in toxicity, mobility, or volume, measured as a percentage of reduction (or order of magnitude) when possible.

- The degree to which the treatment will be irreversible.

- The type and quantity of treatment residuals that will remain following treatment.

- Whether the alternative would satisfy the statutory preference for treatment as a principal element.

3.4.5 Balancing Criterion — Short-Term Effectiveness

The short-term effectiveness of a remedial alternative is evaluated against its effect on human health and the environment during implementation. This is one of the primary balancing criteria on which the detailed analysis is based. Short-term effectiveness is based on four key factors:

- Risks to the community during implementation of the remedial action.
- Risks to workers during implementation of the remedial action.
- Potential for adverse environmental impact as a result of implementation.
- Time until remedial response objectives are achieved.

3.4.6 Balancing Criterion — Implementability

The implementability criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during its implementation. Specifically, this criterion addresses the following:

Technical Feasibility

- Construction and operation relating to the technical difficulties and unknowns associated with a technology.

- Reliability of technology, focusing on the likelihood that technical problems associated with implementation will lead to schedule delays.

- Ease of undertaking remedial action, discussing future remedial actions that may be required, and how difficult it would be to implement such additional actions.

- Feasibility of monitoring the remedy's effectiveness, including an evaluation of the risks of exposure should be insufficient to detect a system failure.

Administrative Feasibility

- Activities needed to coordinate with other offices and agencies.

Availability of Services and Materials

- Availability of adequate offsite treatment, storage capacity, and disposal services.

- Availability of necessary equipment and specialists, and provisions to ensure any necessary additional resources.

- Availability of services and materials, plus the potential to obtain competitive bids, which may be particularly important for innovative technologies.

- Availability of prospective technologies.

3.4.7 Balancing Criterion — Cost

Detailed cost estimates for each remedial alternative are based on engineering analyses and suppliers' estimates of necessary technology. The estimated costs are intended to reflect actual costs with an accuracy of minus 30% to plus 50%, in accordance with USEPA guidelines. This is the final primary balancing criteria on which detailed analysis is based. Costs are expressed in present value dollars. The cost estimate for a remedial alternative consists of four principal elements: capital cost, O&M costs, costs for evaluation reports, and present value analysis. These four elements are further explained as follows.

Capital Costs

- *Direct costs* for equipment, labor, and materials used to develop, construct, and implement a remedial action.

- *Indirect costs* for engineering, financial, and other services that are not actually part of construction, but are required to implement a remedial alternative. The methodology used to estimate the indirect cost varies with the degree of difficulty associated with construction and/or implementation of the alternative. In this FS, the indirect costs include health and safety items, permitting and legal fees, bid and scope contingencies, engineering design and services, and miscellaneous supplies or costs.

Annual O&M Costs

O&M costs refer to post-construction costs necessary to ensure the continued effectiveness of a remedial action. They typically refer to long-term power and material costs (such as the operational cost of a treatment facility), equipment maintenance and replacement, and long-term monitoring.

Evaluation Reports

This refers to the costs associated with reports prepared every 5 years to evaluate the results of the selected alternative.

Present Value Analysis

This analysis makes it possible to compare the RAAs on the basis of a single cost representing an amount that would be sufficient to cover all costs associated with the remedial action during its planned life, if invested in the base year and disbursed as needed. A performance period appropriate to each alternative is assumed for the present value analyses. A discount rate of 6% is used for the present value estimates.

3.4.8 Modifying Criterion — Support Agency Acceptance

This assessment evaluates the technical and administrative issues and concerns USEPA and FDEP may have regarding each alternative. This criterion is largely satisfied through state involvement in the entire remedial process, including review of the FS.

3.4.9 Modifying Criterion — Community Acceptance

This assessment evaluates the public's potential issues and concerns regarding each alternative. As with state acceptance, this criterion will be addressed in the ROD when comments on the FS and proposed plan have been received.

3.5 Comparative Analysis of Alternatives

Once the alternatives have been fully described and individually assessed against the nine criteria, the relative performance of each is evaluated. The purpose of the comparative analysis is to identify the advantages and disadvantages of each alternative in relation to one another. The differences between alternatives for each criterion should be highlighted, especially the balancing criteria. The focus should help determine which options are cost effective and which remedy uses permanent solutions and treatment to the maximum extent practicable.

4.0 NATURE AND EXTENT OF CONTAMINATION

This section describes the nature and extent of contamination at OU 2, as defined by the RGs for the site. Thus, the soil and groundwater investigation data presented in the 1997 RI and 2003 RI Addendum are evaluated pursuant to Chapter 62-777, FAC, which specifies contaminant cleanup target levels. The media-specific and contaminant-specific remedial volumes are calculated based on the cleanup target level (CTL) exceedances.

4.1 Parameters Used to Define Nature and Extent

This section summarized the samples, remedial goals, and decision criteria used to estimate the soil and groundwater volumes that require remedial action.

4.1.1 Samples

RI sampling was conducted in three phases at OU 2, and the samples are referred as Phase I, II, and III samples. The investigated media includes surface soil (0 to 2 ft below grade level [bgl]), subsurface soil (2 ft bgl to the top of the water table), and shallow and intermediate groundwater (upper 20 ft and lower 20 ft of the saturated shallow aquifer, respectively). The sampled parameters are grouped into the broad chemical categories of inorganics (metals), pesticides/PCBs, SVOCs, and VOCs in this presentation of the nature and extent of contamination.

Phase I sampling was completed in 1993, and included comprehensive surface soil, subsurface soil, and groundwater sampling. Phase II sampling was completed in 1995, and consisted on groundwater sampling. Because Phase I groundwater samples were collected with bailers, which would have overestimated the concentration of inorganics, Phase II groundwater samples were collected using a low-flow sampling protocol. Thus, Phase II groundwater samples had less sediment and were more representative of groundwater. Phase III was a comprehensive sampling investigation conducted in 2003, with the intent of assessing the current conditions of shallow and intermediate groundwater and subsurface soil. Phase III groundwater sample locations include the source areas and the downgradient aquifer. Subsurface soil samples were collected to reassess previously identified hotspot areas.

Because Phase III samples are comprehensive and recent, they are exclusively used to define the nature and extent of subsurface soil and groundwater contamination in the FS. Because surface soil samples were not collected in Phase III, Phase I samples are used to define the nature and extent of surface soil contamination. The locations of the Phase I surface soil samples, the Phase III subsurface samples, and the Phase III groundwater samples are shown in Figures 4-1, 4-2, and 4-3, respectively.

4.1.2 Remedial Goals

The nature and extent of contamination is based on exceedances of the CTLs, as defined by Chapter 62-777, FAC, Tables I and II. The soil and groundwater sample analytical results were compared with the following CTLs to define the nature and extent of contamination. These include:

- Surface soil samples were compared with residential and C/I direct exposure SCTLs and groundwater-based leachability SCTLs.

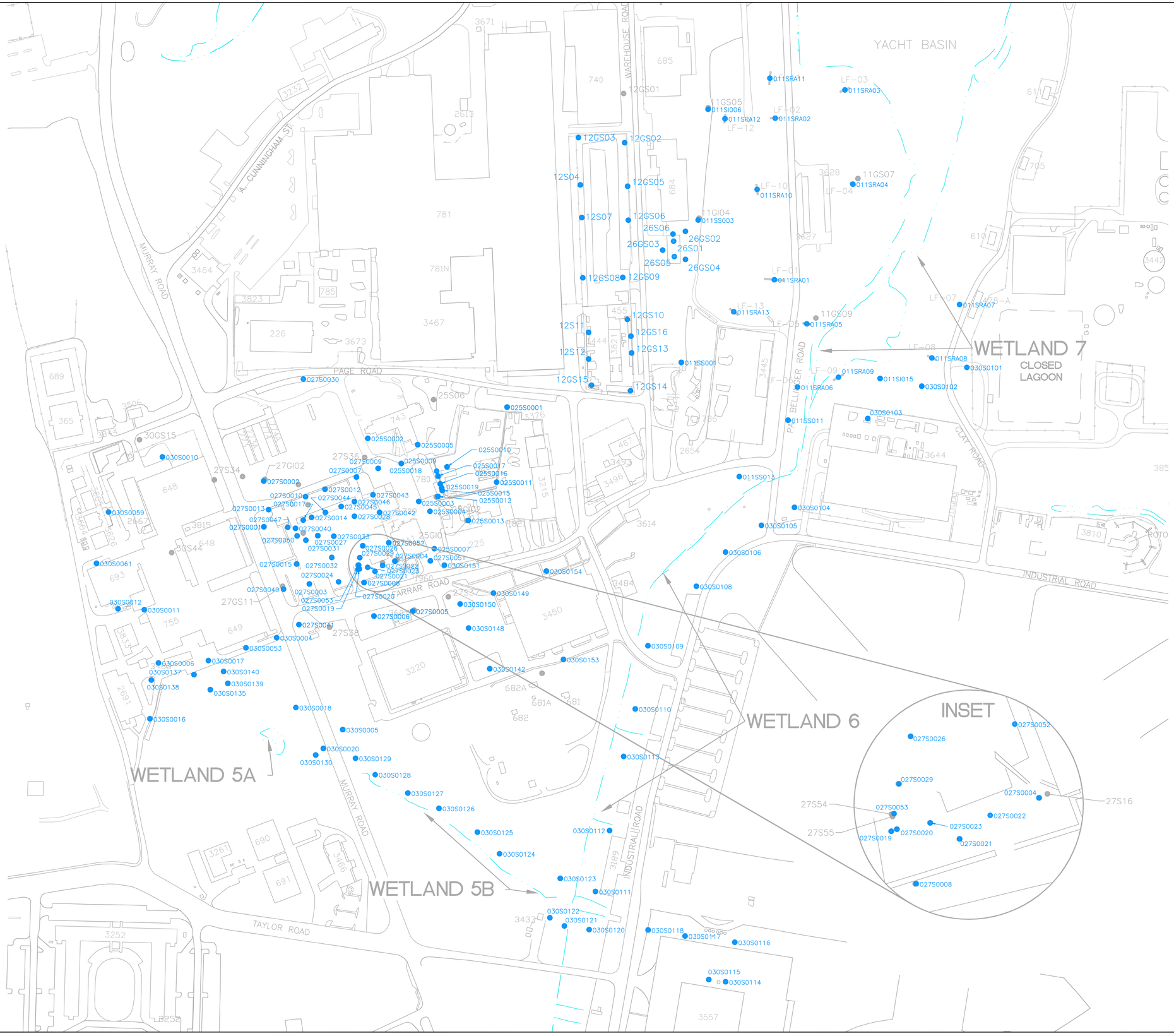
- Subsurface soil samples were compared with groundwater-based leachability SCTLs.

- Groundwater samples were compared with GCTLs based on ingestion (lifetime excess cancer risk of 1E-06) and freshwater and/or marine Class III surface water criteria, as appropriate.

In addition to these screening criteria, all media samples were compared to the NAS Pensacola reference values for inorganics. The results, depicting parameter-specific exceedances for each of the main parameter groups, are included in summary tables and figures. Note that only CTL exceedances are plotted on these accompanying figures; for a plotting of all detections, the reader is referred to the RI and RI Addendum.

4.1.3 Decision Criteria for Estimating Remedial Volumes

The contaminant class-specific volume of surface soil, subsurface soil, and groundwater requiring remediation was estimated using the following media-specific decision criteria:



LEGEND

- SURFACE WATER BODY
- 743 — BUILDING
- LF-12 — TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 30S109 — SURFACE SOIL BORING LOCATION (0-2 FEET BELOW LAND SURFACE)
- 30S109 — SOIL BORING LOCATION

NOTES

SAMPLE LOCATION AND ID LABEL DESCRIPTION:
S = SOIL BORING SAMPLE
SRA/SLF = TRENCH SOIL SAMPLE

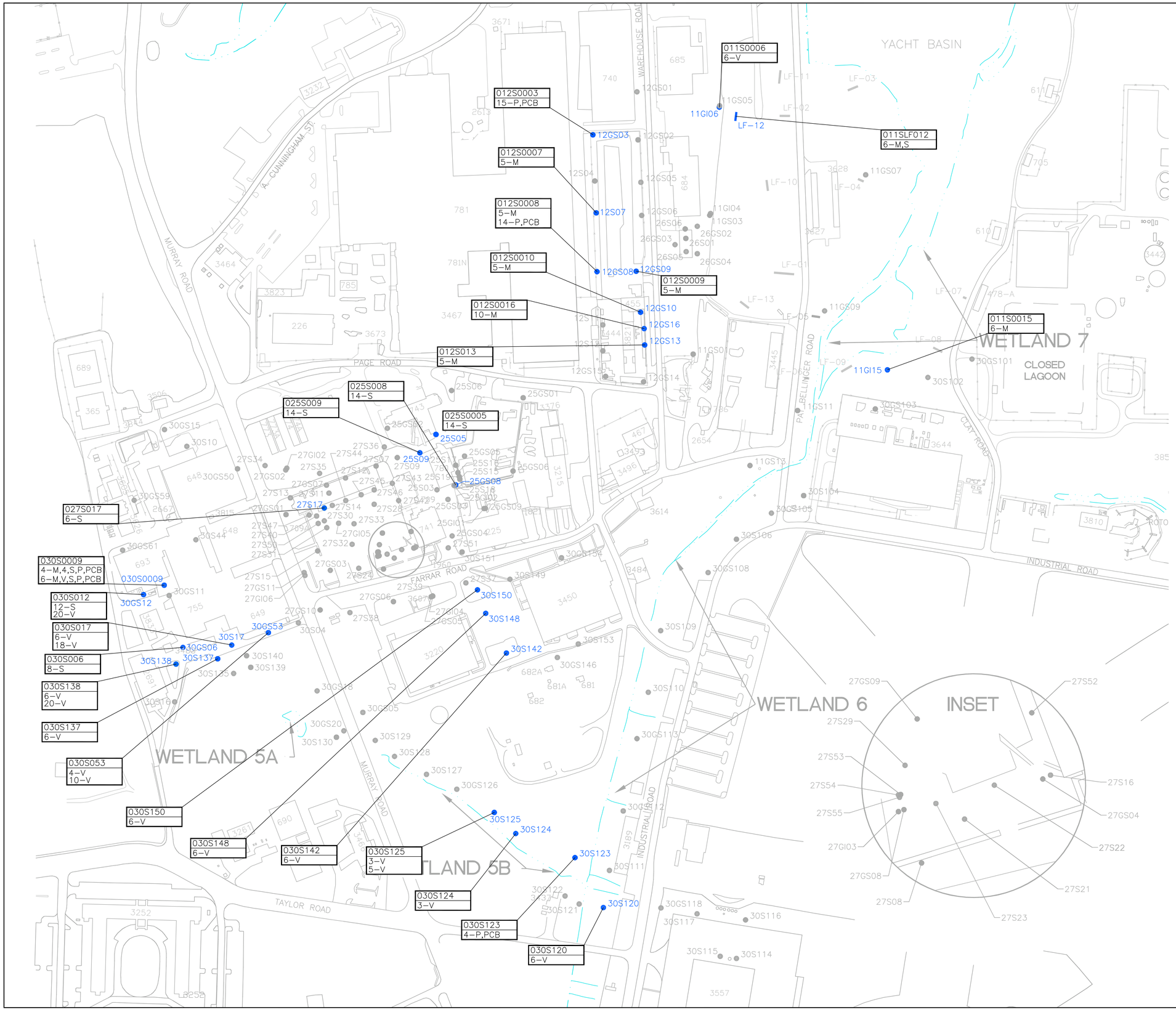
160 0 160
SCALE FEET

NAVFAC Naval Facilities Engineering Command SOUTHERN DIVISION

FEASIBILITY STUDY
OPERABLE UNIT 2
NAS PENSACOLA
PENSACOLA, FLORIDA

FIGURE 4-1
SURFACE SOIL SAMPLE LOCATIONS
1993

Dr by: K. WOOSLEY	Proj. Code: 0059-001	
Ck by: T. KAFKA	App by: A. HARRIS	Sheet 1
Date: 12JAN05	DWG Name: 0059001W065	Of 1



LEGEND

- SURFACE WATER BODY
- 743 — BUILDING
- LF–12 — TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 12S0009 5–M — SUBSURFACE SOIL BORING LOCATION (GREATER THAN 2 FEET BELOW LAND SURFACE) WITH SAMPLE DEPTH AND PARAMETER GROUP SAMPLED IN MARCH 2003
- 30S109 — NOT SAMPLED IN 2003

SAMPLE ID
DEPTH–PARAMETER GROUP

PARAMETER GROUP KEY

M = METALS
V = VOLATILE ORGANIC COMPOUNDS
S = SEMIVOLATILE ORGANIC COMPOUNDS
P = PESTICIDES
PCB = POLYCHLORINATED BIPHENYLS

NOTES

SAMPLE LOCATION AND ID LABEL DESCRIPTION:
S = SOIL BORING SAMPLE
GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
GI = INTERMEDIATE GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
SRA/SLF = TRENCH SOIL SAMPLE

160 0 160
SCALE FEET

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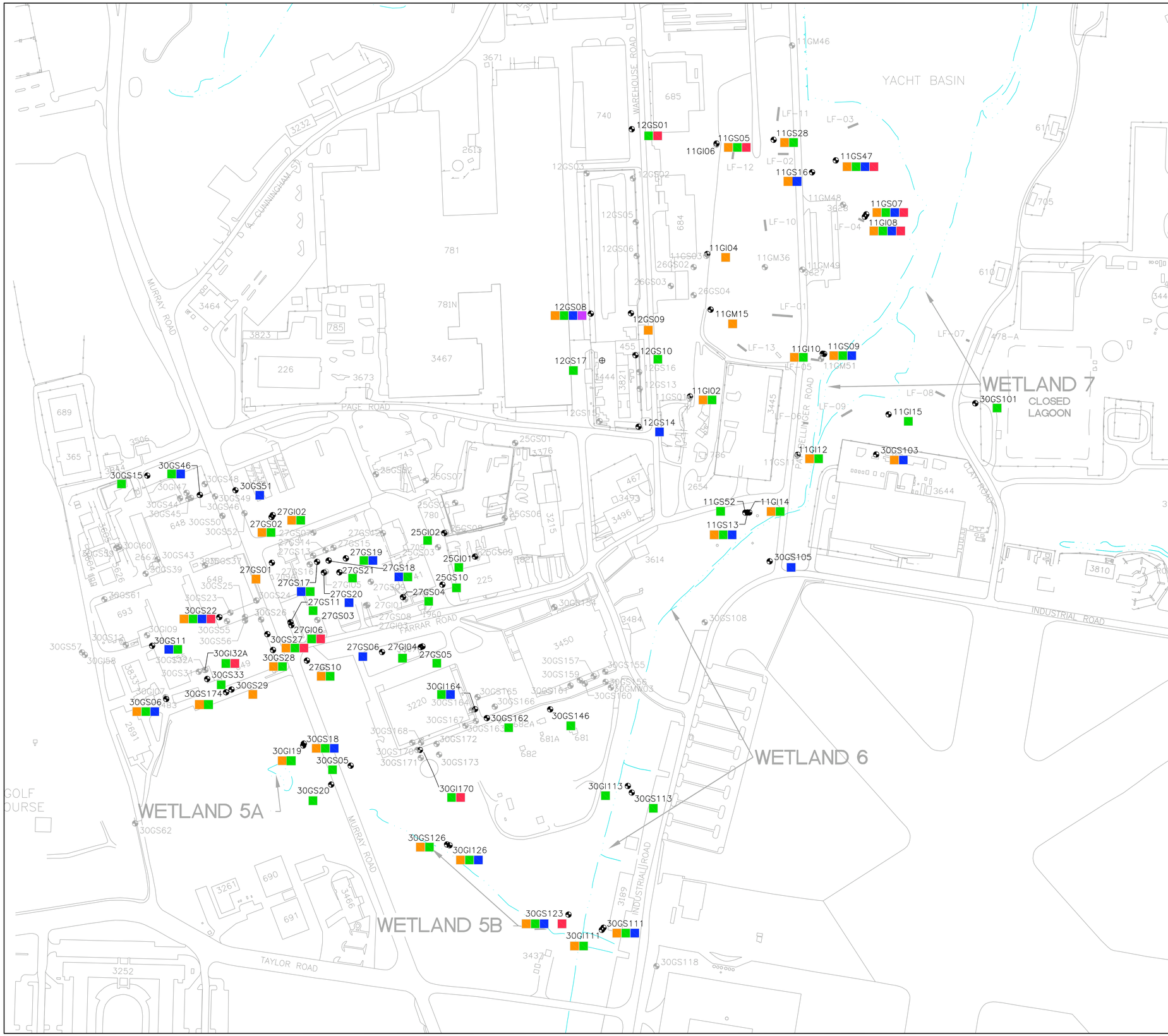
PENSACOLA, FLORIDA

FIGURE 4–2
SUBSURFACE SOIL SAMPLE LOCATIONS
MARCH 2003

Dr by: K. WOOSLEY	Proj. Code: 0059–001	
Ck by: C. TRIPP	App by: A. HARRIS	Sheet 1
Date: 12JAN05	DWG Name: 0059001W064	Of 1



LEGEND

- SURFACE WATER BODY
- 743 — BUILDING
- LF-10 — TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 30GS111 — SHALLOW OR INTERMEDIATE MONITORING WELL SAMPLED AND PARAMETER GROUP
- 30GS165 — MONITORING WELL NOT SAMPLED

RESAMPLING PARAMETERS LEGEND

- Metals
- Volatile Organic Compounds
- Semivolatile Organic Compounds
- Pesticides/PCBs
- MNA

NOTES

SAMPLE LOCATION AND ID LABEL DESCRIPTION:
GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
GI = INTERMEDIATE GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE

160 0 160
SCALE FEET

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PENSACOLA, FLORIDA

FIGURE 4-3
GROUNDWATER SAMPLING LOCATIONS
MARCH 2003

Dr by: K. WOOSLEY	Proj. Code: 0059-001	
Ck by: C. TRIPP	App by: A. HARRIS	Sheet 1
Date: 12JAN05	DWG Name: 0059001W079	Of 1

Soil

- Volumetric determinations were based on residential and C/I direct exposure SCTL exceedances for surface soil, and leachability-based GCTL exceedances for surface and subsurface soil.

- Isolated impacted soil areas were assumed to extend 20 ft from the sampling point.

Groundwater

- Volumetric determinations were based on monitoring wells with GCTL exceedances.

- The estimates of groundwater distribution were based on the direction of groundwater flow. The adjacent surface water bodies (Wetlands 5A, 5B, 6, 7, and 64) receive groundwater and can be classified as gaining. In gaining water bodies, the potentiometric gradient, and thus the groundwater flow, is generally perpendicular to the surface water body. Therefore, unless the groundwater pathway from a well exhibiting an exceedance had an intervening well that did not exhibit an exceedance, the affected groundwater was estimated to extend from the GCTL exceedance to the nearest wetland.

- In order to account for dispersion, the effected groundwater was assumed to extend 50 ft laterally from the observed GCTL exceedance.

- The saturated volume of aquifer matrix used in the calculations was 20 ft for the shallow and 20 ft for the intermediate, for a total saturated aquifer thickness of 40 ft.

- The estimated porosity of the aquifer matrix was 30%.

4.2 Estimated Volumes of Soil and Groundwater that Require Remediation

The soil and groundwater volumes requiring remediation are estimated for the chemical categories of metals, pesticides/PCBs, SVOCs, and VOCs. This section summarizes the sample exceedances,

the estimated areal distributions of contamination, and the estimated remedial volumes. The sample results, and their CTL exceedances, are given in Appendix B.

4.2.1 Metals

Figure 4-4 shows the surface soil samples and estimated areas that exceed the residential direct exposure SCTLs. Given a 2-ft depth of contamination, which is based on surface soil definition, 19,520 CY of surface soil exceeds the residential direct exposure SCTL.

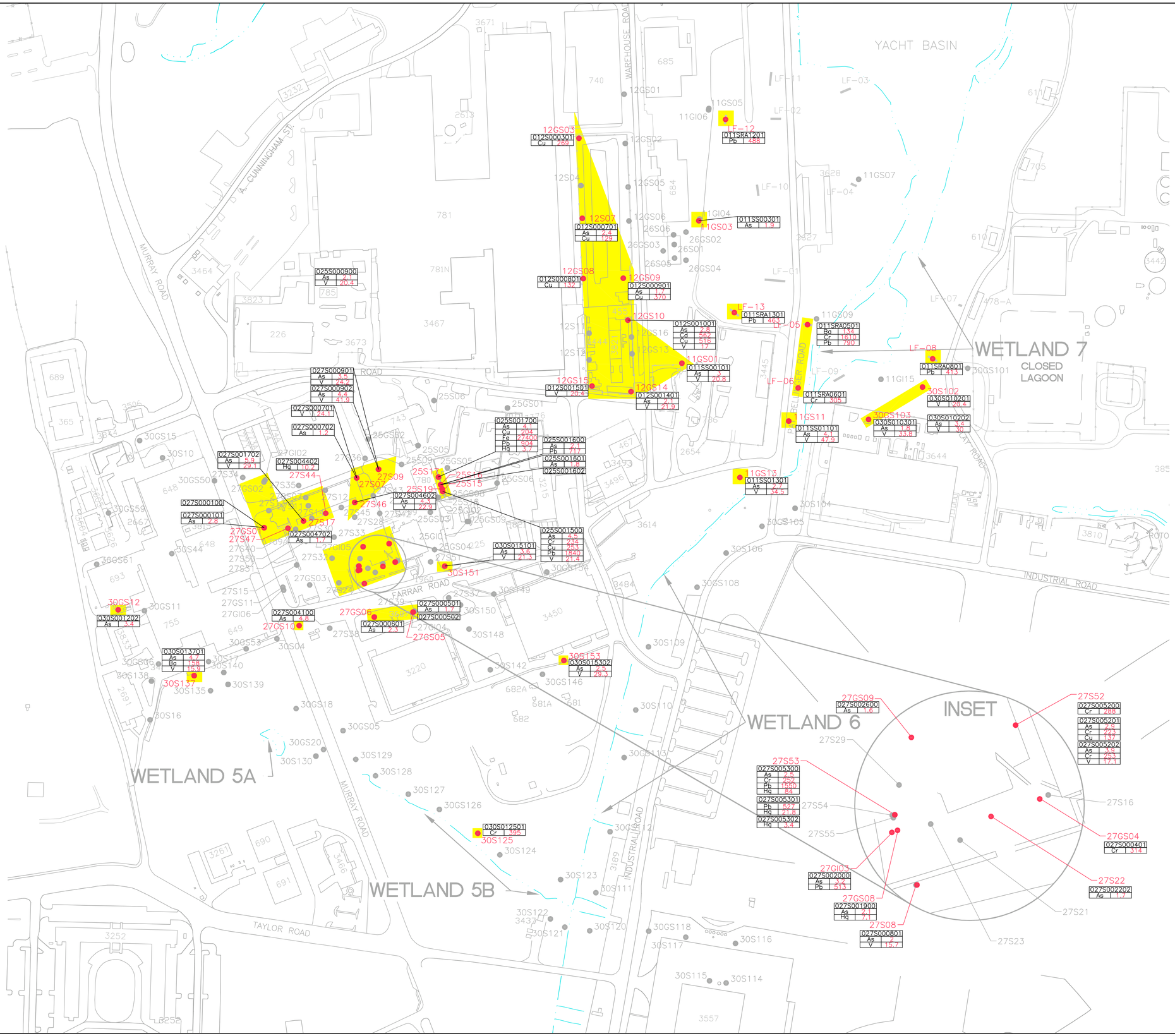
Figure 4-5 shows the surface soil samples and estimated areas that exceed the C/I direct exposure SCTLs. Given a 2-ft depth of contamination, 1,590 CY of surface soil exceeds the C/I direct exposure SCTL.

Figure 4-6 shows the surface soil samples and estimated areas that exceed the groundwater-based leachability SCTLs for metals. Given a 2-ft depth of contamination, 15,690 CY of surface soil exceeds the groundwater-based leachability SCTLs for metals.

Figure 4-7 shows the subsurface soil samples and estimated areas that exceed the groundwater-based leachability SCTLs for metals. Given a 2-ft depth of contamination for the single detection, 120 CY of subsurface soil exceeds the groundwater-based leachability SCTLs for metals.

Figure 4-8 shows the groundwater samples and estimated areas that exceed GCTLs for secondary drinking water standard metals; specifically aluminum, iron, and manganese. Based on the decision criteria defined in Section 4.1.3, an estimated 14.4 million gallons of groundwater exceed secondary drinking water standards.

Figure 4-9 shows the groundwater samples and estimated areas that exceed GCTLs for barium, cadmium, chromium, and lead. Based on the decision criteria defined in Section 4.1.3, an estimated 2.26 million gallons of groundwater exceed GCTLs for these metals.



LEGEND

- SURFACE WATER BODY
- 743 — BUILDING
- AREA OF REMEDIAL VOLUME – DEPTH IS 2 FEET
- LF-12 — TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 11GI15 — SURFACE SOIL BORING LOCATION EXCEEDING THE RESIDENTIAL DIRECT EXPOSURE SCTL
- 30S109 — SOIL BORING LOCATION

SAMPLE ID	
PARAMETER KEY	CONCENTRATION

PARAMETER KEY

METALS	FDEP Residential Direct Exposure SCTL (ppm)
Arsenic (As)	0.8 (RC=1.56)
Barium (Ba)	110
Cadmium (Cd)	75
Chromium (Cr)	210 (Hexavalent)
Copper (Cu)	110
Iron (Fe)	23000
Lead (Pb)	400
Mercury (Hg)	3.4
Vanadium (V)	15

NOTES

1. ALL CONCENTRATIONS ARE IN PARTS PER MILLION (PPM)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:
   - S = SOIL BORING SAMPLE
   - GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - GI = INTERMEDIATE GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - SRA/SLF = TRENCH SOIL SAMPLE
3. LAST TWO DIGITS OF SAMPLE ID INDICATE SAMPLE DEPTH

160 0 160
SCALE FEET

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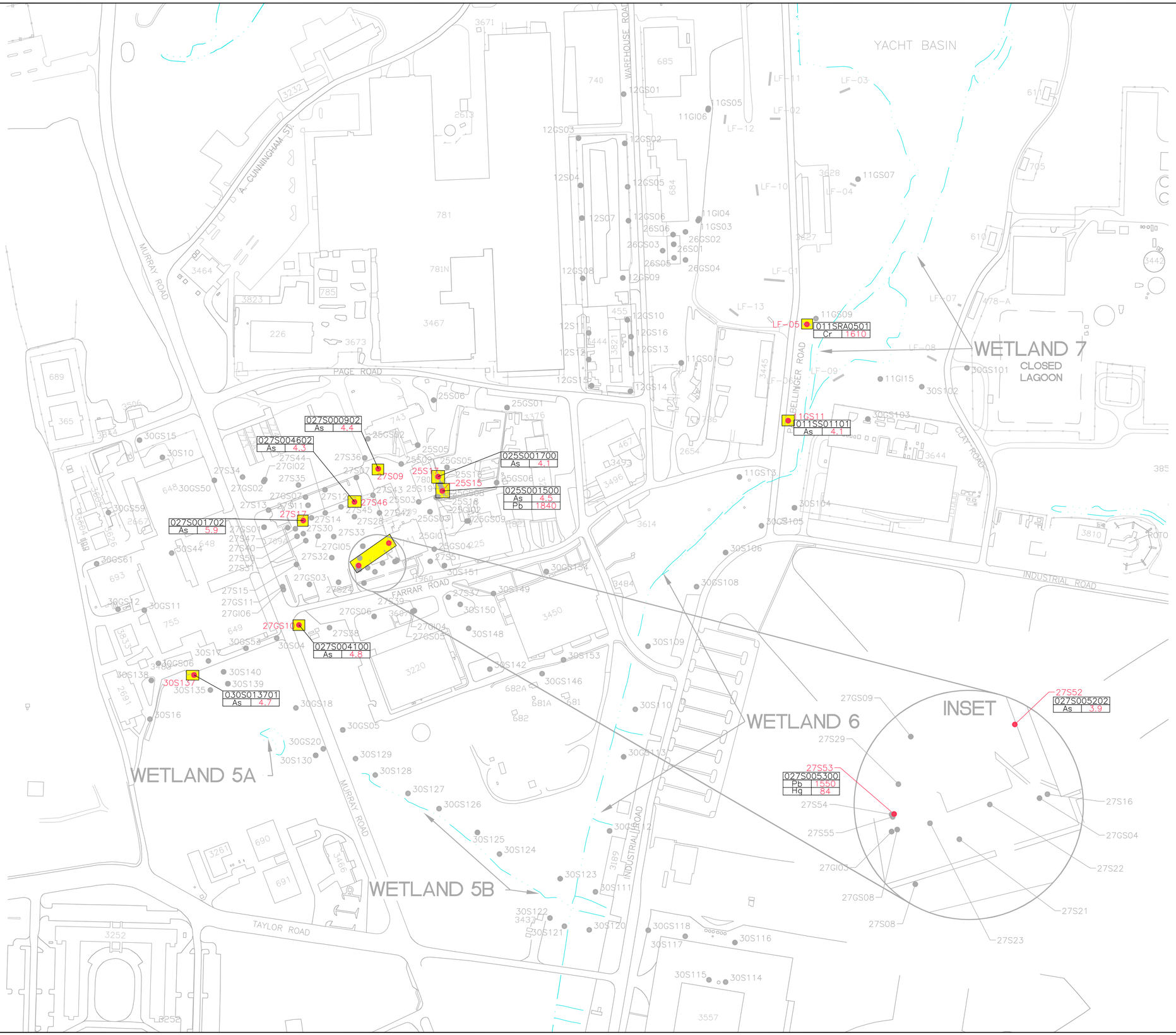
FIGURE 4-4
METALS-RESIDENTIAL DIRECT EXPOSURE SCTL
EXCEEDANCES AND REMEDIAL AREAS IN SURFACE SOIL

Dr by: K. WOOSLEY	Proj. Code: 0059-001	
Ck by: C. TRIPP	App by: A. HARRIS	Sheet 1
Date: 12JAN05	DWG Name: 0059001W080	Of 1



LEGEND

- SURFACE WATER BODY
- 743 BUILDING
- AREA OF REMEDIAL VOLUME – DEPTH IS 2 FEET
- LF-12 TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 11GI15 ● SURFACE SOIL BORING LOCATION EXCEEDING THE DIRECT C/I EXPOSURE SCTL
- 30S109 ● SOIL BORING LOCATION

SAMPLE ID	
PARAMETER KEY	CONCENTRATION

PARAMETER KEY

METALS	FDEP Direct C/I Exposure SCTL (ppm)
Arsenic (As)	3.7
Chromium (Cr)	420 (Hexavalent)
Lead (Pb)	920
Mercury (Hg)	26

NOTES

1. ALL CONCENTRATIONS ARE IN PARTS PER MILLION (PPM)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:
   - S = SOIL BORING SAMPLE
   - GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - GI = INTERMEDIATE GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - SRA/SLF = TRENCH SOIL SAMPLE
3. LAST TWO DIGITS OF SAMPLE ID INDICATE SAMPLE DEPTH

160 0 160
SCALE FEET

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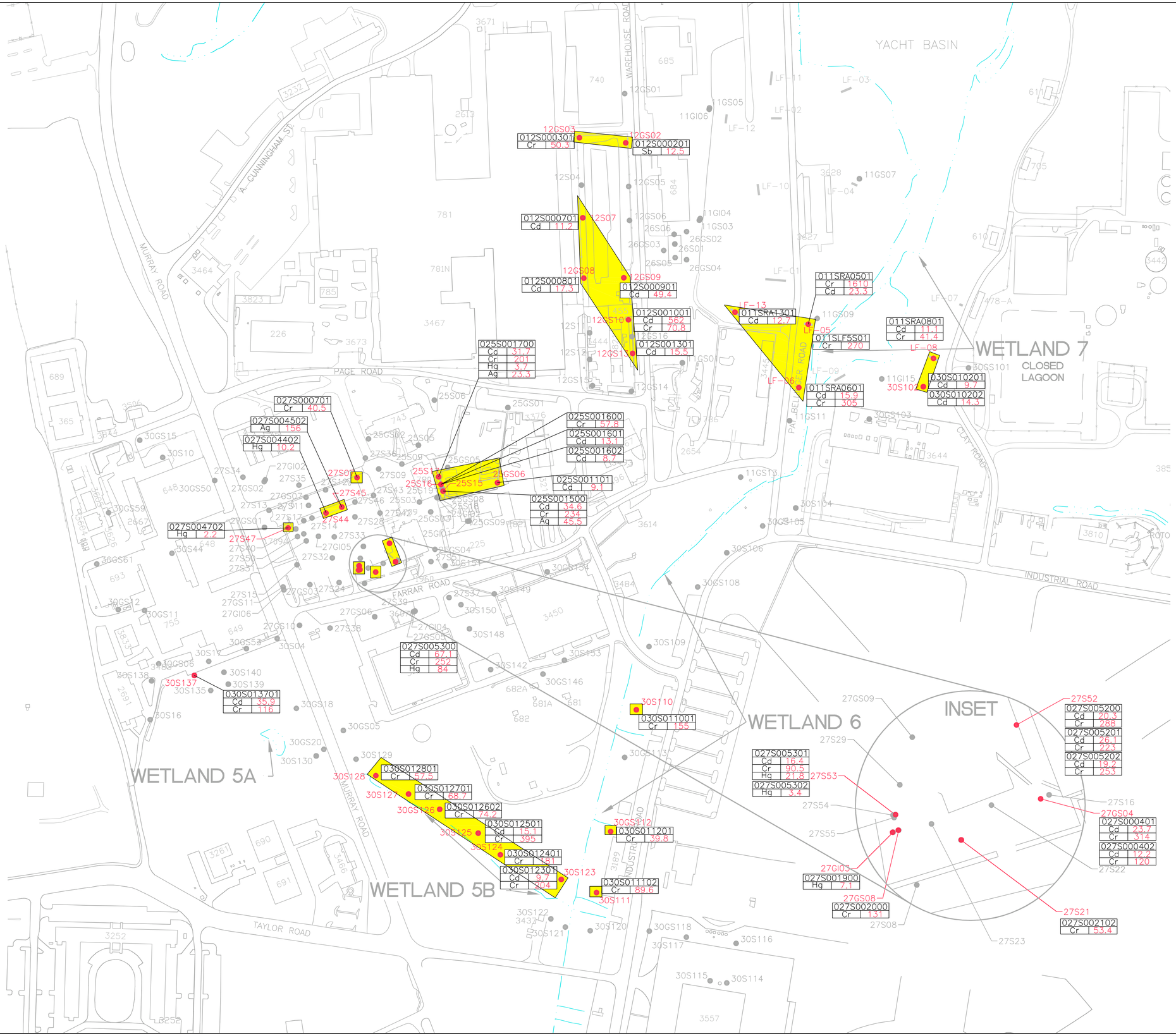
PENSACOLA, FLORIDA

FIGURE 4–5
METALS–DIRECT C/I EXPOSURE SCTL
EXCEEDANCES AND REMEDIAL AREAS IN SURFACE SOIL

Dr by: K. WOOSLEY	Proj. Code: 0059–001	
Ck by: C. TRIPP	App by: A. HARRIS	Sheet 1
Date: 12JAN05	DWG Name: 0059001W072	Of 1



LEGEND

- SURFACE WATER BODY
- 743 BUILDING
- AREA OF REMEDIAL VOLUME – DEPTH IS 2 FEET
- LF-12 TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 30S109 SURFACE SOIL BORING LOCATION EXCEEDING THE GROUNDWATER LEACHABILITY SCTL
- 12S12 SOIL BORING LOCATION

SAMPLE ID	
PARAMETER KEY	CONCENTRATION

PARAMETER KEY

METALS	FDEP Groundwater Leachability SCTL (ppm)
Cadmium (Cd)	8
Chromium (Cr)	38 (Hexavalent)
Mercury (Hg)	2.1
Silver (Ag)	17

NOTES

1. ALL CONCENTRATIONS ARE IN PARTS PER MILLION (PPM)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:
   - S = SOIL BORING SAMPLE
   - GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - GI = INTERMEDIATE GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - SRA/SLF = TRENCH SOIL SAMPLE
3. LAST TWO DIGITS OF SAMPLE ID INDICATE SAMPLE DEPTH

160 0 160
SCALE FEET

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FIGURE 4–6
METALS–GROUNDWATER LEACHABILITY SCTL EXCEEDANCES AND REMEDIAL AREAS IN SURFACE SOIL

Dr by: K. WOOSLEY	Proj. Code: 0059–001	
Ck by: C. TRIPP	App by: A. HARRIS	Sheet 1
Date: 12JAN05	DWG Name: 0059001W066	Of 1

LEGEND

- SURFACE WATER BODY
- 743 BUILDING
- AREA OF REMEDIAL VOLUME
- LF-12 TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 11GI15 SUBSURFACE SOIL BORING LOCATION EXCEEDING THE GROUNDWATER LEACHABILITY SCTL
- 30S109 SOIL BORING LOCATION

SAMPLE ID	
PARAMETER KEY	CONCENTRATION

PARAMETER KEY

METALS	FDEP Groundwater Leachability SCTL (ppm)
Total Chromium	38 (Hexavalent)

NOTES

1. ALL CONCENTRATIONS ARE IN PARTS PER MILLION (PPM)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:
   - S = SOIL BORING SAMPLE
   - GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - GI = INTERMEDIATE GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - SRA/SLF = TRENCH SOIL SAMPLE
3. LAST TWO DIGITS OF SAMPLE ID INDICATE SAMPLE DEPTH

160 0 160
SCALE FEET

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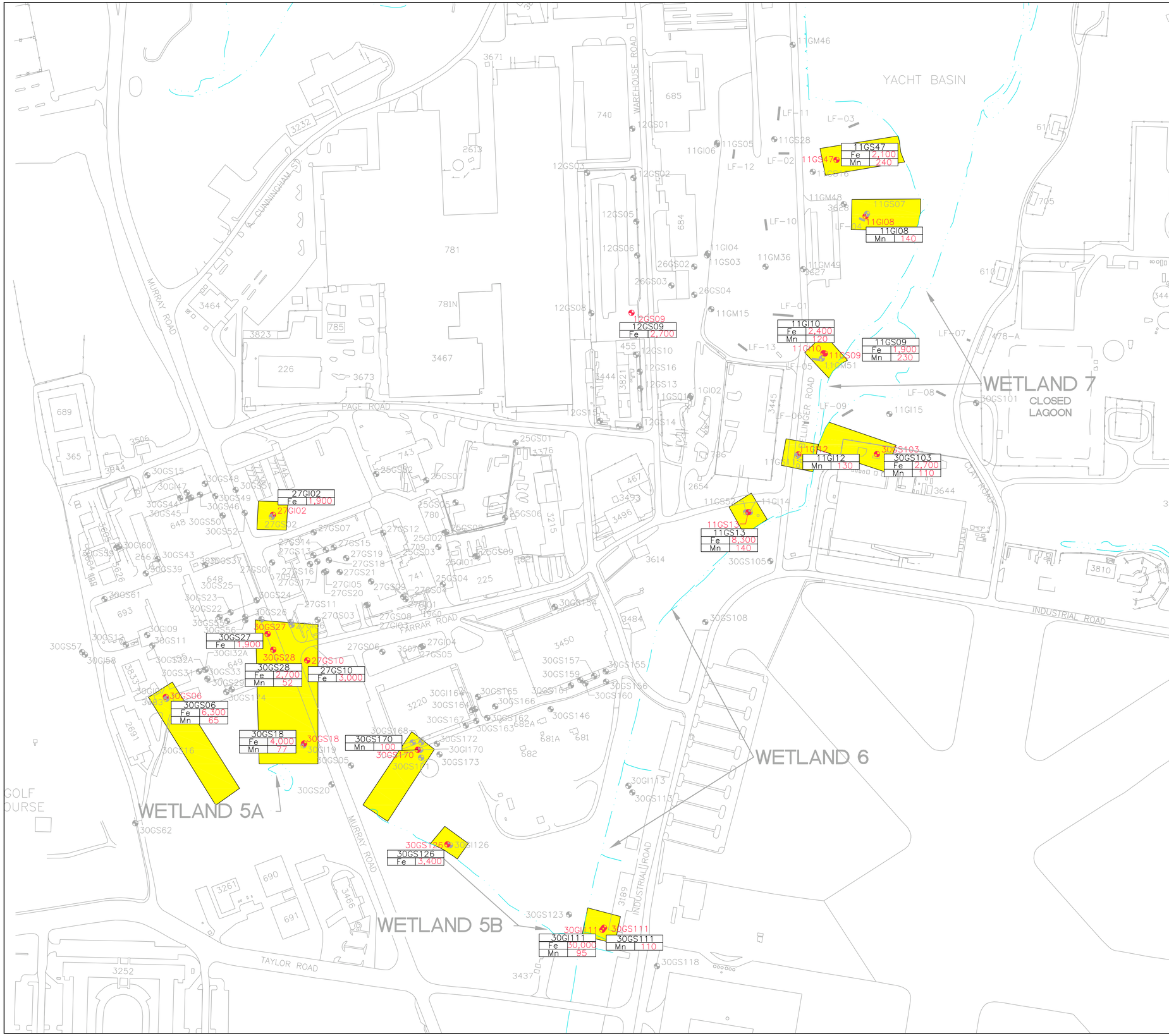
PENSACOLA, FLORIDA

FIGURE 4-7
METALS-GROUNDWATER LEACHABILITY SCTL
EXCEEDANCES IN SUBSURFACE SOIL
MARCH 2003

Dr by: K. WOOSLEY	Proj. Code: 0059-001	
Ck by: C. TRIPP	App by: A. HARRIS	Sheet 1
Date: 12JAN05	DWG Name: 0059001W070	Of 1



LEGEND

- SURFACE WATER BODY
- 743 — BUILDING
- AREA OF REMEDIAL VOLUME
- LF-10 — TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 30GS155 — SHALLOW OR INTERMEDIATE MONITORING WELL
- 30GS111 — SHALLOW GROUNDWATER MONITORING WELL LOCATIONS/IDs WITH SAMPLE EXCEEDING THE GROUNDWATER CTL OR REFERENCE CONCENTRATION

SAMPLE ID	
PARAMETER KEY	CONCENTRATION

PARAMETER KEY

INORGANIC	FLORIDA GCTL (ppb)	REFERENCE CONC.
Aluminum (Al)	200	3882.80
Iron (Fe)	300	1707.80
Manganese (Mn)	50	22

NOTES

1. ALL CONCENTRATIONS ARE IN PARTS PER BILLION (PPB)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:
   - S = SOIL BORING SAMPLE
   - GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - GI = INTERMEDIATE GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - SRA/SLF = TRENCH SOIL SAMPLE

160 0 160
SCALE FEET

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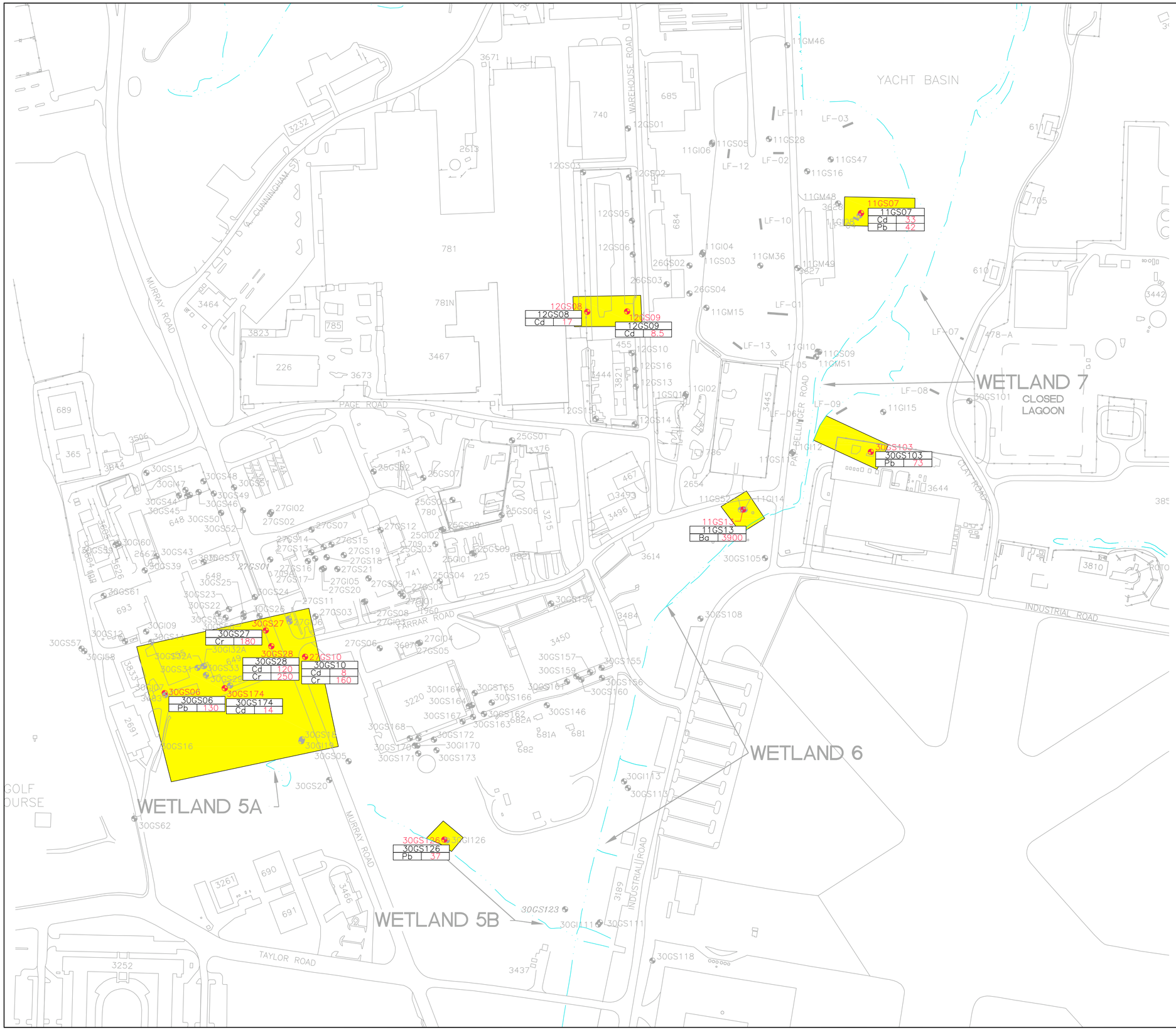
FIGURE 4-8
ALUMINUM, IRON, AND MANGANESE GCTL EXCEEDANCES AND REMEDIAL AREAS IN GROUNDWATER
MARCH 2003

Dr by: K. WOOSLEY	Proj. Code: 0059-001	
Ck by: C. TRIPP	App by: A. HARRIS	Sheet 1
Date: 12JAN05	DWG Name: 0059001W078	Of 1



LEGEND

- SURFACE WATER BODY
- 743 — BUILDING
- AREA OF REMEDIAL VOLUME
- LF-10 — TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 30GS155 — SHALLOW OR INTERMEDIATE MONITORING WELL
- 30GS111 — SHALLOW GROUNDWATER MONITORING WELL LOCATIONS/IDs WITH SAMPLE EXCEEDING THE GROUNDWATER CTL

SAMPLE ID	
PARAMETER KEY	CONCENTRATION

PARAMETER KEY

METALS	FLORIDA GCTL (ppb)
Barium (Ba)	2000
Cadmium (Cd)	5
Chromium (Cr)	100
Lead (Pb)	15

NOTES

1. ALL CONCENTRATIONS ARE IN PARTS PER BILLION (PPB)
2. ALTHOUGH OTHER INORGANICS WERE DETECTED, IF NO GCTL EXCEEDANCES OCCURRED IN ANY OU-2 SAMPLES, THEY ARE NOT PLOTTED HERE. REFER TO THE SUMMARY TABLES FOR THESE CONSTITUENTS.
3. SAMPLE LOCATION AND ID LABEL DESCRIPTION:
   - S = SOIL BORING SAMPLE
   - GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - GI = INTERMEDIATE GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - SRA/SLF = TRENCH SOIL SAMPLE

160 0 160
SCALE FEET

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FIGURE 4-9
BARIUM, CADMIUM, CHROMIUM, AND LEAD – GCTL EXCEEDANCES AND REMEDIAL AREAS IN GROUNDWATER
MARCH 2003

Dr by: K. WOOSLEY	Proj. Code: 0059-001	
Ck by: C. TRIPP	App by: A. HARRIS	Sheet 1
Date: 12JAN05	DWG Name: 0059001W075	Of 1

4.2.2 Pesticides/Polychlorinated Biphenyls

Figure 4-10 shows the surface soil samples and estimated areas that exceed the residential direct exposure SCTLs for pesticides and PCBs. Given a 2-ft depth of contamination, which is based on surface soil definition, 7,530 CY of surface soil exceeds the residential direct exposure SCTL for pesticides and PCBs.

Figure 4-11 shows the surface soil samples and estimated areas that exceed the C/I direct exposure SCTLs for pesticides and PCBs. Given a 2-ft depth of contamination, which is based on surface soil definition, 1,780 CY of surface soil exceeds the residential direct exposure SCTL for pesticides and PCBs.

Figure 4-12 shows the surface soil samples and estimated areas that exceed the groundwater-based leachability SCTLs for pesticides and PCBs. Given a 2-ft depth of contamination, 9,210 CY of surface soil exceeds the groundwater-based leachability SCTLs for pesticides and PCBs.

There were no exceedances of groundwater-based leachability SCTLs in the subsurface soil samples for pesticides and PCBs. There also were no exceedances of the GCTLs for pesticides and PCBs.

4.2.3 Semivolatile Organic Compounds

Figure 4-13 shows the surface soil samples and estimated areas that exceed the residential direct exposure SCTLs for SVOCs. Given a 2-ft depth of contamination, which is based on surface soil definition, 13,550 CY of surface soil exceeds the residential direct exposure SCTL for SVOCs.

Figure 4-14 shows the surface soil samples and estimated areas that exceed the C/I direct exposure SCTLs for SVOCs. Given a 2-ft depth of contamination, 3,010 CY of surface soil exceeds the C/I direct exposure SCTL for SVOCs.

Figure 4-15 shows the surface soil samples and estimated areas that exceed the groundwater-based leachability SCTLs for SVOCs. Given a 2-ft depth of contamination, 830 CY of surface soil exceeds the groundwater-based leachability SCTLs for SVOCs.

LEGEND

- SURFACE WATER BODY
- 743 BUILDING
- AREA OF REMEDIAL VOLUME – DEPTH IS 2 FEET
- LF-12 TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 11GI15 ● SURFACE SOIL BORING LOCATION EXCEEDING THE DIRECT RESIDENTIAL EXPOSURE SCTL
- 30S109 ● SOIL BORING LOCATION

SAMPLE ID	
PARAMETER KEY	CONCENTRATION

PARAMETER KEY

PESTICIDE/PCBs	FDEP Residential Direct Exposure SCTL (ppm)
Aroclor-1260 (PCB1)	0.5 (PCBs-Aroclor mixture)
Aroclor-1242 (PCB2)	0.5 (PCBs-Aroclor mixture)
Aroclor-1254 (PCB3)	0.5 (PCBs-Aroclor mixture)
Dieldrin (D)	0.07

NOTES

1. ALL CONCENTRATIONS ARE IN PARTS PER MILLION (PPM)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:
   - S = SOIL BORING SAMPLE
   - GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - GI = INTERMEDIATE GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - SRA/SLF = TRENCH SOIL SAMPLE
3. LAST TWO DIGITS OF SAMPLE ID INDICATE SAMPLE DEPTH

160 0 160
SCALE FEET

NAVFAC Naval Facilities Engineering Command SOUTHERN DIVISION

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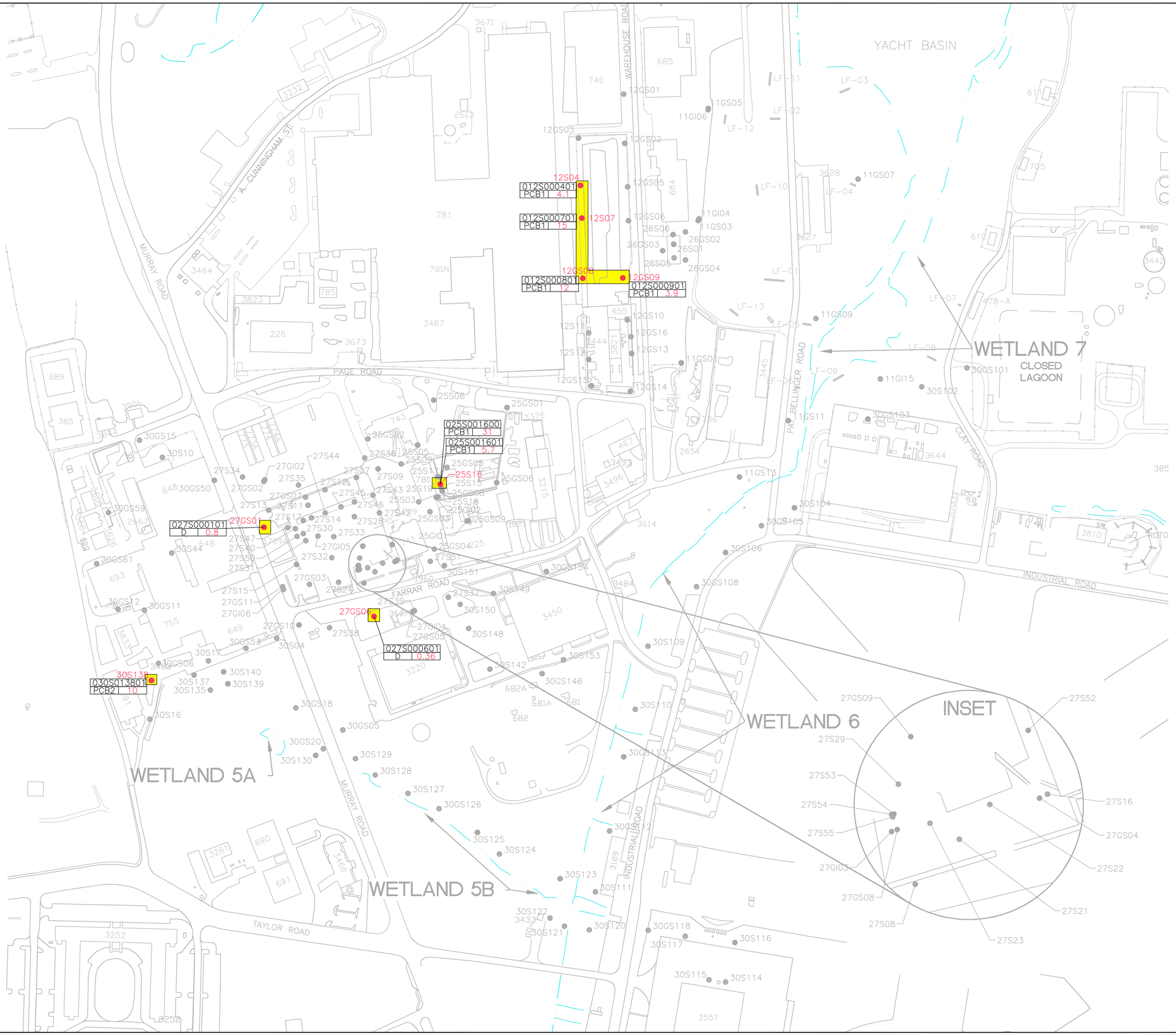
PENSACOLA, FLORIDA

FIGURE 4-10
PESTICIDES/PCBs-RESIDENTIAL DIRECT EXPOSURE SCTL EXCEEDANCES AND REMEDIAL AREAS IN SURFACE SOIL

Dr by: K. WOOSLEY	Proj. Code: 0059-001	
Ck by: C. TRIPP	App by: A. HARRIS	Sheet 1
Date: 12JAN05	DWG Name: 0059001W081	Of 1



LEGEND

- SURFACE WATER BODY
- 743 BUILDING
- AREA OF REMEDIAL VOLUME
- LF-12 TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 27GS06 SURFACE SOIL BORING LOCATION EXCEEDING THE DIRECT C/I EXPOSURE SCTL
- 30S109 SOIL BORING LOCATION

SAMPLE ID	
PARAMETER KEY	CONCENTRATION

PARAMETER KEY

PESTICIDE/PCBs	FDEP Direct C/I Exposure SCTL (ppm)
Aroclor-1260 (PCB1)	2.1 (PCBs-Aroclor mixture)
Aroclor-1242 (PCB2)	2.1 (PCBs-Aroclor mixture)
Dieldrin	0.3

NOTES

1. ALL CONCENTRATIONS ARE IN PARTS PER MILLION (PPM)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:
   - S = SOIL BORING SAMPLE
   - GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - GI = INTERMEDIATE GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - SRA/SLF = TRENCH SOIL SAMPLE
3. LAST TWO DIGITS OF SAMPLE ID INDICATE SAMPLE DEPTH

160 0 160
SCALE FEET

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PENSACOLA, FLORIDA

FIGURE 4-11
PESTICIDES/PCBs-DIRECT C/I EXPOSURE SCTL
EXCEEDANCES AND REMEDIAL AREAS IN SURFACE SOIL

Dr by: K. WOOSLEY	Proj. Code: 0059-001	
Ck by: C. TRIPP	App by: A. HARRIS	Sheet 1
Date: 12JAN05	DWG Name: 0059001W073	Of 1

LEGEND

- SURFACE WATER BODY
- 743 BUILDING
- AREA OF REMEDIAL VOLUME
- LF-12 TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 27S52 ● SURFACE SOIL BORING LOCATION EXCEEDING THE GROUNDWATER LEACHABILITY SCTL
- 30S109 ● SOIL BORING LOCATION

SAMPLE ID	
PARAMETER KEY	CONCENTRATION

PARAMETER KEY

PESTICIDE/PCBs	FDEP Groundwater Leachability SCTL (ppm)
alpha-BHC (ABHC)	0.0003
Aroclor-1260 (PCB1)	17 (PCBs Aroclor mixture)
Dieldrin (D)	0.004
Endrin aldehyde (EAH)	1 (Endrin)

NOTES

1. ALL CONCENTRATIONS ARE IN PARTS PER MILLION (PPM)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:
   - S = SOIL BORING SAMPLE
   - GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - GI = INTERMEDIATE GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - SRA/SLF = TRENCH SOIL SAMPLE
3. LAST TWO DIGITS OF SAMPLE ID INDICATE SAMPLE DEPTH

160 0 160
SCALE FEET

NAVFAC Naval Facilities Engineering Command SOUTHERN DIVISION

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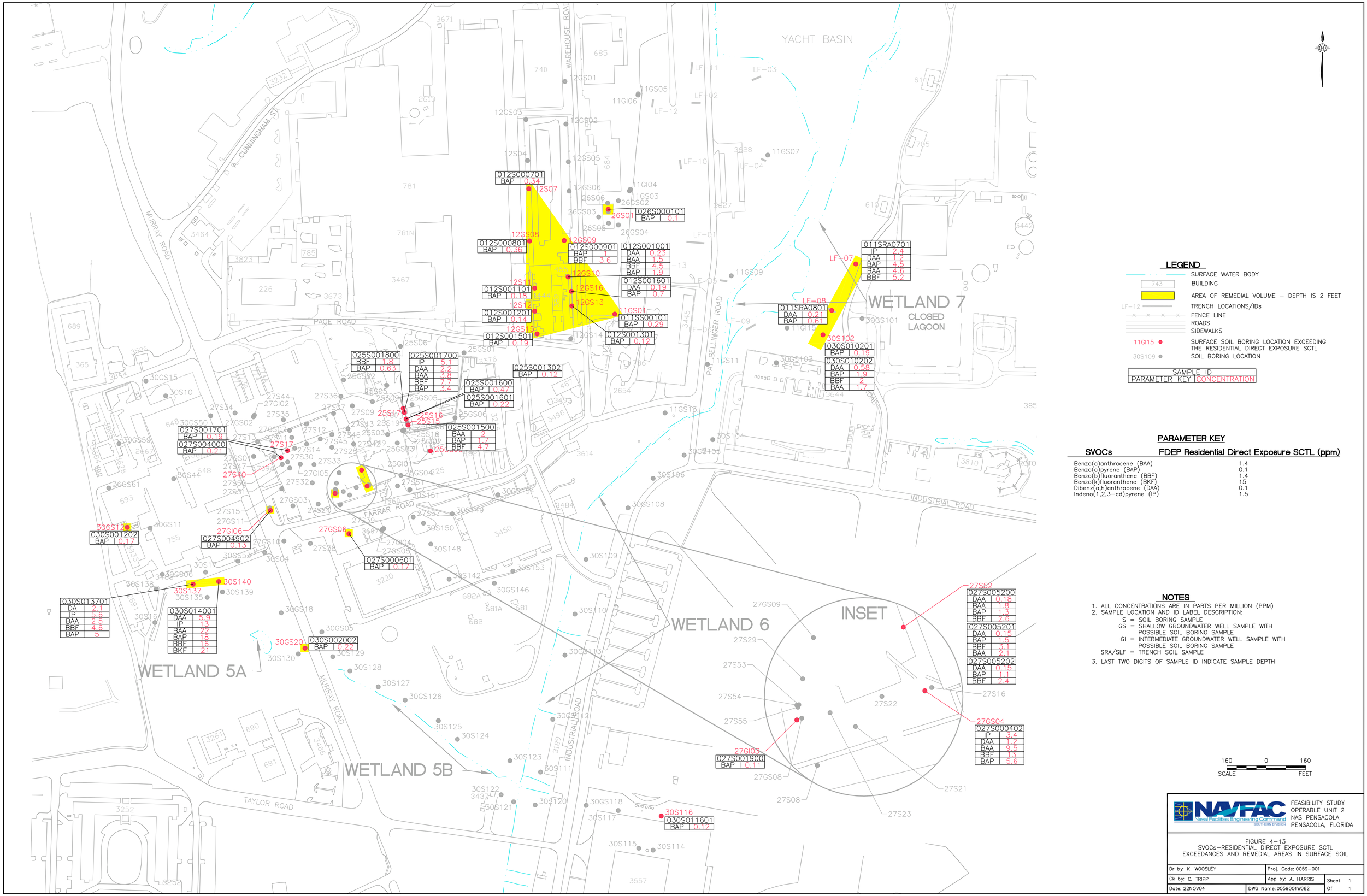
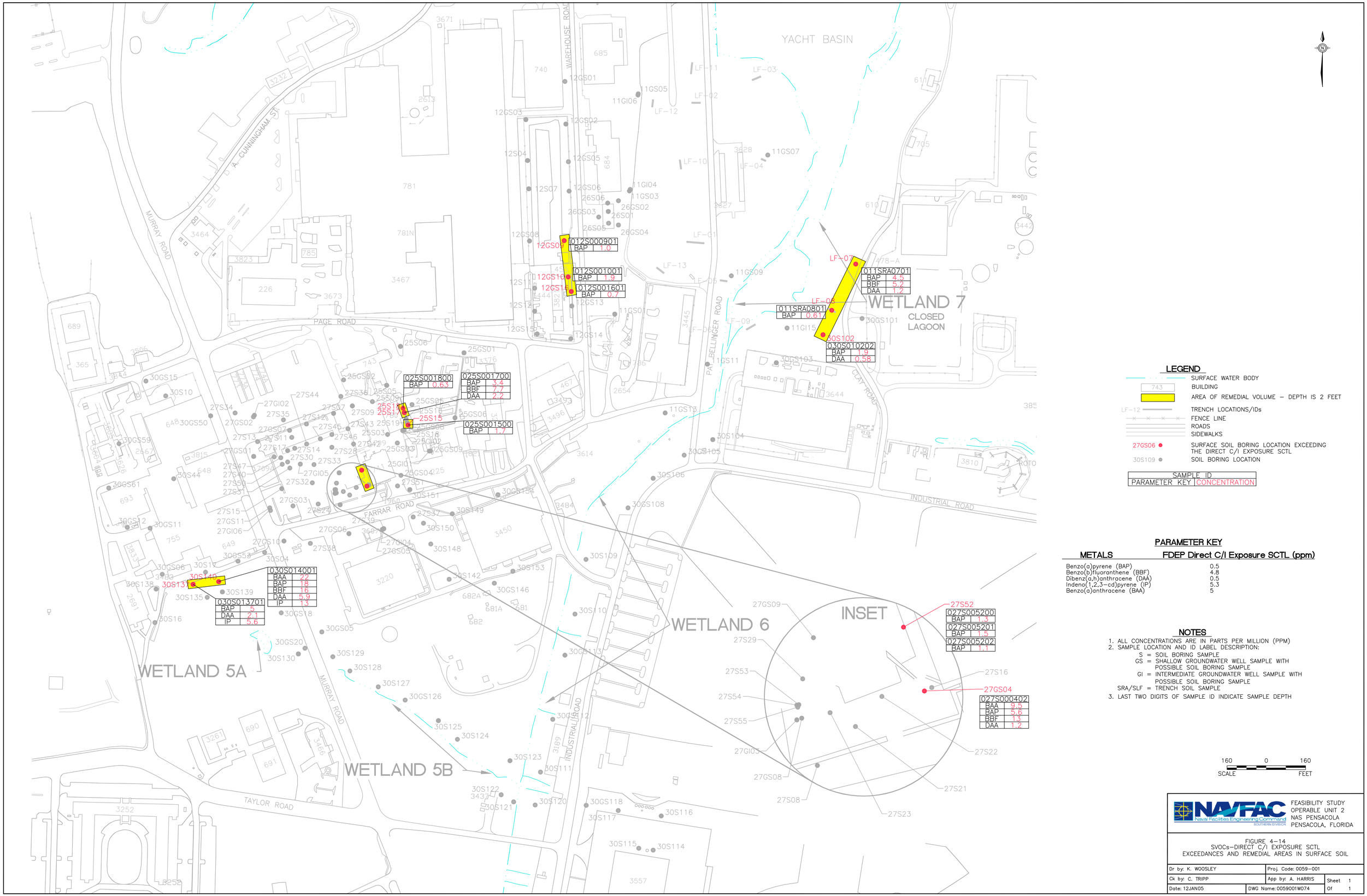
FIGURE 4-12
PESTICIDES/PCBs-GROUNDWATER LEACHABILITY SCTL EXCEEDANCES AND REMEDIAL AREAS IN SURFACE SOIL

Dr by: K. WOOSLEY	Proj. Code: 0059-001	
Ck by: C. TRIPP	App by: A. HARRIS	Sheet 1
Date: 12JAN05	DWG Name: 0059001W067	Of 1


YACHT BASIN
WETLAND 7
CLOSED LAGOON
WETLAND 6
WETLAND 5A
WETLAND 5B
INSET
WAREHOUSE ROAD
MURRAY ROAD
A. CUNNINGHAM ST.
PAGE ROAD
FARRAR ROAD
TAYLOR ROAD
INDUSTRIAL ROAD
PAT BELLINGER ROAD
012S000701 BAP 0.34
012S000801 BAP 0.36
012S000901 BAP 1 BBF 3.6
012S001001 DAA 0.23 BAA 1.5 BBF 4.5 BAP 1.9
012S001601 DAA 0.19 BAP 0.7
012S001101 BAP 0.18
012S001201 BAP 0.14
012S001501 BAP 0.19
011SS00101 BAP 0.29
012S001301 BAP 0.12
026S000101 BAP 0.1
011SRA0701 IP 2.4 DAA 1.2 BAP 4.5 BAA 4.6 BBF 5.2
011SRA0801 DAA 0.21 BAP 0.61
030S010201 BAP 0.19
030S010202 DAA 0.58 BAP 1.9 BBF 2 BAA 1.7
025S001800 BBF 1.8 BAP 0.63
025S001700 IP 5.7 DAA 2.2 BAA 3.8 BBF 7.7 BAP 3.4
025S001302 BAP 0.12
025S001600 BAP 0.47
025S001601 BAP 0.22
025S001500 BAA 2 BAP 1.7 BBF 4.7
027S001701 BAP 0.19
027S004000 BAP 0.21
030GS12 030S001202 BAP 0.17
027S004902 BAP 0.13
027S000601 BAP 0.17
030S013701 DA 2.1 IP 5.6 BAA 2.5 BBF 4.6 BAP 5
030S014001 DAA 5.9 IP 5.3 BAA 22 BAP 18 BBF 16 BKF 21
30GS20 030S002002 BAP 0.22
030S111601 BAP 0.12
027S001900 BAP 0.11
027S005200 DAA 0.18 BAA 1.8 BAP 1.3 BBF 2.6
027S005201 DAA 0.15 BAP 1.5 BBF 3.1 BAA 2.1
027S005202 DAA 0.15 BAP 1.1 BBF 2.4
027S000402 IP 3.4 DAA 1.2 BAA 9.5 BBF 13 BAP 5.6
LEGEND
SURFACE WATER BODY
BUILDING
AREA OF REMEDIAL VOLUME – DEPTH IS 2 FEET
TRENCH LOCATIONS/IDs
FENCE LINE
ROADS
SIDEWALKS
SURFACE SOIL BORING LOCATION EXCEEDING THE RESIDENTIAL DIRECT EXPOSURE SCTL
SOIL BORING LOCATION
SAMPLE ID
PARAMETER KEY CONCENTRATION
PARAMETER KEY
SVOCs FDEP Residential Direct Exposure SCTL (ppm)
Benzo(a)anthracene (BAA) 1.4
Benzo(a)pyrene (BAP) 0.1
Benzo(b)fluoranthene (BBF) 1.4
Benzo(k)fluoranthene (BKF) 15
Dibenz(a,h)anthracene (DAA) 0.1
Indeno(1,2,3-cd)pyrene (IF) 1.5
NOTES
1. ALL CONCENTRATIONS ARE IN PARTS PER MILLION (PPM)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:
S = SOIL BORING SAMPLE
GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
GI = INTERMEDIATE GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
SRA/SLF = TRENCH SOIL SAMPLE
3. LAST TWO DIGITS OF SAMPLE ID INDICATE SAMPLE DEPTH
160 0 160
SCALE FEET
NAVFAC Naval Facilities Engineering Command SOUTHERN DIVISION
FEASIBILITY STUDY
OPERABLE UNIT 2
NAS PENSACOLA
PENSACOLA, FLORIDA
FIGURE 4-13
SVOCs-RESIDENTIAL DIRECT EXPOSURE SCTL EXCEEDANCES AND REMEDIAL AREAS IN SURFACE SOIL
Dr by: K. WOOSLEY
Proj. Code: 0059-001
Ck by: C. TRIPP
App by: A. HARRIS
Sheet 1
Date: 22NOV04
DWG Name: 0059001W082
Of 1



PARAMETER KEY

METALS	FDEP Direct C/I Exposure SCTL (ppm)
Benzo(a)pyrene (BAP)	0.5
Benzo(b)fluoranthene (BBF)	4.8
Dibenz(a,h)anthracene (DAA)	0.5
Indeno(1,2,3–cd)pyrene (IP)	5.3
Benzo(a)anthracene (BAA)	5

NOTES

1. ALL CONCENTRATIONS ARE IN PARTS PER MILLION (PPM)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:
   - S = SOIL BORING SAMPLE
   - GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - GI = INTERMEDIATE GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - SRA/SLF = TRENCH SOIL SAMPLE
3. LAST TWO DIGITS OF SAMPLE ID INDICATE SAMPLE DEPTH

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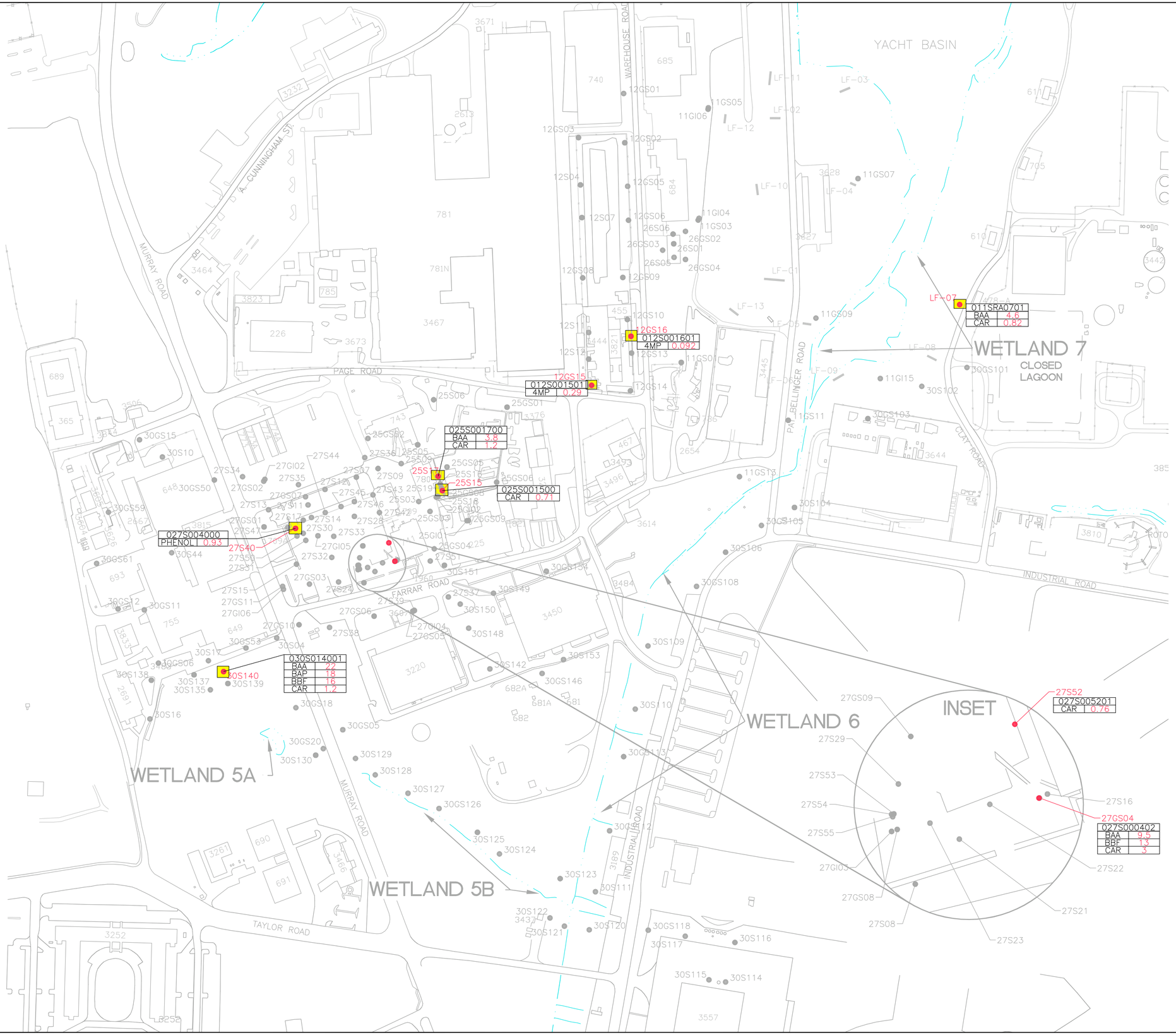
PENSACOLA, FLORIDA

FIGURE 4–14
SVOCs–DIRECT C/I EXPOSURE SCTL
EXCEEDANCES AND REMEDIAL AREAS IN SURFACE SOIL

Dr by: K. WOOSLEY	Proj. Code: 0059–001	
Ck by: C. TRIPP	App by: A. HARRIS	Sheet 1
Date: 12JAN05	DWG Name: 0059001W074	Of 1



LEGEND

- SURFACE WATER BODY
- 743 — BUILDING
- AREA OF REMEDIAL VOLUME – DEPTH IS 2 FEET
- LF-12 — TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 27S52 — SURFACE SOIL BORING LOCATION EXCEEDING THE GROUNDWATER LEACHABILITY SCTL
- 30S109 — SOIL BORING LOCATION

SAMPLE ID	
PARAMETER KEY	CONCENTRATION

PARAMETER KEY

SVOCs	FDEP Groundwater Leachability SCTL (ppm)
4-Methylphenol (p-Cresol) (4MP)	0.03
Benzo(a)anthracene (BAA)	3.2
Benzo(a)pyrene (BAP)	8
Benzo(b)fluoranthene (BBF)	10
Carbazole (CAR)	0.6
Phenol (PHENOL)	0.05

NOTES

1. ALL CONCENTRATIONS ARE IN PARTS PER MILLION (PPM)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:
   - S = SOIL BORING SAMPLE
   - GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - GI = INTERMEDIATE GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - SRA/SLF = TRENCH SOIL SAMPLE
3. LAST TWO DIGITS OF SAMPLE ID INDICATE SAMPLE DEPTH

160 0 160
SCALE FEET

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FIGURE 4-15
SVOCs-GROUNDWATER LEACHABILITY SCTL
EXCEEDANCES AND REMEDIAL AREAS IN SURFACE SOIL

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There were no exceedances of groundwater-based leachability SCTLs in subsurface soil for SVOCs.

Figure 4-16 shows the groundwater samples and estimated areas that exceed GCTLs for SVOCs. Based on the decision criteria defined in Section 4.1.3, an estimated 0.82 million gallons of groundwater exceed GCTLs for SVOCs.

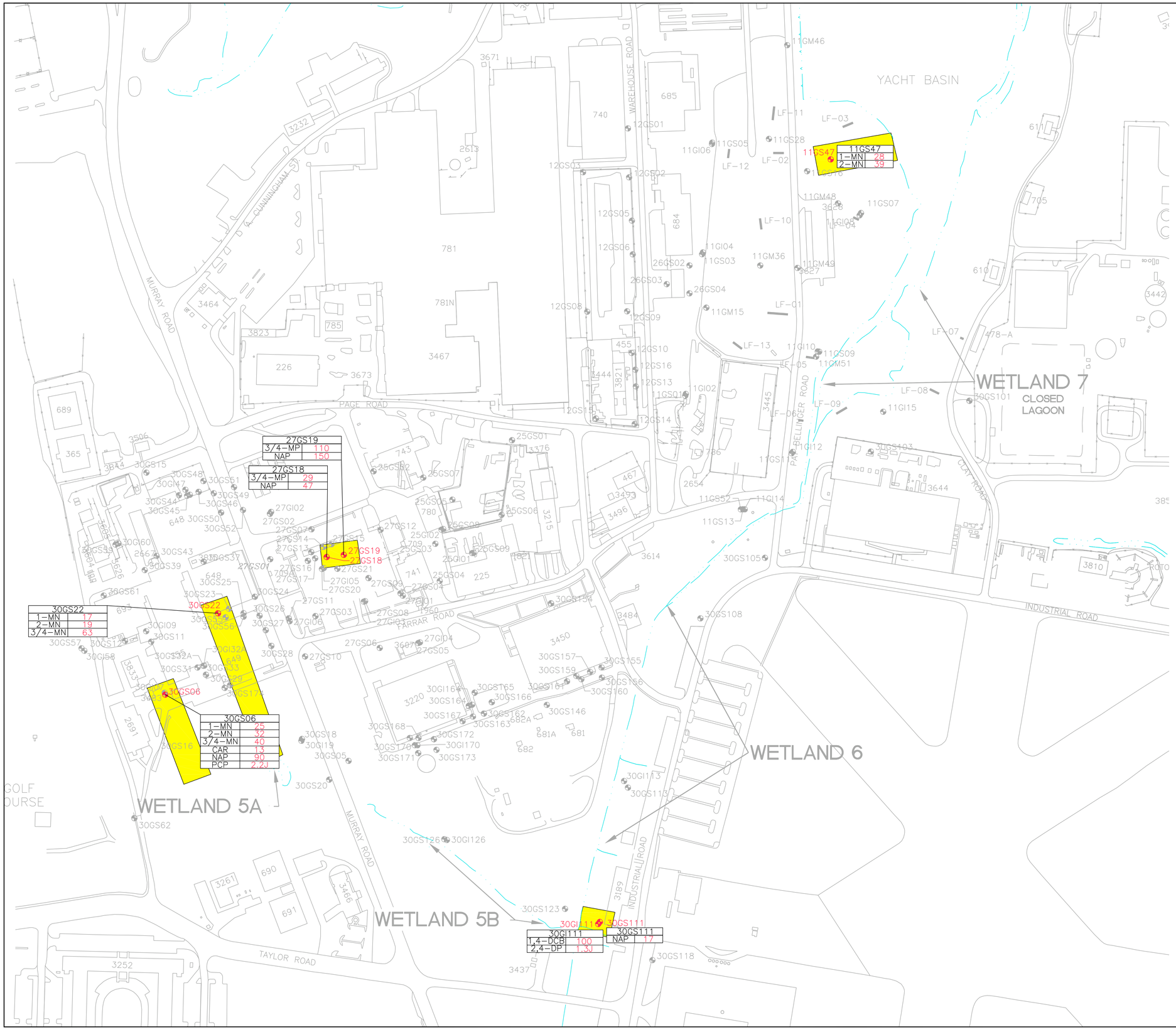
4.2.4 Volatile Organic Compounds

There were no exceedances of the residential or C/I direct exposure SCTLs for VOCs in surface soil.

Figure 4-17 shows the surface soil samples and estimated areas that exceed the groundwater-based leachability SCTLs for VOCs. Given a 2-ft depth of contamination, 2,960 CY of surface soil exceeds the groundwater-based leachability SCTLs for VOCs.

Figure 4-18 shows the subsurface soil samples and estimated areas that exceed the groundwater-based leachability SCTLs for VOCs. Given a 2-ft depth of contamination for the two detections, 240 CY of subsurface soil exceeds the groundwater-based leachability SCTLs for VOCs. The two GCTL exceedances were in samples collected immediately above the water table. Contamination in these samples is presumably a consequence of groundwater contamination, as opposed to leached soil contamination. This presumption is based on the lack of contamination above this interval, as determined from of photoionization detector readings; the seasonally variable water table; and the thickness of the capillary fringe. Thus, these leachability SCTL exceedances are associated with the aquifer matrix, and not the subsurface soil.

Figure 4-19 shows the groundwater samples and estimated areas that exceed GCTLs for VOCs. Based on the decision criteria defined in Section 4.1.3, an estimated 13.5 million gallons of groundwater exceeds GCTLs for VOCs.



LEGEND

- SURFACE WATER BODY
- 743 BUILDING
- AREA OF REMEDIAL VOLUME
- LF-10 TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 30GS155 SHALLOW OR INTERMEDIATE MONITORING WELL
- 30GS111 SHALLOW GROUNDWATER MONITORING WELL LOCATIONS/IDs WITH SAMPLE EXCEEDING THE GROUNDWATER CTL

SAMPLE ID	
PARAMETER KEY	CONCENTRATION

PARAMETER KEY

SVOCs	FLORIDA GCTL (ppb)
1,4-Dichlorobenzene (1,4-DCB)	75
1-Methylnaphthalene (1-MN)	15
2,4-Dichlorophenol (2,4-DP)	0.3
2-Methylnaphthalene	15
3-Methylphenol/4-Methylphenol (3/4-MP)	3.8
Carbazole (CAR)	1.9
Naphthalene (NAP)	15
Pentachlorophenol (PCP)	1

NOTES

1. ALL CONCENTRATIONS ARE IN PARTS PER BILLION (PPB)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:
   - S = SOIL BORING SAMPLE
   - GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - GI = INTERMEDIATE GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - SRA/SLF = TRENCH SOIL SAMPLE

160 0 160
SCALE FEET

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FIGURE 4-16
SVOCs-GCTL EXCEEDANCES AND REMEDIAL AREAS IN GROUNDWATER
MARCH 2003

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Ck by: C. TRIPP	App by: A. HARRIS	Sheet 1
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LEGEND

- SURFACE WATER BODY
- 743 BUILDING
- AREA OF REMEDIAL VOLUME – DEPTH IS 2 FEET
- LF-12 TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 27S52 ● SURFACE SOIL BORING LOCATION EXCEEDING THE GROUNDWATER LEACHABILITY SCTL
- 30S109 ● SOIL BORING LOCATION

SAMPLE ID	
PARAMETER KEY	CONCENTRATION

PARAMETER KEY

VOCs	FDEP Groundwater Leachability SCTL (ppm)
Methylene Chloride (MC)	0.02
1,2-Dichloroethane (1,2-DCA)	0.01

NOTES

1. ALL CONCENTRATIONS ARE IN PARTS PER MILLION (PPM)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:
   - S = SOIL BORING SAMPLE
   - GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - GI = INTERMEDIATE GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - SRA/SLF = TRENCH SOIL SAMPLE
3. LAST TWO DIGITS OF SAMPLE ID INDICATE SAMPLE DEPTH

160 0 160
SCALE FEET

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FIGURE 4-17
VOCs-GROUNDWATER LEACHABILITY SCTL
EXCEEDANCES AND REMEDIAL AREAS IN SURFACE SOIL

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YACHT BASIN
WETLAND 7
CLOSED LAGOON
WETLAND 6
WETLAND 5A
WETLAND 5B
INSET
11GI06
011S000606
PCE 0.03
30S138
030S013820
PCE 0.22
EBZ 19
XY 110
WAREHOUSE ROAD
A. CUNNINGHAM ST.
MURRAY ROAD
PAGE ROAD
FARRAR ROAD
PAT BELLINGER ROAD
CLAY ROAD
INDUSTRIAL ROAD
TAYLOR ROAD
LEGEND
SURFACE WATER BODY
BUILDING
TRENCH LOCATIONS/IDs
FENCE LINE
ROADS
SIDEWALKS
SUBSURFACE SOIL BORING LOCATION EXCEEDING THE GROUNDWATER LEACHABILITY SCTL
SOIL BORING LOCATION
SAMPLE ID
PARAMETER KEY CONCENTRATION
PARAMETER KEY
VOCs
FDEP Groundwater Leachability SCTL (ppm)
Tetrachloroethene (PCE) 0.03
Ethylbenzene (EBZ) 0.6
Xylene (XY) 0.2
NOTES
1. ALL CONCENTRATIONS ARE IN PARTS PER MILLION (PPM)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:
S = SOIL BORING SAMPLE
GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
GI = INTERMEDIATE GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
SRA/SLF = TRENCH SOIL SAMPLE
3. LAST TWO DIGITS OF SAMPLE ID INDICATE SAMPLE DEPTH
160 0 160
SCALE FEET
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FIGURE 4-18
VOCs-GROUNDWATER LEACHABILITY SCTL EXCEEDANCES AND REMEDIAL AREAS IN SUBSURFACE SOIL
MARCH 2003
Dr by: K. WOOSLEY
Proj. Code: 0059-001
Ck by: C. TRIPP
App by: A. HARRIS
Sheet 1
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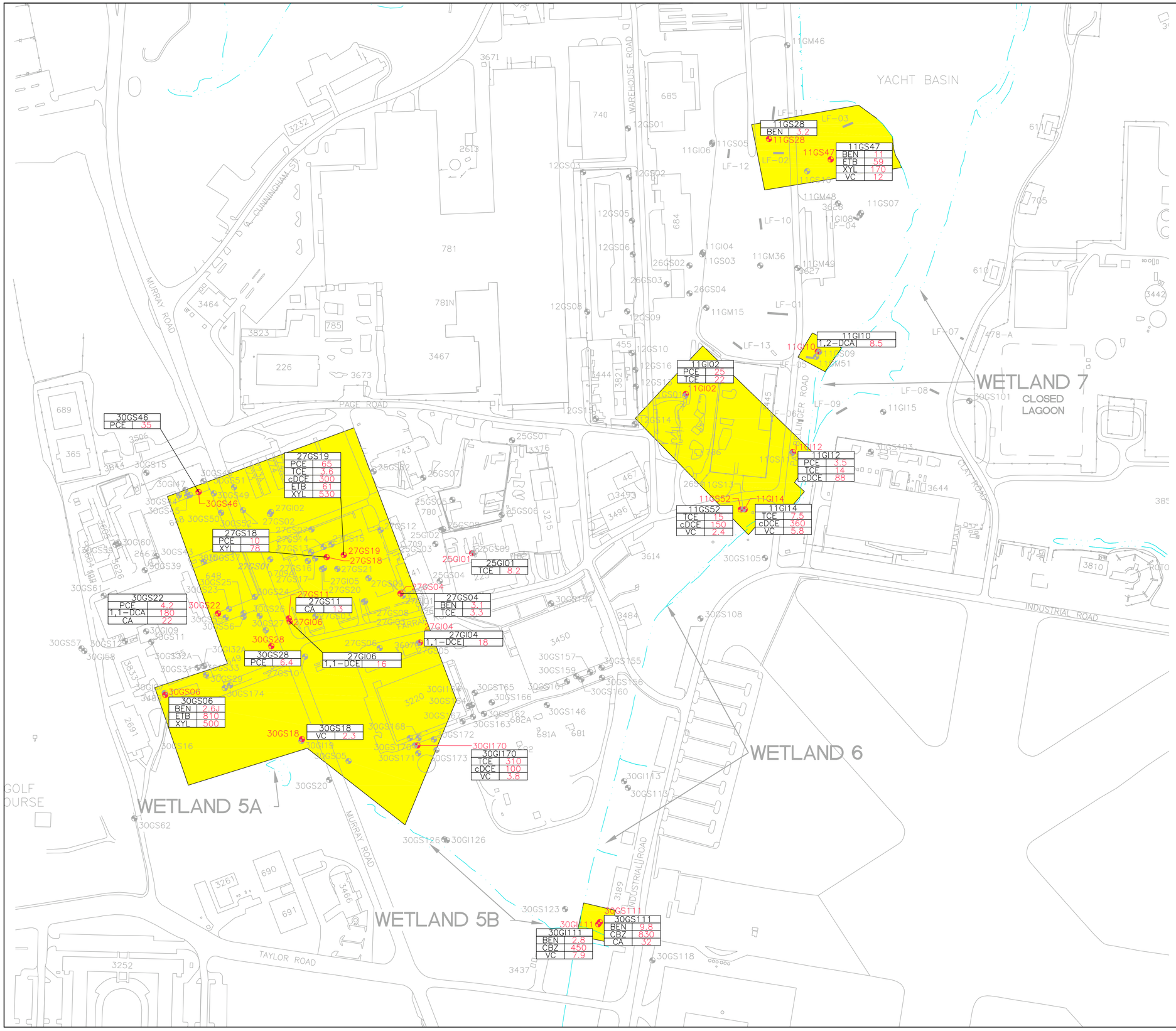

LEGEND

- SURFACE WATER BODY
- 743 — BUILDING
- AREA OF REMEDIAL VOLUME
- LF-10 — TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 30GS155 — SHALLOW OR INTERMEDIATE MONITORING WELL
- 30GS111 — SHALLOW GROUNDWATER MONITORING WELL LOCATIONS/IDs WITH SAMPLE EXCEEDING THE GROUNDWATER CTL

SAMPLE ID	
PARAMETER KEY	CONCENTRATION

PARAMETER KEY

VOC	FLORIDA GCTL (ppb)
Benzene (BEN)	1
Chlorobenzene (CBZ)	100
Chloroethane (CA)	13
1,1-Dichloroethane (1,1-DCA)	76
1,2-Dichloroethane (1,2-DCA)	3
1,1-Dichloroethene (1,1-DCE)	7
cis-1,2-Dichloroethene (cDCE)	70
Ethylbenzene (ETB)	30
Tetrachloroethene (PCE)	3
Trichloroethene (TCE)	3
Vinyl Chloride (VC)	1
Xylenes [Total] (XYL)	20

NOTES

1. ALL CONCENTRATIONS ARE IN PARTS PER BILLION (PPB)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:
   - S = SOIL BORING SAMPLE
   - GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - GI = INTERMEDIATE GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - SRA/SLF = TRENCH SOIL SAMPLE

160 0 160
SCALE FEET

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FIGURE 4-19
VOCs-GCTL EXCEEDANCES AND REMEDIAL AREAS IN GROUNDWATER
MARCH 2003

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Ck by: C. TRIPP	App by: A. HARRIS	Sheet 1
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4.2.5 Exceedances of Surface Water Criteria

As stated in 62-780.680(2)(c)3, when groundwater potentially affects marine water, or freshwater surface water separating the source property from marine surface water, the 62-777, FAC, Table 1 marine surface water criteria shall apply to groundwater. Figure 4-20 shows the surface water exceedances in downgradient monitoring wells closest to surface water.

LEGEND

- SURFACE WATER BODY
- 743 — BUILDING
- LF-10 — TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 30GS155 — SHALLOW OR INTERMEDIATE MONITORING WELL
- 30GS111 — SHALLOW GROUNDWATER MONITORING WELL LOCATIONS/IDs WITH SAMPLE EXCEEDING THE GROUNDWATER CTL

SAMPLE ID	
PARAMETER KEY	CONCENTRATION

DETECTIONS THAT EXCEED MSWCTL BUT DO NOT EXCEED GCTL ARE SHOWN IN BOLD.

PARAMETER KEY

PARAMETERS	MSWCTL	NASP GROUNDWATER REFERENCE
Aluminum	1500	3882
Cadmium	9.3	3.40
Iron	300	1707
Lead	8.5	1.60
Copper	3.7	16.20
Zinc	86	153.2
2-Methylnapthalene (2-MN)	30	NA
Anthracene (ANTH)	110000	NA
Fluoranthene (FLUOR)	370	NA
Napthalene (NAP)	26	NA
Pyrene (PYR)	11000	NA
1,4 Dichlorobenzene (1,4DCB)	3	NA
Chlorobenzene (CBZ)	17	NA
Tetrachloroethene (PCE)	8.85	NA
Ethylbenzene (EBZ)	610	NA
Xylenes (XY)	370	NA
Vinyl Chloride (VC)	2.4	NA

NOTES

1. ALL CONCENTRATIONS ARE IN PARTS PER BILLION (PPB)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:

FSWCTL = FRESH SURFACE WATER CLEANUP TARGET LEVEL
MSWCTL = MARINE SURFACE WATER CLEANUP TARGET LEVEL
NA = NOT APPLICABLE

160 0 160
SCALE FEET

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FIGURE 4-20
SURFACE WATER CRITERIA EXCEEDANCES IN DOWNGRADIENT GROUNDWATER LOCATIONS
MARCH 2003

Dr by: K. WOOSLEY	Proj. Code: 0059-001	
Ck by: C. TRIPP	App by: A. HARRIS	Sheet 1
Date: 11/09/05	DWG Name: 0059001B046	Of 1

5.0 TECHNOLOGY SCREENING

This section describes the identification and screening of applicable remedial technologies. Once identified, the technologies are qualitatively evaluated for effectiveness, implementability, and cost. The identified remedial technologies are subsequently eliminated from, or retained for, further consideration.

5.1 Identification and Evaluation of Remedial Technologies

Remedial technologies were identified from the *Remediation Technologies Screening Matrix and Reference Guide, Fourth Edition* (Van Deuren et al., 2002). This screening matrix provided a basis for the identification of remedial technologies, as some technologies were added and others discounted. The technology screening matrix facilitated the identification of in situ biological and physical/chemical soil treatment technologies; ex situ biological, physical/chemical, and thermal soil treatment technologies; containment and other technologies for soil; in situ biological and physical/chemical groundwater treatment technologies; ex situ biological and physical/chemical groundwater treatment technologies; and groundwater containment technologies. The screening matrix provides qualitative estimates of the technology's availability, suitability for different types of contaminants, relative overall cost, and whether the technology is capital or O&M cost intensive. Technology descriptions are also given in this documentation.

In Tables 5-1 and 5-2, the identified soil and groundwater technologies are briefly described and qualitatively evaluated for OU 2 based on the implementability, effectiveness, and cost criteria. These tables are consistent with technology screening techniques presented in the NCP and USEPA guidance because they include containment, removal, disposal, and treatment options.

Table 5-1
Soil Technology Screening for Operable Unit 2

Technology	Description	Implementability	Effectiveness	Cost
In situ Biological Treatment				
Bioventing	Air is either extracted from or injected into the unsaturated soils to increase oxygen concentrations and stimulate biological activity. Bioventing is applicable for any contaminant that more readily degrades aerobically than anaerobically. This process is used to deliver amendments to zones deeper than can be managed by bioremediation practices alone. Flow rates are much lower than soil vapor extraction, minimizing volatilization and release of contaminants to the atmosphere. Where preferential pathways exist in the vadose zone, air flow may not reach all contaminated media.	Bioventing would require the construction of wells and surface trenches for associated piping. O&M equipment would need to be maintained. Bioventing would need to be coordinated with radioactive soil remediation plans.	Bioventing is generally not applicable for the remediation of shallow soils. The high water table and permeable cover may preclude its use. Not effective for metals and trichloroethene. For amenable contaminants, bioventing is unlikely to be more effective than natural degradation processes at this site, given that surface soil is already highly oxygenated.	Bioventing is relatively inexpensive, though ongoing use of blowers and ancillary piping will require O&M. A high spatial resolution under permeable cover may make bioventing relatively expensive.
Enhanced Bioremediation	Indigenous aerobic and/or anaerobic microbes are stimulated by amending contaminated soils with substrate, nutrients, oxygen, and water to enhance biodegradation. Bioaugmentation is also possible. Amendments may be applied through irrigation or mechanical means such as tillers or rippers. Effectiveness is limited at depth for mechanical mixing. Effectiveness may be limited if deeper zones exhibit preferential pathways and amendment delivery is irregular.	May limit land use. Equipment access (for mechanical mixing) may be limited in areas. Bioremediation near Wetlands 7 and 64 would require floodplain compliance. Bioremediation would need to be coordinated with radioactive soil remediation plans.	Generally only effective for contaminated soil at less than 2-foot depth, which can be amended by mechanical means. The homogeneity of the sandy soils may facilitate uniform amendment delivery, however. Non-halogenated SVOCs and VOCs may be readily bioremediated, although degradation rates are slower for SVOCs. Bioremediation may be limited in sandy soils because of natural carbon concentrations, but is unlikely to be restricted by other environmental factors.	Bioremediation costs are typically variable because the need for amendments is highly site specific. However, in situ bioremediation costs are typically lower than other in situ technologies such as SVE.

Table 5-1
Soil Technology Screening for Operable Unit 2

Technology	Description	Implementability	Effectiveness	Cost
Phyto-remediation	Phytoremediation is the use of plants to remove, contain, and/or degrade contaminants. Examples include: enhanced rhizosphere biodegradation, phytoaccumulation, phytodegradation, and phytostabilization. Climatic or hydrologic conditions may restrict the rate of growth of the remediation plants.	Current and future site use may make phytoremediation may preclude its implementation. Impacted areas posing risk are currently used for parking and access to adjacent buildings. Phytoremediation would eliminate the use of these areas. Phytoremediation would need to be coordinated with radioactive soil remediation plans.	Phytoremediation is an innovative technology that may be effective for shallow contamination, within the root zones of plants. Shallow contamination is easily monitored and controlled. Although high concentrations of hazardous materials can be toxic to plants, contaminant concentrations at OU 2 are not excessive. Although phytoremediation is a treatment technology, it is also an immobilization and containment technology. Because of plant mortality, the immobilization and containment mechanisms may be reversible.	Costs for phytoremediation are expected to be low compared with other in situ techniques. Maintenance costs are also expected to be relatively low, consisting of monitoring, watering costs, and plant replacement.
In situ Physical/Chemical Treatment				
In situ Solidification/ Stabilization (S/S)	In situ S/S immobilizes contaminants by mixing site soil with Portland cement, lime, or a chemical reagent to reduce the mobility of the contaminant. Large augering equipment is used for in-place mixing of soils with the reagent. This technology will likely leave a solid mass (similar to concrete) onsite.	In situ S/S is technically implementable at OU 2. The addition of amendments would increase the soil volume and result in some mounding. The stabilized mass may be left in place, and use of the area for parking and access may continue. S/S would need to be coordinated with radioactive soil remediation plans.	In situ S/S can be an effective containment strategy for PAH compounds. However, this technology works better for inorganics including radionuclides. Some organic-contaminated soils may delay or inhibit reactions necessary for solidification. Long-term, the stabilized mass can degrade, particularly if subject to repeated abuse. S/S is not a permanent treatment technology and does not remove or destroy contaminants; rather, contaminants are immobilized. Treated media typically must be managed long term (e.g., through land use controls and monitoring).	In situ S/S costs typically vary given the stabilizing material required (e.g., fly ash, Portland cement, etc.). The shallow depths of contaminated soil may facilitate less expensive construction methods.

Table 5-1
Soil Technology Screening for Operable Unit 2

Technology	Description	Implementability	Effectiveness	Cost
Ex situ Biological Treatment (Assuming Excavation)				
Solid Phase Bioremediation	Excavated soils are mixed with amendments, nutrients, enzymes, or fillers and placed in aboveground enclosures. Mixing may be required, as in a traditional landfarming application. Conversely, biopiles may be used simply to deliver oxygen uniformly throughout a large pile. Ex situ biological systems may be designed to degrade specific compounds and maintain specified degradation conditions (aerobic vs. anaerobic). Mechanical mixing such as tilling or turning of windrows may be required.	Existing structures and utilities may impede or restrict excavation. Landfarming may have large space requirements, precluding its use. Any ex situ remedial action would need to be coordinated with radioactive soil remediation plans.	Ex situ bioremediation systems may be tailored to the specific contaminant requiring treatment. Bioremediation is typically limited to organic compounds. Heavy metals may be toxic to microorganisms. Bioremediation half-lives for PAHs and PCBs may be longer than more degradable compounds such as BTEX, which may extend the remediation time frame.	Ex situ solid phase bioremediation is inexpensive compared with other ex situ techniques. However, given the need to design specific nutrient amendments and process control systems, more recalcitrant organics are typically more expensive to treat.
Slurry Phase Biological Treatment	Slurry-phase bioreactors containing co-metabolites and specially adapted microorganisms can be used to treat halogenated VOCs and SVOCs, pesticides, and PCBs. An aqueous slurry is created by combining soil with water and other additives. The slurry is mixed continuously to keep solids suspended and microorganisms in contact with the soil contaminants. Upon completion of the process, the slurry is dewatered and the treated soil is disposed.	Existing structures and utilities may impede or restrict excavation. Moreover, a large amount of space is required for slurry phase ex situ bioremediation. Any ex situ remedial action would need to be coordinated with radioactive soil remediation plans.	Slurry-phase bioreactors are used primarily to treat nonhalogenated SVOCs and VOCs in excavated soils or dredged sediments. Ex situ bioremediation systems may be tailored to the specific contaminant requiring treatment. Biodegradation is typically limited to organic compounds, and heavy metals may be toxic to microorganisms. Remediation half-lives for PAHs may be slower than more degradable compounds such as BTEX, which may extend the remediation time frame.	Ex situ slurry phase bioremediation is expensive compared with other biological techniques, due to the controls and materials handling required.

Table 5-1
Soil Technology Screening for Operable Unit 2

Technology	Description	Implementability	Effectiveness	Cost
Ex situ Physical/Chemical Treatment (Assuming Excavation)				
Chemical/ Physical Oxidation (permangan-ate flooding, Fenton's reagent, wet air oxidation, supercritical water oxidation)	Chemical oxidation is a process in which the oxidation state of a contaminant is increased while the oxidation state of the reactant is decreased. The reactant can be another element, including the oxygen molecule, or it may be a chemical species containing oxygen such as hydrogen peroxide or chlorine dioxide. In the case of physical oxidation technologies, wet air oxidation and supercritical water oxidation both use high pressure and temperature to treat organic contaminants.	Existing structures and utilities may impede or restrict excavation. Moreover, a large amount of space is required for ex situ chemical/physical oxidation bioremediation. Any ex situ remedial action would need to be coordinated with radioactive soil remediation plans.	This technology is effective in treating media contaminated with halogenated and non-halogenated SVOCs and VOCs, PCBs, pesticides, cyanides, and volatile and nonvolatile metals. Wet air oxidation can treat hydrocarbons and other organic compounds. Supercritical water oxidation is applicable for PCBs and other stable compounds.	Costs for chemical oxidation processes may be comparable to soil washing costs, given the need to construct and operate ex situ reactors, and the need to control reagents and reactor conditions. Costs may vary widely with the type of oxidation technique implemented.
Soil Washing (Chemical, Acid, and Solvent Extraction and Separation Techniques)	Excavated soil is washed with aqueous-based solutions to separate contaminants sorbed onto fine particles from the rest of the soil matrix. The fractions of soil to be treated are processed in a slurry with specific leachant mixtures to ionize target metals. The solvent/waste mixture is then treated further to develop a concentrated leaching solution which may be treated or disposed offsite. Traditional soil washing options may also include separation techniques that concentrate contaminated solids through physical and chemical means. These processes seek to detach contaminants from their medium (e.g., soil, sand, or other binding material). Gravity separation, magnetic separation, and sieving/physical separation are examples of this technology.	Existing structures and utilities may impede or restrict excavation. Soil washing systems will require operational space as well as possible water and sewer connections. Any ex situ remedial action would need to be coordinated with radioactive soil remediation plans.	Overall, this technology is effective at removing SVOCs and inorganics. It is less effective at treating VOCs. In general, acid extraction techniques are suitable for treating soils contaminated by heavy metals. Solvent extraction has been shown to be effective in treating soils containing primarily organic contaminants, but is generally least effective on very high molecular-weight organic and very hydrophilic substances. Soils with higher clay content may reduce extraction efficiency and require longer contact times. High humic content in soil may require pretreatment. It may be difficult to remove organics adsorbed to clay-size particles. Soil washing is a permanent treatment technology that removes contaminants from soil to another medium (e.g., solvent, carbon, etc.). Treatment residuals then may require treatment or disposal. Soil washing solvents may also pose environmental risks.	Soil washing is typically an expensive remediation alternative because of the highly site-specific design requirements and the need to treat and/or dispose of the leaching solvent. Magnetic separation is specifically used on heavy metals, radionuclides, and magnetic radioactive particles such as uranium and plutonium compounds.

Table 5-1
Soil Technology Screening for Operable Unit 2

Technology	Description	Implementability	Effectiveness	Cost
Ex situ Solidification/ Stabilization (S/S)	Contaminants are physically bound or encased within a stabilized mass, or chemical reactions are induced with stabilizing agents. The contaminants are not removed or destroyed, but their mobility is reduced. Examples of S/S technologies include: bituminization, emulsified asphalt, modified sulfur cement, polyethylene extrusion, pozzolan/Portland cement, radioactive waste solidification, sludge stabilization, and soluble phosphates.	Existing structures and utilities may impede or restrict excavation. Moreover, a large amount of space is required for ex situ S/S. Any ex situ remedial action would need to be coordinated with radioactive soil remediation plans.	Ex situ S/S is the best demonstrated technology for multiple compounds. This technology works well for inorganics including radionuclides. Although organic-contaminated soil may be treated with solidification/stabilization, some organics can delay or inhibit reactions necessary for solidification. S/S is not a permanent treatment technology and does not remove or destroy contaminants; rather, contaminants are immobilized. Treated media typically must be managed appropriately, i.e., landfilled or contained onsite. Where used as asphalt or similar covers, degradation due to normal asphalt weathering should be considered.	Ex situ S/S costs typically vary given the stabilizing material required (e.g., fly ash, Portland cement, etc.). However, ex situ S/S is relatively inexpensive, compared with other ex situ technologies.
Ex situ Thermal Treatment (Assuming Excavation)				
Incineration/ Pyrolysis	Incineration burns contaminated soil at high temperatures (1,600 - 2,200°F) to volatilize and combust organic contaminants. A combustion gas treatment system must be included with the incinerator. The circulating bed combustor, fluidized bed reactor, infrared combustor, and rotary kiln are several types of incinerators. Pyrolysis chemically changes contaminated soil by heating it in the absence of air. Pyrolysis can be achieved by limiting oxygen to rotary kilns and fluidized bed reactors. Molten salt destruction is another example of pyrolysis.	Existing structures and utilities may impede or restrict excavation. Offsite incineration and/or pyrolysis is the most practicable means of remedy. Soils would need to be dried to decrease moisture content to below 1%. The offsite treated soils would be disposed as nonhazardous waste. Any ex situ remedial action would need to be coordinated with radioactive soil remediation plans.	Incineration may be effective in treating organic-contaminated soil but not for soil with metals as the primary contaminants. The target contaminant groups for pyrolysis are SVOCs and pesticides. Pyrolysis is not effective in either destroying or physically separating inorganics from the contaminated medium. Volatile metals may be removed by the higher temperatures, but are not destroyed.	Incineration and pyrolysis are typically very expensive remedial options compared with other ex situ technologies.

Table 5-1
Soil Technology Screening for Operable Unit 2

Technology	Description	Implementability	Effectiveness	Cost
Thermal Desorption	Soil is heated to 200 - 1,000°F to separate VOCs, water, and some SVOCs from the solids into a gas stream. The applied temperature is dependent on the volatility of the contaminants. The organics in the gas stream must be treated or captured.	Existing structures and utilities may impede or restrict excavation. Thermal desorption may be conducted onsite and vendors are readily available. Some thermal desorbers may be regulated as incinerators, depending on construction. Testing and optimization would be required. Treated soil may be returned to place of origin. Any ex situ remedial action would need to be coordinated with radioactive soil remediation plans.	Thermal desorption units are primarily effective at removing organic contaminants. Residence time and temperature inside the unit can be varied to volatilize recalcitrant organics. Inorganic contaminants or metals that are not particularly volatile will not be effectively removed by thermal desorption. Vapor phase organics must be concentrated and treated or otherwise disposed.	Although less expensive than other ex situ thermal treatment methods, thermal desorption is still comparatively expensive. Costs increase with the degree of materials handling, pre-and post-treatment, and off-gas controls required.
Containment				
Surface Cap	Capping is a containment technology that limits direct human exposure and reduces the infiltration of precipitation and leaching of soil contamination. Capping materials include soil, asphalt, and concrete.	Soil contamination is adjacent to roadways and parking lots and could be readily paved. Utility re-routing may be required under capped areas. Capping near Wetlands 7 and 64 would require floodplain compliance. Capping would need to be coordinated with radioactive soil remediation plans.	Surface caps eliminate the direct exposure pathway and limit infiltration, which reduces the leachate exposure pathway. With ongoing maintenance, the long-term effectiveness of a cap is high. Although capping is an effective means of eliminating risk pathways and limiting contaminant mobility, it does not meet the preference for treatment, nor does it reduce contaminant toxicity or volume.	Costs vary based on cap design. When only direct exposure exceedances are observed, the cap need only eliminate the direct exposure. When leachate CTL exceedances are observed, the cap should be designed to sufficiently reduce infiltration. Costs for common capping material such as soil, asphalt, or concrete are comparatively low. Maintenance costs are also low.

Table 5-1
Soil Technology Screening for Operable Unit 2

Technology	Description	Implementability	Effectiveness	Cost
Other Treatment Technologies				
Excavation and Offsite Disposal	Contaminated soil is excavated and disposed offsite at a licensed waste disposal facility.	Existing structures and utilities may impede or restrict excavation. The excavated areas would be backfilled with clean fill with minimal impact to operations at adjacent buildings. Any ex situ remedial action would need to be coordinated with radioactive soil remediation plans.	Excavation with offsite disposal is expected to be an effective remediation option for all contaminants because the risk pathway is eliminated.	Costs for excavation and offsite disposal vary, depending on whether waste is classified as hazardous. If contaminant concentrations exceed 10 times universal treatment standards (UTS), soils may require ex situ treatment prior to disposal.

Notes:

BTEX = benzene, toluene, ethylbenzene, and xylene
CTL = cleanup target level
O&M = operation and maintenance
PAH = polynuclear aromatic hydrocarbons
PCB = polychlorinated biphenyl
SVE = soil vapor extraction
SVOC = semivolatile organic compound
UTS = universal treatment standard
VOC = volatile organic compound

Table 5-2
Groundwater Technology Screening for Operable Unit 2

Technology	Objectives	Implementability	Effectiveness	Cost
In situ Biological Treatment				
Enhanced Bioremediation	Indigenous microbes are stimulated by circulating amended groundwater through contaminated groundwater to enhance biodegradation. Amendments may include nutrients, carbon sources, and oxidants. Biostimulation can induce aerobic or anaerobic conditions. Bioaugmentation is possible.	Technology may require pilot testing to gauge effectiveness and to scale remedy.	In situ bioremediation most readily treats non-halogenated VOCs and SVOCs but can be applied for halogenated VOCs and SVOCs. Although anaerobic bioremediation may be applied for Cr(VI), it is generally ineffective for inorganics.	In situ bioremediation is generally less expensive than other in situ treatment technologies.
Monitored Natural Attenuation (MNA)	The effectiveness of natural attenuation processes are monitored to determine whether RGs can be achieved naturally.	MNA may be implementable in lower-risk groundwater at OU 2, which is sufficiently distant from surface water receptors.	Natural attenuation processes may include dilution, dispersion, volatilization, stabilization, degradation, and sorption. Because metals, VOCs, and SVOCs exceeded surface waters CTLs in monitoring wells adjacent to Wetlands 5A, 6, and 7, MNA is not a viable technology for OU 2.	MNA costs are predominantly associated with monitoring but may include capital costs for monitoring well construction. If feasible, MNA has a lower cost than other treatment options.
Phyto-remediation	Plants are used to remove, contain, and/or degrade contaminants in groundwater. Groundwater phytoremediation includes processes rhizofiltration, phytotransformation, and phytostimulation. Deep-rooted trees may be capable of hydraulically capturing groundwater in lower permeability areas adjacent to surface water.	A treatability study is required prior to full-scale implementation. Plant species are selected based on the 1) groundwater evapotranspiration potential, 2) ability to produce degradative enzymes, 3) contaminant bioaccumulation rate, 4) depth of the root zone, and 5) ability to adapt to the specific climate.	Phytoremediation may be capable of treating a wide range of contaminants, including petroleum hydrocarbons, chlorinated solvents, pesticides, metals, radionuclides, explosives, and excess nutrients. Because it is an emerging technology, limited data are available to evaluate its overall effectiveness. Contamination is reduced over a long period of time (years). Limited to shallow groundwater.	Phytoremediation costs are relatively low compared to other in situ technologies. Maintenance costs are relatively low and consist of monitoring, watering, and horticulture costs.

Table 5-2
Groundwater Technology Screening for Operable Unit 2

Technology	Objectives	Implementability	Effectiveness	Cost
In situ Physical/Chemical Treatment				
Air Sparging/ Soil Vapor Extraction (SVE)	Volatile contaminants are removed from groundwater by increasing the air flow through the saturated or vadose zone. Air may be sparged into the saturated zone and may be captured in the vadose zone through SVE. Bioventing is similar technology, where sufficient air is supplied to stimulated indigenous aerobic microbes.	Air sparging is generally accompanied by SVE, especially under foundations and covered surfaces. SVE air emissions must be permitted and may require treatment.	Although effective for VOCs, air sparging and SVE do not treat SVOCs and inorganics. Because of the permeable soil and high water table, SVE would have limited effectiveness under pervious cover.	Air sparging capital and O&M costs are generally lower than other in situ technologies. SVE costs are more moderate, because capital and O&M costs of treatment.
Chemical Oxidation	Oxidants are applied to groundwater through wells and/or temporary direct push points. Oxidants include peroxide, permanganate, ozone, and Fenton's reagent. Oxidants increase the contaminant's oxidation state, which may promote sorption or lower toxicity end-products.	Generally implemented as a source area treatment. Groundwater UIC permit required to inject oxidant through wells and temporary direct push points. Hazardous conditions could be created when high oxidant concentrations are applied to explosive vapors.	Chemical oxidation can be effective for treating halogenated and non-halogenated VOCs and SVOCs, PCBs, pesticides, cyanide, and metals. Oxidants are also consumed by other reduced species, which may increase oxidant requirements. Oxidants should be well mixed with contaminants to be effective, which may be feasible in homogeneous aquifer. There may be limited residual treatment capacity. In heterogeneous aquifers, untreated contaminants may leach into groundwater and require additional treatment.	Chemical oxidation costs are moderate. Capital costs vary because of number of wells, radius of influence, and required oxidant. Maintenance costs are limited to monitoring and possible supplemental treatment.
Chemical Reduction	A chemical reductant, e.g., ferrous iron or dithionite, is added to extracted water and injected into the aquifer. Oxidized contaminants such as TCE and Cr(VI) are reduced to less toxic end-products.	May be applied for source area treatment or to create residual treatment capacity downgradient of plume. Class IV groundwater UIC permit required to re-inject hazardous groundwater. Residual dithionite breakdown products may require extraction.	This is an innovative technology that has been applied for TCE and Cr(VI). Treatment capacity is generally resilient and degrades due to reduction of influent oxygen, nitrate, and oxidized contaminants and leaching of ferrous iron. Although effective for oxidized contaminants, may result in increased iron leaching to surface waters.	Chemical reduction costs are moderate. Capital costs vary because of number of wells, radius of influence, and required reductant. Maintenance costs are limited to monitoring and possible supplemental treatment.
Electrokinetic Remediation	A low-intensity electrical current is applied across electrode pairs that have been implanted in the ground across a contaminated source zone. Contaminants are electro-kinetically transported by electrophoresis, electro osmosis, and electro-migration.	Because of the presence of buried metallic conductors, electrokinetic remediation may not be implementable at OU 2.	Electrokinetic remediation has been successful for the remediation of heavy metals in their elemental form. Potential problems affecting this remedy such as salinity and buried metallic objects make this technology inappropriate for OU 2.	Electrokinetic remediation costs depend on specific chemical and hydraulic properties at the site. Energy consumption is directly proportional to contaminant migration rates.

Table 5-2
Groundwater Technology Screening for Operable Unit 2

Technology	Objectives	Implementability	Effectiveness	Cost
Permeable Reactive Barrier (PRB)	PRBs are typically constructed in trenches downgradient of the source zone. The reactive media is typically designed to reduce contaminants to less-toxic end-products and/or promote their sorption. The reactive media may include zero-valent iron (ZVI), chelators, or biostimulated media. PRBs may be combined with subsurface barriers to funnel groundwater through the PRB.	Because the top of the underlying clay layer exists at 40 to 65 ft at OU 2, the PRB would likely be constructed as a hanging wall. PRBs should have a higher permeability than the surrounding formation to not inhibit flow. This may be problematic given the high permeability of the formation.	PRBs are primarily designed to treat halogenated VOCs and SVOCs and inorganic compounds. The long-term effectiveness is a function of the life span of the reactive media. ZVI may be depleted by groundwater oxidants and chelators by sorption capacity, and they may require periodic replacement. Biostimulated media must be maintained to remain effective.	PRBs have relatively high capital costs associated with barrier installation and testing. ZVI and chelator PRBs have very low O&M costs, but may require periodic replacement. Biostimulated media have higher O&M costs, but do not require replacement.
Containment				
Groundwater Pumping	Groundwater is extracted from recovery wells, French drains, and/or interceptor trenches to hydraulically contain contaminated groundwater.	Although groundwater pumping is implementable at OU 2, the Navy has a preference to not install new pump-and-treat systems.	Groundwater pumping is a proven, effective means of containing groundwater contamination, when the system is reliably operated. When plumes are not reduced below CTLs, groundwater pumping turns into a long-term remedy.	Groundwater pumping is both capital and O&M intensive. Groundwater pumping must be coupled with ex situ treatment. Total remediation costs are moderate.
Subsurface Barriers	Subsurface barriers are constructed as a slurry wall, grout curtain, or sheet piling to inhibit horizontal groundwater flow. Subsurface barriers can be applied to complement a PRB or groundwater pumping or to encapsulate contaminated groundwater under an impervious cover.	Subsurface barriers would need to be constructed to an underlying clay layer to prevent seepage below the structure in the high permeability aquifer at OU 2. The top of the underlying clay layer exists at 40 to 65 ft, which is at the limits of conventional slurry wall construction depths. Due to flowing sands, deep soil augering may be most effective means of constructing barrier.	Subsurface barriers are essentially a complementary technology. They probably could not be used in conjunction with PRBs because the reactive media probably could not be constructed with a high enough permeability to convey and treat the larger groundwater volume. Subsurface barriers may be used to complement groundwater pumping when specific receptors are threatened.	Subsurface barriers are capital cost intensive, but have a moderate overall cost.

Table 5-2
Groundwater Technology Screening for Operable Unit 2

Technology	Objectives	Implementability	Effectiveness	Cost
Ex situ Biological Treatment (Assuming Pumping)				
Bioreactors	Extracted groundwater is treated with attached or suspended biological systems. In suspended growth systems such as activated sludge, contaminated groundwater circulates in an aeration basin, where a microbial population aerobically degrades organic matter. In attached growth systems such as trickling filters, microorganisms are established on an inert support matrix to aerobically degrade groundwater contaminants.	Bioreactors are typically applied to treat municipal wastewater. Implementation at OU 2 is not appropriate because of the low concentrations of contaminants in groundwater may inhibit microbial growth. Equipment and materials are readily available.	Biological reactors can destroy organic contaminants that are prone to aerobic biodegradation. However, biochemical oxygen demand loading must be high enough to support the growth of the microbes. The low level of organic contaminants present in OU 2 groundwater would not be sufficient to support the growth of microbes. Other treatment options are more effective.	Ex situ bioremediation is cost effective for large capacity systems, but impracticable for smaller systems.
Ex situ Physical/Chemical Treatment (Assuming Pumping)				
Air Stripping	Extracted groundwater is aerated to remove VOCs from the water. Aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration.	Air stripping is implementable at OU 2. The vapor discharge would require permitting and sampling. Air stripping units are prone to scaling problems and need to periodically be acid-washed. Inorganics are usually sequestered to minimize scaling.	Although air stripping is effective for VOCs, it has limited effectiveness for SVOCs, pesticides/PCBs, and metals.	Air stripping is moderately expensive. Costs significantly increase when vapor treatment is required. Scaling problems may increase O&M costs.
Granular Activated Carbon (GAC) Adsorption	Extracted groundwater is pumped through GAC canisters and contaminants are removed by sorption to the GAC.	GAC is implementable at OU 2. GAC is typically applied as either the sole treatment process or as a secondary treatment process. GAC requires replacement when the head loss increases or when contaminant breakthrough is observed. GAC canisters are usually applied in series with intermittent sampling.	GAC is a relatively nonspecific adsorbent and is effective for the removal of many organic and some inorganic contaminants. Primary treatment is often required to minimize the replacement frequency of the GAC. GAC is typically applied as a secondary treatment for high concentration organics.	GAC has moderate capital and O&M costs. When applied as secondary treatment, capital and O&M costs are marginal.

Table 5-2
Groundwater Technology Screening for Operable Unit 2

Technology	Objectives	Implementability	Effectiveness	Cost
Ion Exchange	Extracted groundwater is pumped through an ion exchange resin. Contamination is removed when ions replace less selective ions from the ion exchange resin.	Ion exchange is implementable at OU 2. Ion exchange is typically applied as a secondary treatment to remove inorganics from the waste stream.	Ion exchange is effective for inorganics, but less effective for organics. Ion exchange resins are replaced and regenerated when the resin becomes depleted. When natural inorganics, e.g., sulfate, are highly concentrated, the resin replacement frequency increases and may make the technology infeasible.	Ion exchange has moderate capital and O&M costs. When applied as secondary treatment, capital costs are marginal. O&M costs are a function of resin replacement frequency.
Coagulation/ precipitation and solids separation	Coagulants are added to extracted groundwater to form insoluble, agglomerated solids, with separation by settling or mechanical filtration.	Coagulation/precipitation is typically applied to as a primary treatment for drinking water and as a secondary treatment for municipal wastewater. Coagulation/flocculation would generate sludge which may require disposal as hazardous waste. Coagulation/flocculation may be implementable, but inappropriate for OU 2.	Coagulation/precipitation is effective at removing solids and inorganics from water. Organics may be incidentally removed by solids separation, but the effectiveness is limited.	Coagulation/precipitation is cost effective for large capacity systems, but impracticable for smaller systems.
Membrane Filtration	Extracted groundwater is pumped through membrane filters to remove dissolved solids. Polyelectrolyte-enhanced ultra-filtration can be used to remove anionic species, e.g., Cr(VI) by chelation and ultrafiltration.	Membrane filtration is implementable at OU 2. Membrane filtration is typically applied as a secondary treatment to remove dissolved solids.	Membrane filtration is typically applied to remove dissolved solids after primary filtration of the groundwater. In some cases, chelating agents may be used to bind some contaminants to facilitate their removal. High head losses may be associated with membrane filtration, which necessitate frequent membrane replacement.	Membrane filtration has moderate capital and O&M costs. As a secondary treatment, capital costs are marginal. O&M costs are functions of the required quantity of chelating agent and of the membrane replacement frequency.

Table 5-2
Groundwater Technology Screening for Operable Unit 2

Technology	Objectives	Implementability	Effectiveness	Cost
Disposal	Groundwater is extracted and discharged to the FOTW where it is treated along with the sanitary sewage.	Depending of the extraction rate, the FOTW can treat the groundwater generated at OU 2. Groundwater must meet pretreatment standards prior to disposal. High salinity groundwater may interfere with bioreactor treatment processes, however, prohibiting its acceptance.	The FOTW should be able to achieve remedial goals for groundwater.	Capital and O&M costs are marginal, but would increase if pretreatment is required.

Notes:

Cr(VI) = hexavalent chromium
CTL = cleanup target level
FOTW = federally owned treatment works
O&M = operation and maintenance
PCB = polychlorinated biphenyl
RG = remedial goal
SVE = soil vapor extraction
SVOC = semivolatile organic compound
TCE = trichloroethene, trichloroethylene
UIC = underground injection control
VOC = volatile organic compound
ZVI = zero-valent iron

5.2 Technology Screening

This section summarizes the rationale for eliminating or retaining each of the identified technologies for OU 2 soil and groundwater.

5.2.1 Eliminated Technologies

The following technologies were screened from further consideration:

In situ Soil Technologies

Bioventing was eliminated from further consideration because it has limited effectiveness for SVOCs and no effectiveness for inorganics. The high water table, permeable soil, and impervious cover in many areas of OU 2 also preclude its use.

Solidification/stabilization was eliminated from consideration because it has limited effectiveness for SVOCs and VOCs, it does not decrease contamination below the direct exposure CTLs, debris in the Site 11 landfill may inhibit construction, a large percentage of binding agents would be required for the sandy soil, and the presumed 15% bulking of the soil might inhibit further use of the property.

Ex situ Soil Technologies

The ex situ soil treatment technologies are only used when the soil will be reused onsite or when the soil exceeds land disposal restrictions (LDRs). If excavated soil contaminant concentrations exceed 10 x UTS (universal treatment standards) as defined in 40 CFR §268.48, the soil must be treated regardless of the disposal option. If the excavated soil is to be used onsite, it must be treated to C/I direct exposure and groundwater leachate CTLs. Alternately, excavated soil could be capped onsite in a disposal corrective action management unit (CAMU). Because of spatially limitations, however, disposal CAMUs were not evaluated as a disposal option.

To assess whether ex situ soil technologies are necessary, all of the soil samples collected for the OU 2 RI and RI addendum that exceeded the C/I direct exposure or groundwater-based leachability CTLs were screened against the 10 x UTS LDR criteria. Only one organic analyte exceeded the 10 x UTS LDR criterion. In sample 025S001600, the detected concentration of endrin aldehyde was

1.7 milligrams per kilogram (mg/kg). This concentration exceeded the 1 mg/kg leachability criterion for endrin in 62-777, FAC, Table II, and 10 times the 0.13 mg/kg UTS in 40 CFR §268.48. Given the marginal exceedance, the concentration of endrin aldehyde would be expected to be incidentally reduced to below the 10 x UTS LDR criterion by attenuation processes, either before or after excavation.

Although no metals exceeded the UTS, which are expressed in TCLP leachate concentrations, the soil samples were not comprehensively analyzed for TCLP metals. In the 10 soil samples collected from Site 25 and the 36 samples collected from Site 27 that were analyzed for TCLP metals, no metals were detected in the leachate. When the soil concentration of metals (in mg/kg) is divided by 20 (which yields milligrams per liter [mg/L] when all metal is assumed to leach), there were 48 metal analyte exceedances. The possibility of these 48 samples exceeding the 10 x UTS LDR criteria was evaluated by multiplying the soil concentrations (in mg/kg) by the ratio of the leachate detection limits (in mg/L) to the corresponding soil concentrations (in mg/kg) for the 46 TCLP analyte analyses performed at Sites 25 and 27. Because leachate detection limits are used as opposed to actual leachate concentrations, this calculation does not indicate an exceedance of the 10 x UTS LDR criteria. Rather, this calculation indicates that these locations may need to be re-evaluated to determine whether metals treatment may be necessary prior to land disposal. The samples identified for further TCLP evaluation are shown in Table 5-3.

Table 5-3
Soil Samples that Need Further Evaluation
to Determine Whether Land Disposal Restrictions are Pertinent for Excavated Soils

Sample	Potential Analyte Exceedances	Sample	Potential Analyte Exceedances
011SLF0303	Cadmium, Lead	012S001001	Cadmium
011SLF0405	Cadmium, Lead	012S001005	Cadmium
011SLF1006	Cadmium	012S001610	Cadmium
011SLF1305	Lead	025S001500	Lead
011SRA0501	Chromium	027S005300	Cadmium, Lead, Mercury
		027S005301	Mercury

Solid phase bioremediation was eliminated from consideration because excavated soils are not anticipated to exceed LDRs for organic constituents and bioremediation is ineffective for metals treatment.

Slurry phase bioremediation was eliminated from consideration because excavated soils are not anticipated to exceed LDRs for organic constituents and bioremediation is ineffective for metals treatment.

Chemical/physical oxidation was eliminated from consideration because excavated soils are not anticipated to exceed LDRs for organic constituents and probably do not exceed LDRs for metal constituents. Although chemical/physical oxidation may effective for treating hexavalent chromium, the oxidation state of chromium is unknown, and reduction processes may be counterproductive to other metal removal processes.

Soil washing is suitable for metals treatment using an acid extraction process. Soil washing is eliminated from further consideration, however, because the necessity of metals pretreatment is speculative. The pretreatment necessity may be assessed by resampling the locations cited in Table 5-3 and analyzing the samples for TCLP metals. Although organics are not anticipated to exceed LDRs, a separate solvent extraction process would be applicable for organics.

Solidification/stabilization is suitable technology for binding metals in the soil matrix. There is no evidence, however, to suggest that metals leach from the soil under TCLP. Solidification/ stabilization is eliminated from further consideration because the necessity of metals pretreatment is speculative. The pretreatment necessity may be assessed by resampling the locations cited in Table 5-3 and analyzing the samples for TCLP metals.

Incineration/pyrolysis was eliminated from consideration because excavated soils are not anticipated to exceed LDRs for organic constituents and incineration/pyrolysis is ineffective for metals treatment.

Thermal desorption was eliminated from consideration because excavated soils are not anticipated to exceed LDRs for organic constituents and thermal desorption is ineffective for metals treatment.

In situ Groundwater Technologies

Enhanced bioremediation was eliminated from further consideration because it is generally ineffective for metals contamination. The high hydraulic conductivity also limits the effectiveness of enhanced bioremediation. As reported in the RI, the geometric mean of the hydraulic conductivity in the shallow wells at OU 2 was 167.7 feet per day (ft/day). The high hydraulic conductivity limits the duration of organic groundwater contaminants in the enhanced groundwater area, which limits the bioremediation effectiveness.

Monitored natural attenuation was eliminated from further consideration because several metal, VOC, and SVOC surface water CTL exceedances were observed in monitoring wells adjacent to Wetlands 5A, 6, and 7. The high permeability aquifer and the proximity of the surface water receptors also preclude the application of MNA.

Air sparging/soil vapor extraction was eliminated from further consideration because a significant mass of VOCs is not present and is ineffective for SVOC and metals. The high water table and impervious cover would also limit its effectiveness.

Chemical oxidation was eliminated from further consideration because it is ineffective for metals remediation. Because it is generally applied as a source zone technology, it was eliminated from further consideration for SVOCs and VOCs.

Chemical reduction was eliminated from further consideration because it is generally only effective for chlorinated ethenes and hexavalent chromium. Furthermore, the high water table and low soil iron content limit its effectiveness. Iron leaching to the adjacent wetlands would also be undesirable.

Electrokinetic remediaton was eliminated from further consideration because the presence of buried metallic debris in the Site 11 landfill and the presence of utilities near the buildings. In addition, the high salinity makes implementation difficult.

Ex situ Groundwater Technologies

Bioreactors were eliminated from further consideration because these systems are generally applicable to larger scale systems and the limited organic concentration in the extracted groundwater may inhibit the system. Bioreactors also have limited effectiveness for chlorinated ethenes and metals.

Ion exchange was eliminated from further consideration because ion exchange is typically applied as a secondary treatment for metals after the primary filtration of groundwater. Metal contamination has limited severity and would be adequately treated by alternative treatment methods.

Coagulation/precipitation and solids separation was eliminated from further consideration because this process is generally applicable to larger scale water and wastewater treatment systems. Although this technology is effective for metal contamination, large quantities of sludge would be generated, which may be classified as hazardous waste. Organics would only be treated when sorbed to solids and precipitated.

Membrane filtration was eliminated from consideration because it is typically applied as secondary treatment to remove dissolved contaminants after the primary filtration of groundwater. High head losses are also associated with membrane filtration, making this treatment technology impractical for groundwater treatment at OU 2, which must be pumped at a high rate because of the high hydraulic conductivity.

5.2.2 Retained Technologies

Soil technologies retained for further consideration:

- surface capping
- phytoremediation
- excavation and offsite disposal

Groundwater technologies retained for further consideration:

- phytoremediation
- permeable reactive barrier
- groundwater pumping and discharge to FOTW
- groundwater pumping, treatment, and discharge to the wetlands, with air stripping used as primary treatment and granular activated carbon used as secondary treatment

6.0 ASSEMBLY OF ALTERNATIVES

RAAs are assembled from the retained technologies for OU 2 soil and groundwater. Media-specific RAAs can be developed when interactions among media are not significant. Although source areas were not explicitly identified at OU 2, soil CTL exceedances were predominantly related to the leachate based on groundwater criteria. Although soil leachate pathway is a concern, there is no current beneficial use for groundwater. Groundwater contamination was observed to exceed surface water CTLs in monitoring wells adjacent to Wetlands 5A, 6, and 7. Thus, the protection of surface water receptors is a principal concern. Although there may be a significant interaction between soil and groundwater contamination, media-specific RAAs are developed because of these RAAs may principally address different receptors.

The media-specific RAAs are developed on a site-wide basis for OU 2. Site-wide RAAs are developed because remedial actions would presumably be performed concurrently for Sites 11, 12, 25, 26, 27, and 30, and contamination is similar. The assembled alternatives can contain multiple treatment technologies. As stated in OSWER Directive 9355.3-01, the assembled alternatives should preferably include a no-action alternative, one or more containment alternatives, one or more treatment alternatives, and a removal alternative.

6.1 Remedial Action Alternatives for Soil Contamination

The RAAs for soil contamination include the no-action alternative, land use controls (LUCs) as a limited action alternative, soil and asphalt capping as a control alternative, phytoremediation covers and selected asphalt capping as a treatment alternative, and excavation and offsite disposal as a removal alternative.

6.1.1 Alternative 1: No Action

The NCP requires that a no-action alternative be considered as a "baseline" for the evaluation of other alternatives. Under this alternative, no changes would be made to existing site operations. While the current and projected land use for this site is expected to remain industrial, there would be no additional LUCs to guarantee the exposure pathway would remain industrial. Without LUCs,

the site would be managed under Risk Management Option Level I, pursuant to 62-780.680(1), FAC, and residential direct exposure CTLs would govern.

Implementability

Although not a remedy component, the NCP requires any alternative that leaves contamination onsite be reevaluated every 5 years to ensure its adequacy. Therefore, the Navy would be required to perform a 5-year review to assess the adequacy of the no-action alternative.

Effectiveness

The no-action alternative is not effective at protecting human health, as contaminants above residential and C/I soil CTLs are left onsite. As shown in Figures 4-4, 4-10, and 4-13, there would be numerous metal, pesticide, and SVOC exceedances of the residential direct exposure CTL for potential future site residents. Residential development in some areas is unlikely, however. The Site 11 landfill and the land adjacent to Wetlands 7 and 64 would be undesirable for future residential development. As shown in Figures 4-6, 4-7, 4-12, 4-15, 4-17, and 4-18, the soil leachate CTLs would be exceeded in several locations. Thus, soil contamination would likely continue to leach to groundwater in OU 2.

Cost

The no-action alternative includes conducting six 5-year reviews. The default parameters in RACER are based on the *Comprehensive Five-Year Review Guidance* (OSWER No. 9355.7-03B-P, EPA/540/R-01/007, June 2001). The RACER cost summary reports for the no-action alternative are given in Appendix C. The cost summary reports include 1) the site cost over time and 2) the 5-year review report cost detail. The 5-year review tasks include the document review of the 5-year review check list and previous 5-year review reports; interviews with current and previous staff management, state contacts, and local government contacts; general site inspection and documentation; regulatory compliance inspection; report generation; and 2 days of travel. The estimated cost of the 5-year reviews is $16,625, multiplied by the escalation factor. The present value cost is calculated by discounting the site costs over time at a 6% discount rate. The present value cost of the no-action alternative is $54,262.

The no-action alternative cost was developed as a basis for comparison with other media-specific RAAs. Because media-specific RAAs for soil and groundwater would likely be performed concurrently, tasks such as the 5-year reviews may be redundant. In order to avoid redundancy, the 5-year review costs are not estimated in the groundwater RAAs, which are given in Section 6.2.

6.1.2 Alternative 2: Land Use Controls

This alternative would be limited to LUCs, which would permit OU 2 to be managed using Risk Management Option Level II, pursuant to 62-780.680(2), FAC. This option permits soil to be evaluated using C/I direct exposure CTLs. Although not included in this alternative, this option also permits the use of engineering controls for the management of onsite contamination.

Implementability

NAS Pensacola currently operates as a C/I facility and the base is not proposed for closure. Thus, C/I status can be achieved through the implementation of LUC agreements to limit site access and property use. Annual compliance with the LUC agreements may be necessary. In the event that the property was transferred and onsite contamination remains above applicable requirements, the Navy would be required to deed restrict OU 2 as C/I property. The Navy has qualified planners and attorneys which can develop and implement proper LUCs for OU 2.

C/I direct exposure criteria are based on the intermittent exposure of adults, and are only appropriate when engineering controls or LUCs proposed for the site would reliably restrict the exposure frequency and duration. Although construction workers do not fit the assumptions for residential exposure, FDEP requires that a LUC specify that construction workers be notified of potential contamination, using residential direct exposure criteria, and that proper protective equipment should be used based on requirements from the Occupational Safety and Health Administration (OSHA) (FDEP, 1999). Therefore, notification of the Base Environmental Office would be required to ensure proper notification before invasive activities begin.

Although not a remedy component, the NCP requires any alternative that leaves contamination onsite be reevaluated every 5 years to ensure its adequacy. Therefore, the Navy would be required to perform a 5-year review to assess the adequacy of the LUCs alternative.

Effectiveness

The LUCs alternative would not provide any additional effectiveness for the current use scenario, but would provide long-term effectiveness by restricting future use and access. As shown in Figures 4-5, 4-11, and 4-14, there would be numerous metal, pesticide, and SVOC exceedances of the C/I direct exposure CTL. Exposure to site workers would be minimized by proper notification and OSHA compliance. As shown in Figures 4-6, 4-7, 4-12, 4-15, 4-17, and 4-18, the soil leachate CTLs would be exceeded in several locations. Thus, soil contamination would likely continue to leach to groundwater in OU 2.

Cost

The LUCs alternative includes the planning and implementation of LUCs and conducting six 5-year reviews. The default parameters in RACER are based on the *Comprehensive Five-Year Review Guidance* (OSWER No. 9355.7-03B-P, EPA/540/R-01/007, June 2001). The RACER cost summary reports for the LUCs alternative are given in Appendix C. The cost summary reports include 1) the site cost over time, 2) the LUCs cost detail, and 3) the 5-year review report cost detail. The LUCs tasks include institutional analysis, plan development, processing agreement, plan execution, and deed notice. The 5-year review tasks include the document review of the 5-year review check list and previous 5-year review reports; interviews with current and previous staff management, state contacts, and local government contacts; general site inspection and documentation; regulatory compliance inspection; report generation; and 2 days of travel. The estimated cost of LUCs is $21,974. The estimated cost of the 5-year reviews is $16,625, multiplied by the escalation factor. The present value cost is calculated by discounting the site costs over time at a 6% discount rate. The present value cost of the LUC alternative is $76,566.

6.1.3 Alternative 3: Soil and Asphalt Capping

Surface capping reduces the risk of exposure to contaminated soil, thus eliminating the direct exposure pathway. When constructed as low permeability covers, they also reduce infiltration, which permits higher CTLs to be calculated based on leachability criteria. The proposed surface capping areas are shown in Figure 6-1. Asphalt covers would be constructed in four distinct areas and soil covers would be constructed in four distinct areas. The capping locations are selected based on SCTL exceedances shown in Figures 4-5 to 4-7, 4-11, 4-12, 4-14, 4-15, 4-17, and 4-18. Table 6-1 describes the locations and dimensions of the proposed capping areas.

Table 6-1
Description of Proposed Capping Areas (Shown in Figure 6-1)

Description	Location	Dimensions
Asphalt Cap No. 1	Site 12, east of Building 781, south of Building 740, north of Building 455	280-ft x 600-ft rectangular cap
Asphalt Cap No. 2	Site 12, east of Building 3821	80-ft x 160-ft rectangular cap
Asphalt Cap No. 3	Site 25, east of Building 780	160-ft x 240-ft rectangular cap
Asphalt Cap No. 4	Site 27	360-ft x 440-ft rectangular cap
Soil Cap No. 1	Site 11, east of Pat Bellinger Road	50-ft x 300-ft rectangular cap
Soil Cap No. 2	Site 11, east of Yacht Basin, west of Clay Road	240-ft x 240-ft right-triangular cap
Soil Cap No. 3	Site 30, along Wetland 5B	100-ft x 970-ft rectangular cap
Soil Cap No. 5	Site 30, south of Building 649	100-ft x 400-ft rectangular cap

Although the proposed asphalt and soil caps are protective of most of the C/I direct exposure and leachability SCTL exceedances, several isolated exceedances occur near Sites 27 and 30. The isolated exceedances include sample locations 27GS06, 27GS10, 27S09, 30GS154, 30S138, 30S148, 30S150, and 30S151. These exceedances would be addressed by excavating the top 2 ft of soil from these locations and consolidating it under Site 27 asphalt cap. The total estimated excavation volume is 950 CY. Excavated soil would remain in the same area, and although not contiguous, may be managed as an area of contamination. Otherwise, the Site 27 asphalt cap would need to be constructed pursuant to the disposal CAMU regulations (40 CFR §264.552). Excavated areas would be recovered with clean fill. The proposed excavation areas are shown in Figure 6-1.

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FIGURE 6-1
SOIL ALTERNATIVE 3
LOCATIONS OF SOIL COVERS AND ASPHALT CAPS

Dr by: K. WOOSLEY	Proj. Code: 0059-001	
Ck by: C. TRIPP	App by: A. HARRIS	Sheet 1
Date: 12JAN05	DWG Name: 0059001B044	Of 1

Implementability

The construction of soil and asphalt covers is technically feasible at OU 2, and the designated areas are amenable to the specified capping materials. Before the full-scale design and concurrent with construction activities, confirmation samples would need to be collected to verify that the contaminated soils are properly addressed by this remedy. The soil covers would require regular maintenance to minimize the erosion of the cap, and additional construction may be necessary if sufficient erosion of the cap is observed.

Because contamination would be left onsite, the soil and asphalt capping alternative includes the implementation of LUCs. This permits OU 2 to be managed using Risk Management Option Level II, pursuant to 62-780.680(2), FAC. This option permits soil to be evaluated using C/I direct exposure CTLs and for surface capping to be used as an engineering control.

As stated in OSWER No. 9355.7-03B-P, 5-year reviews may no longer be needed when no hazardous substances, pollutants, or contaminants remain onsite above levels that allow for unlimited use and unrestricted exposure. Because surface capping does not meet this criterion, 5-year reviews are included with this alternative.

Effectiveness

Surface capping is a control technology that does not reduce the volume or toxicity of waste. Surface capping provides reliable protection against the direct exposure to contaminated soils. When constructed as low permeability covers, they also reduce infiltration, which permits higher CTLs to be calculated based on leachability criteria, pursuant to 62-777, FAC, Figure 8. In this equation, the dilution factor can be increased based on the decreased infiltration rate using equations presented in the USEPA's *Soil Screening Guidance: Technical Background Document* (EPA/540/R95/128). Soil covers require regular maintenance to ensure their reliability, and soil and asphalt covers require periodic inspection.

The construction of the asphalt caps also benefits the industrial usage of the site. The area of the proposed Site 25 asphalt cap is currently covered with interlocking, perforated metal sheets and is

used for heavy vehicle parking. The area of the proposed Site 27 asphalt cap is currently used as a parking lot for light vehicles.

Cost

The asphalt caps would be constructed of hydraulic asphalt concrete, which is used as a hydraulic barrier. The asphalt thickness is 4 inches, which may be suitable for light vehicle traffic. The asphalt is underlain by 12 inches of base rock, a geotextile drainage fabric, and 6 inches of leveling fill. The soil covers would be constructed of 6 inches of topsoil, 12 inches of soil cover, 12 inches of compacted clay, and 6 inches of leveling fill. The asphalt and soil caps would be contoured to prevent the run-on of surface water and to direct the runoff into the storm sewer or onto adjacent grassy areas, as appropriate. The proposed locations would be cleared and grubbed and the debris would be disposed offsite.

The RACER cost summary reports for the soil and asphalt capping alternative are given in Appendix C. The cost summary reports include 1) the site cost over time, 2) the asphalt caps cost detail, 3) the soil caps cost detail, 4) the excavation cost detail, 5) the design cost summary, 6) the LUCs cost detail, and 7) the 5-year review report cost detail. The first year cost of the soil and asphalt capping alternative is $2,682,063. Long-term costs are limited to conducting 5-year reviews, which are required when contamination is left onsite. When discounted at 6%, the total present value of the soil and asphalt capping alternative is $2,736,325.

6.1.4 Alternative 4: Phytoremediation Covers and Asphalt Capping

Phytoremediation is a process that uses plants to remove, transfer, stabilize, and degrade contaminants in soil and groundwater. Phytoremediation processes are distinguished as follows (EPA/600/R-99/107):

- *Phytoextraction* is the uptake of contaminants by plant roots and translocation within the plants.

- *Rhizofiltration* is the adsorption or precipitation onto plant roots, or absorption into the roots

of contaminants that are in solution surrounding the root zone, due to biotic or abiotic processes.

- *Phytostabilization* is defined as (1) immobilization of a contaminant in soil through absorption and accumulation by roots, adsorption onto roots, or precipitation within the root zone of plants, and (2) the use of plants and plant roots to prevent contaminant migration via wind and water erosion, leaching, and soil dispersion.

- *Rhizodegradation* (also known as *rhizosphere bioremediation*) is the breakdown of an organic contaminant in soil through microbial activity that is enhanced by the presence of the root zone.

- *Phytodegradation* (also known as *phytotransformation*) is the breakdown of contaminants taken up by plants through metabolic process within the plant, or breakdown of contaminants external to the plant through the effect of enzymes produced by the plant.

- *Phytovolatization* (also known as *phytotransformation*) is the uptake and transpiration of a contaminant by the plant, with release of the contaminant or a modified form of the contaminant to the atmosphere from the plant through contaminant uptake, plant metabolism, and plant transpiration.

In a soil remedy, phytoremediation is typically applied as a vegetative cover system. Vegetative covers are designed as long-term, self-sustaining systems of plants growing in and/or over materials that pose environmental risk. A vegetative cover may reduce the risk to an acceptable level and generally requires minimal maintenance. Vegetative covers are distinguished as follows:

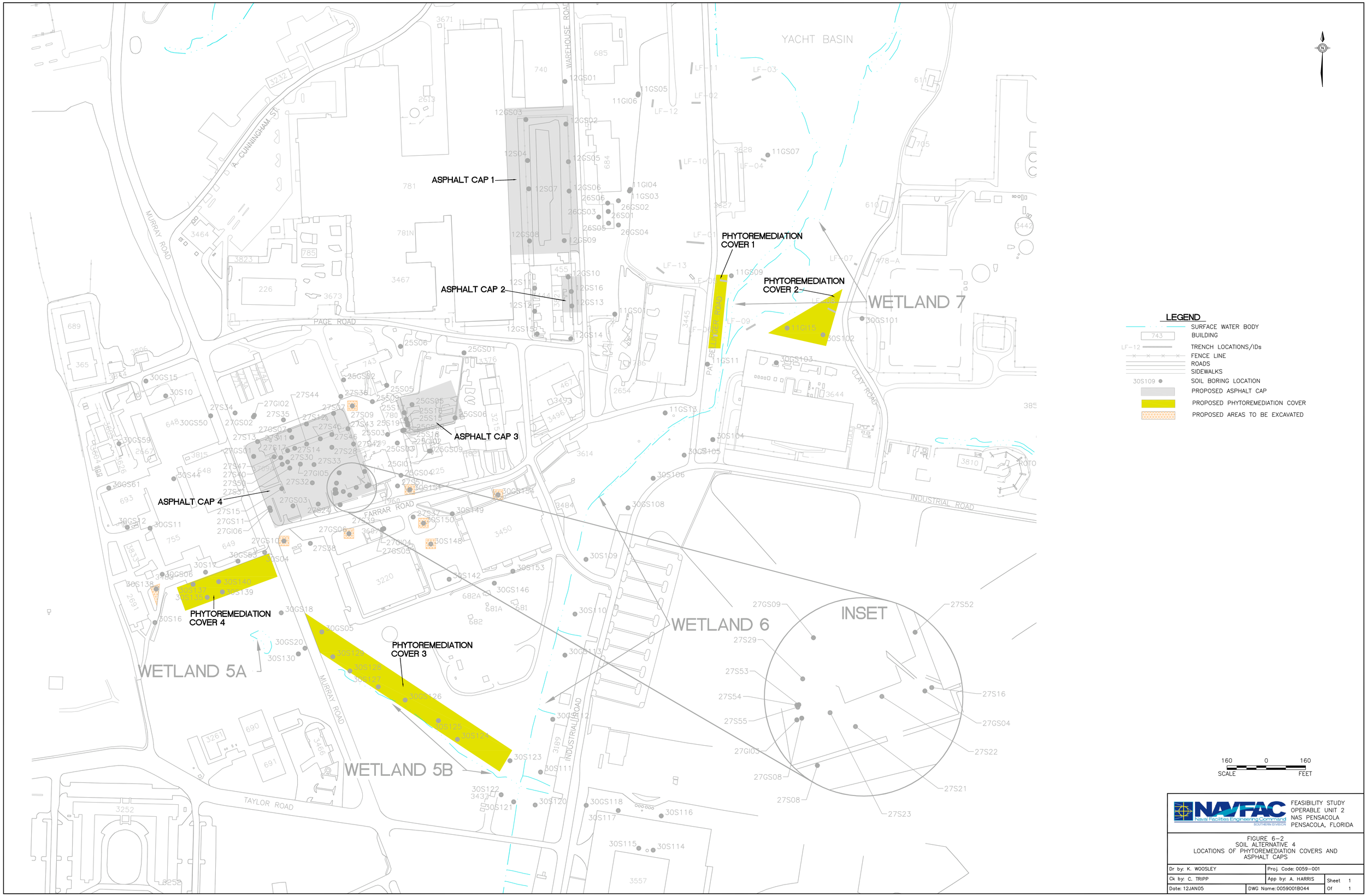
- *Evapotranspiration covers* are composed of soil and plants engineered to maximize the available storage capacity of soil, evaporation rates, and transpiration processes of plants to minimize water infiltration. The evapotranspiration cap is a form of hydraulic control by plants. Risk reduction relies on the isolation of contaminants to prevent human or wildlife exposure and the reduction of leachate formation and movement. Caps are designed with sufficient thickness and permeability to hold moisture such that infiltration is minimized by evapotranspiration processes.

- *Phytoremediation covers* consist of soil and plants to minimize infiltration of water and to aid in the degradation of underlying waste. Risk reduction relies on the degradation of contaminants, the isolation of contaminants to prevent human or wildlife exposure, and the reduction of leachate formation and movement. Phytoremediation covers incorporate certain aspects of hydraulic control, phytodegradation, rhizodegradation, phytovolatilization, and perhaps phytoextraction.

The phytoremediation covers and asphalt capping alternative is identical to the soil and asphalt capping alternative, except that phytoremediation covers are used instead of soil covers. Phytoremediation covers may be especially applicable near the adjacent wetlands, where surface capping is invasive and where site use is limited. Phytoremediation covers may also be more compatible with the selected groundwater RAA. The locations of the proposed asphalt caps, phytoremediation covers, and areas to be excavated are shown in Figure 6-2.

Implementability

The construction of phytoremediation covers is technically feasible at OU 2. The designated areas adjacent to Wetlands 5A and 5B and the Yacht Basin are in undeveloped areas and are amenable to phytoremediation covers. This alternative would continue to include asphalt capping in areas designated in Figure 6-2. Before the full-scale design and concurrent with construction activities, confirmation samples would need to be collected to verify that the contaminated soils are properly addressed by this remedy. The phytoremediaton covers would require regular maintenance to maintain a vegetative presence and possibly to harvest plants designed for phytoextraction.


YACHT BASIN
ASPHALT CAP 1
ASPHALT CAP 2
ASPHALT CAP 3
ASPHALT CAP 4
PHYTOREMEDIATION COVER 1
PHYTOREMEDIATION COVER 2
PHYTOREMEDIATION COVER 3
PHYTOREMEDIATION COVER 4
WETLAND 7
WETLAND 6
WETLAND 5A
WETLAND 5B
INSET
A. CUNNINGHAM ST.
MURRAY ROAD
WAREHOUSE ROAD
PAGE ROAD
FARRAR ROAD
CLAY ROAD
INDUSTRIAL ROAD
TAYLOR ROAD
LEGEND
SURFACE WATER BODY
BUILDING
TRENCH LOCATIONS/IDs
FENCE LINE
ROADS
SIDEWALKS
SOIL BORING LOCATION
PROPOSED ASPHALT CAP
PROPOSED PHYTOREMEDIATION COVER
PROPOSED AREAS TO BE EXCAVATED
160 0 160
SCALE FEET
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FEASIBILITY STUDY
OPERABLE UNIT 2
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PENSACOLA, FLORIDA
FIGURE 6-2
SOIL ALTERNATIVE 4
LOCATIONS OF PHYTOREMEDIATION COVERS AND ASPHALT CAPS
Dr by: K. WOOSLEY
Proj. Code: 0059-001
Ck by: C. TRIPP
App by: A. HARRIS
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Date: 12JAN05
DWG Name: 0059001B044
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Pilot-testing is needed to facilitate the final design of the phytoremediaton cover. The purpose of the pilot test would be to identify and verify that appropriate plants can be grown in the site soils. These studies are typically performed using samples of site soil in which the prospective vegetation is grown in an offsite greenhouse. Pilot studies are also used to determine the nutrients amendments needed for successful application.

Because contamination would be left onsite, the phytoremediation covers alternative includes the implementation of LUCs. This permits OU 2 to be managed using Risk Management Option Level II, pursuant to 62-780.680(2), FAC. This option permits soil to be evaluated using C/I direct exposure CTLs and for phytoremediation covers to be used as engineering controls.

As stated in OSWER No. 9355.7-03B-P, 5-year reviews may no longer be needed when no hazardous substances, pollutants, or contaminants remain onsite above levels that allow for unlimited use and unrestricted exposure. Asphalt capping does not meet this criterion. Although phytoremediaton covers provide stimulated treatment and hydraulic control, contamination would likely remain onsite. Thus, 5-year reviews are included with this alternative.

Effectiveness

Phytoremediation covers are designed for several purposes. Contaminants may be treated by rhizodegradation and phytotransformation processes, removed by phytoextraction, or controlled by phytostabilization and hydraulic control. As discussed in *Introduction to Phytoremediation* (EPA/600/R-99/107), several of the phytoremediation treatment processes are applicable to the organic and metal COPCs found in OU 2. The treatment and removal mechanisms may be sufficient to reduce contamination to below C/I direct exposure and leachability-based SCTLs. Hydraulic control holds the moisture in place so that evapotranspiration processes limit the infiltration. When reduced infiltration rates are verified, it may be appropriate to calculate higher, remedy-specific leachability-based SCTLs, pursuant to 62-777, FAC, Figure 8.

Asphalt capping is a control technology that does not reduce the volume or toxicity of waste. Asphalt capping provides reliable protection against the direct exposure to contaminated soils.

When constructed as low permeability covers, they also reduce infiltration, which permits higher CTLs to be calculated based on leachability criteria.

The construction of the asphalt caps also benefits the industrial usage of the site. The area of the proposed Site 25 asphalt cap is currently covered with interlocking, perforated metal sheets and is used for heavy vehicle parking. The area of the proposed Site 27 asphalt cap is currently used as a parking lot for light vehicles.

Cost

The asphalt caps would be constructed of hydraulic asphalt concrete, which is used as a hydraulic barrier. The asphalt thickness is 4 inches, which may be suitable for light vehicle traffic. The asphalt is underlain by 12 inches of base rock, a geotextile drainage fabric, and 6 inches of leveling fill. The asphalt caps would be contoured to prevent the run-on of surface water and to direct the runoff into the storm sewer or onto adjacent grassy areas, as appropriate. The proposed locations would be cleared and grubbed and the debris would be disposed offsite.

The phytoremediation covers would consist of the selected phytoremediation vegetation and would include the construction of an irrigation and nutrient amendment system. The proposed locations would be cleared and grubbed and the debris would be disposed offsite. The phytoremediation covers would be actively managed for 10 years. Active management includes irrigation and nutrient amendment, replanting, inspection, mowing/maintenance, and natural attenuation monitoring.

The RACER cost summary reports for the phytoremediation cover and asphalt capping alternative are given in Appendix C. The cost summary reports include 1) the site cost over time, 2) the asphalt caps cost detail, 3) the phytoremediation covers cost detail, 4) the excavation cost detail, 5) the design cost summary, 6) the LUCs cost detail, and 7) the 5-year review report cost detail. The first year cost of the phytoremediation cover and asphalt capping alternative is $2,136,689. O&M and natural attenuation sampling would be conducted for 10 years, with annual costs of $12,833 and $20,605, respectively, multiplied by escalation factors. Long-term costs also include conducting 5-year reviews, which are required when contamination is left onsite. When discounted

at 6%, the total present value of the phytoremediation covers and asphalt capping alternative is $2,445,454.

6.1.5 Alternative 5: Excavation and Offsite Disposal

This alternative involves excavating surface soil that exceeds C/I direct exposure CTLs and vadose zone soil that exceeds leachability CTLs based on groundwater. Figure 6-3 shows the proposed areas for excavation. These are based on CTL exceedances shown in Figures 4-5 to 4-7, 4-11, 4-12, 4-14, 4-15, 4-17, and 4-18. When soil contamination appears contiguous, larger areas of soil would be excavated. In cases were the soil contamination appears isolated, surgical excavation would be performed in 40-ft x 40-ft sections. The proposed areas of excavation would be excavated to 2 ft bgl, and subsurface soil contamination is not addressed.

Subsurface CTLs were only exceeded in three locations. In sample 30S013820, the sample depth was 20 ft bgl and presumably below the water table, and thus would be treated as part of the aquifer matrix. In sample 011S001506, total chromium concentration was 48 µg/kg, which barely exceeded the hexavalent chromium leachability CTL of 38 µg/kg. Because most of the chromium presumably exists as trivalent chromium, this was excluded from consideration. In sample 011S000606, the concentration of PCE was 30 µg/kg, which was equal to leachability CTL of 30 µg/kg. This sample was also excluded from consideration.

The excavated soils would be disposed offsite. Although the excavated soils would not be characteristic of hazardous waste, they may include listed hazardous waste. If the excavated soils are determined to contain listed hazardous waste above health-based limits, the excavated soils would be hazardous waste because of the contained-in policy. FDEP's August 21, 2002 Memorandum on "Management of Contaminated Media Under RCRA" explicitly states that the heath-based limits are residential soil CTLs. Because soils would be excavated based on C/I CTLs, it is assumed in this FS that the excavated soils would be hazardous waste. Thus, if the excavated soils are disposed offsite, they must be disposed in a RCRA Subtitle D landfill. Although the excavated soils could also be disposed in an onsite disposal CAMU, this was not explored in this FS.

YACHT BASIN
WETLAND 7
CLOSED LAGOON
WETLAND 6
WETLAND 5A
WETLAND 5B
INSET
A. CUNNINGHAM ST.
MURRAY ROAD
PAGE ROAD
WAREHOUSE ROAD
PAT BELLINGER ROAD
CLAY ROAD
INDUSTRIAL ROAD
FARRAR ROAD
TAYLOR ROAD
LEGEND
SURFACE WATER BODY
BUILDING
TRENCH LOCATIONS/IDs
FENCE LINE
ROADS
SIDEWALKS
SOIL BORING LOCATION
PROPOSED AREAS TO BE EXCAVATED
160 0 160
SCALE FEET
NAVFAC
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SOUTHERN DIVISION
FEASIBILITY STUDY
OPERABLE UNIT 2
NAS PENSACOLA
PENSACOLA, FLORIDA
FIGURE 6-3
SOIL ALTERNATIVE 5
AREAS TO BE EXCAVATED
Dr by: K. WOOSLEY
Proj. Code: 0059-001
Ck by: C. TRIPP
App by: A. HARRIS
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DWG Name: 0059001B045

Hazardous waste is subject to the LDRs. When soil contamination exceeds 10 x UTS, as defined in 40 CFR §268.48, the soil must be treated before land disposal. As discussed in Section 5.2.1, a detection of endrin aldehyde in sample 025S001600 was the only analyte found to exceed both risk and treatment criteria, and its exceedance was marginal. The concentration of endrin aldehyde would be anticipated to incidentally attenuate to below risk and/or treatment criteria, either before or after excavation. Although no metals were identified to exceed the TCLP LDR criteria, sample locations listed in Table 5-3 may need further evaluation to assess the pretreatment necessity.

Implementability

Excavation and offsite disposal is technically and administratively feasible at OU 2. Excavation is performed frequently and is a reliable method to remove contaminated soil within given boundaries. The excavated soil volume is not anticipated to be sufficient to impose landfill capacity limitations.

Because contamination exceeding residential direct exposure CTLs would be left onsite, the excavation and offsite disposal alternative includes the implementation of LUCs. This permits OU 2 to be managed using Risk Management Option Level II, pursuant to 62-780.680(2), FAC.

As stated in OSWER No. 9355.7-03B-P, 5-year reviews may no longer be needed when no hazardous substances, pollutants, or contaminants remain onsite above levels that allow for unlimited use and unrestricted exposure. With the implementation of LUCs, this criterion is satisfied for soil. Thus, 5-year reviews are not needed with this alternative. Nevertheless, groundwater contamination would be left onsite. In the media-specific RAAs in this FS, 5-year reviews are burdened for the soil remedies. Thus, 5-year reviews are included in the excavation and offsite disposal alternative.

Effectiveness

Excavation and offsite disposal reduces the volume of contamination. Because soil exceeding C/I direct exposure and groundwater-based leachability CTLs would be removed from the site, reductions of toxicity and mobility are not relevant.

Although the short-term inhalation, ingestion, and contact risk to site workers (excavation crew) would increase during excavation, this would be limited to the remedial action period. Occupational risk would be reduced through proper use of PPE and engineering controls. Because no residential areas are adjacent to OU 2, there are no short-term risks to the surrounding community. There are no onsite long-term risks associated with the excavation and offsite disposal alternative because the exposed soil exceeding CTLs would be removed from the site.

Cost

The 246,400 square feet of contaminated surface soil, as identified in Figure 6-3, would be excavated to 2 ft bgl. Because direct exposure criteria is not applicable below 2 ft, bottom samples would not be collected. In this cost estimate, side-wall samples are also not considered. This cost estimate includes the collection and analysis of 40 samples for waste characterization. The samples would be analyzed for metal, pesticides/PCBs, SVOCs, VOCs, and TCLP metals, SVOCs, and VOCs. The 18,252 CY of excavated soil would be disposed offsite as hazardous waste. This estimate assumes that the excavated soil would be transported 200 miles to a RCRA Subtitle C landfill in Emelle, Alabama. Although the estimated disposal fee of $185.64/CY is the primary cost-driver for this alternative, the disposal fee was not verified.

The RACER cost summary reports for the excavation and offsite disposal alternative are given in Appendix C. The cost summary reports include 1) the site cost over time, 2) the excavation, transport, and disposal cost detail, 3) the LUCs cost detail, and 4) the 5-year review report cost detail. The first year cost of the excavation and offsite disposal alternative is $5,071,284. Long-term costs are limited to conducting 5-year reviews, which are required when contamination is left onsite. When discounted at 6%, the total present value of the excavation and offsite disposal alternative is $5,125,545.

6.2 Remedial Action Alternatives for Groundwater Contamination

The RAAs for groundwater contamination include the no-action alternative, a LUCs alternative; monitored natural attenuation (MNA), riparian corridors, and PRBs as treatment alternatives; and groundwater pumping as a removal and control alternative.

Groundwater remedies are inherently long-term and contamination is usually left onsite. Thus, 5-year reviews are needed for all of the groundwater RAAs. Because 5-year reviews are considered in the media-specific RAAs for soil, however, they are not also estimated for the groundwater RAAs. Similarly, the inclusion of LUCs would be redundant and they are not included as a component in the groundwater RAAs.

6.2.1 Investigation of the Groundwater/Surface Water Interface

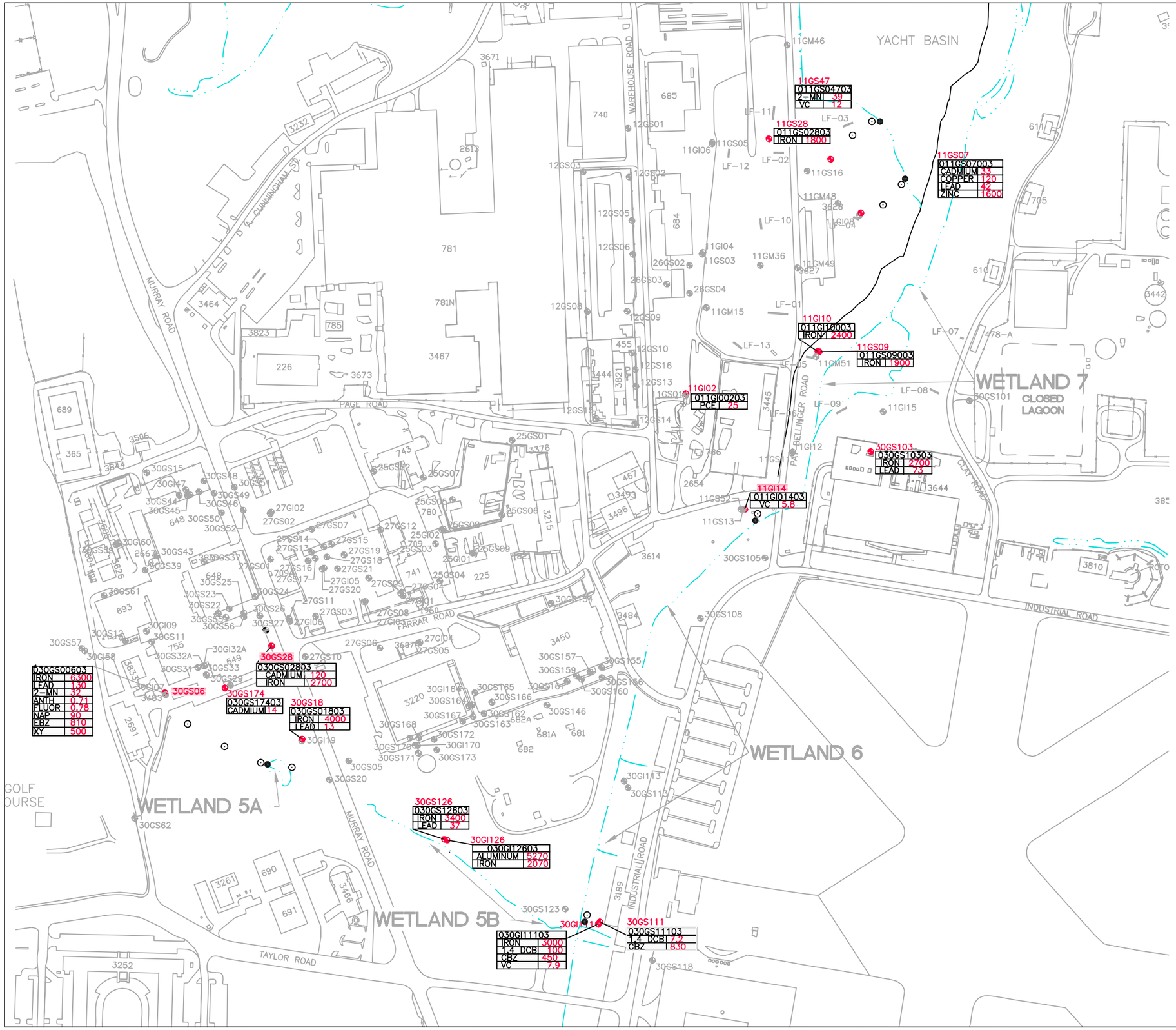
The groundwater/surface water interface (GSI) will be investigated during preliminary design. As discussed in 62-780.600(3)(g)4, the site assessment should assess the hydraulic interaction between groundwater and any surface water within the vicinity of the site. In the RI, this assessment was limited to creating groundwater potentiometric maps in the area of interest, where groundwater concentrations in shoreline monitoring wells were assumed to be representative of surface water conditions. Because some shoreline wells are 100 ft or more from the surface water body, attenuating processes within the plume and at the GSI were not considered. The objective of the GSI is to determine whether groundwater affects freshwater and marine surface water, and consequently, whether contaminated groundwater has the potential to affect surface water. This may be used to satisfy 62-780.680(1)(c)2, which would facilitate the feasibility of LUCs, MNA, and passive engineering control RAAs.

There are several unique physical, chemical, and biological processes occurring at the GSI that can affect contaminant transport. Tidal and density mixing zones form adjacent to marine surface water, which enhances contaminant sorption and hydraulically limits the infiltration of groundwater contaminant plumes into marine surface water. Intermittent surface water creates hyporheic zones, where pore water migrates bi-directionally, which creates unique water quality conditions. The groundwater in the hyporheic zone is generally characterized by higher nutrient loads, with

both anaerobic and aerobic zones, that may be favorable for natural attenuation. Low permeability sediment in the freshwater surface water bodies may limit the infiltration of groundwater and increase the groundwater residence time in the biologically favorable natural attenuation zones.

The GSI investigation will be conducted in two phases. Phase I will be a DPT investigation of the groundwater plumes at Sites 11 and 30. DPT groundwater samples would be collected downgradient of existing monitoring wells in the direction of groundwater flow. The purposes of these samples will be to evaluate contaminant levels downgradient from existing monitoring wells and to evaluate natural attenuation processes occurring along the groundwater flow path towards Wetlands 5A, 5B, 7, and 64. Groundwater samples will be analyzed for metals, VOCs, PAHs, pesticides/PCBs, and natural attenuation parameters. Nested monitoring wells will also be installed along the banks of wetlands. The purpose of the monitoring wells will be to evaluate the groundwater hydraulics and geochemistry to determine the nature and extent of natural attenuation processes occurring at the GSI. Hydraulic data (e.g., water levels) will be collected from monitoring wells and staff gauges installed in the wetlands to establish a better understanding of groundwater flow near the GSI. Figure 6-4 shows the locations of the proposed direct push and nested monitoring wells.

Based on information collected from the Phase I investigation, a Phase II GSI investigation will be conducted in areas where the groundwater plumes at OU2 appear to discharge into Wetlands 5A, 5B, 7, and 64. The Phase II investigation will use tools recently developed by the Navy's Space and Naval Warfare Command (SPAWAR) in San Diego, CA. SPAWAR has successfully demonstrated the use of the Trident Probe and the UltraSeep system through a research grant funded by the Department of Defense's Environmental Security Technology Certification Program. The Trident Probe measures temperature and chemical contrasts between groundwater and surface water to map areas of potential groundwater discharge. The UltraSeep system is an integrated ultrasonic seepage meter and water sampling system for quantifying discharge rates and chemical loading from groundwater flow to surface waters. The UltraSeep system is restricted to use in waters greater than one foot deep. Figure 6-5 shows the proposed sample grid for the Trident Probe and potential sample locations for the UltraSeep system.



LEGEND

- SURFACE WATER BODY
- 743 — BUILDING
- LF-10 — TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 30GS155 — SHALLOW OR INTERMEDIATE MONITORING WELL
- 30GS111 — SHALLOW GROUNDWATER MONITORING WELL LOCATIONS/IDs WITH SAMPLE EXCEEDING THE GROUNDWATER CTL
- PROPOSED DIRECT PUSH LOCATIONS
- PROPOSED NESTED MONITORING WELL LOCATIONS

SAMPLE ID	
PARAMETER KEY	CONCENTRATION

PARAMETER KEY

PARAMETERS	MSWCTL	NASP GROUNDWATER REFERENCE
Aluminum	1500	3882
Cadmium	9.3	3.40
Iron	300	1707
Lead	8.5	1.60
Copper	3.7	16.20
Zinc	86	153.2
2-Methylnapthalene (2-MN)	30	NA
Anthracene (ANTH)	110000	NA
Fluoranthene (FLUOR)	370	NA
Napthalene (NAP)	26	NA
Pyrene (PYR)	11000	NA
1,4 Dichlorobenzene (1,4DCB)	3	NA
Chlorobenzene (CBZ)	17	NA
Tetrachloroethene (PCE)	8.85	NA
Ethylbenzene (EBZ)	610	NA
Xylenes (XY)	370	NA
Vinyl Chloride (VC)	2.4	NA

NOTES

1. ALL CONCENTRATIONS ARE IN PARTS PER BILLION (PPB)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:

FSWCTL = FRESH SURFACE WATER CLEANUP TARGET LEVEL
MSWCTL = MARINE SURFACE WATER CLEANUP TARGET LEVEL
NA = NOT APPLICABLE

160 0 160
SCALE FEET

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FIGURE 6-4
GSI INVESTIGATION PHASE I
PROPOSED DIRECT PUSH AND NESTED
MONITORING WELL LOCATIONS

Dr by: S. REED	Proj. Code: 0059-001	
Ck by: C. TRIPP	App by: A. HARRIS	Sheet 1
Date: 11/09/05	DWG Name: 0059001B053	Of 1

LEGEND

- SURFACE WATER BODY
- 743 — BUILDING
- LF-10 — TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 30GS155 — SHALLOW OR INTERMEDIATE MONITORING WELL
- 30GS111 — SHALLOW GROUNDWATER MONITORING WELL LOCATIONS/IDs WITH SAMPLE EXCEEDING THE GROUNDWATER CTL
- PROPOSED TRIDENT PROBE SAMPLING GRID 50'x50' INTERVALS
- PROPOSED ULTRASEEP SAMPLE LOCATIONS

SAMPLE ID	
PARAMETER KEY	CONCENTRATION

PARAMETER KEY

PARAMETERS	MSWCTL	NASP GROUNDWATER REFERENCE
Aluminum	1500	3882
Cadmium	9.3	3.40
Iron	300	1707
Lead	8.5	1.60
Copper	3.7	16.20
Zinc	86	153.2
2-Methylnapthalene (2-MN)	30	NA
Anthracene (ANTH)	110000	NA
Fluoranthene (FLUOR)	370	NA
Napthalene (NAP)	26	NA
Pyrene (PYR)	11000	NA
1,4 Dichlorobenzene (1,4DCB)	3	NA
Chlorobenzene (CBZ)	17	NA
Tetrachloroethene (PCE)	8.85	NA
Ethylbenzene (EBZ)	610	NA
Xylenes (XY)	370	NA
Vinyl Chloride (VC)	2.4	NA

NOTES

1. ALL CONCENTRATIONS ARE IN PARTS PER BILLION (PPB)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:

FSWCTL = FRESH SURFACE WATER CLEANUP TARGET LEVEL
MSWCTL = MARINE SURFACE WATER CLEANUP TARGET LEVEL
NA = NOT APPLICABLE

160 0 160
SCALE FEET

NAVFAC Naval Facilities Engineering Command SOUTHERN DIVISION

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FIGURE 6-5
GSI INVESTIGATION PHASE II
PROPOSED TRIDENT PROBE AND
ULTRASEEP SAMPLE LOCATIONS

Dr by: S. REED	Proj. Code: 0059-001	
Ck by: C. TRIPP	App by: A. HARRIS	Sheet 1
Date: 11/09/05	DWG Name: 0059001B054	Of 1

The first part of the GSI investigation will be a survey of potential groundwater discharge zones in Wetlands 5A, 5B, 7, and 64 using the Trident Probe. The survey will be conducted by deploying the Trident Probe in off-shore locations in the wetlands. Depending on the groundwater and surface water characteristics, the temperature or conductivity sensor, or a combination of both sensors, will be used to map areas of potential groundwater discharge. A grid of stations will be established in the area offshore from the suspected groundwater plume. Because the Trident Probe relies on contrast in temperature and/or salinity to identify groundwater discharge, it is important to apply the technology in areas where this contrast is present. Because Wetlands 5A and 5B are freshwater bodies, conductivity contrast is not expected to be strong. Instead, contrast in temperature between the groundwater and surface water will be used. For Wetland 64 (Yacht Basin), salinity and temperature contrast will be used because this is a brackish water body. The Trident Probe will be deployed over the sampling grid, and the temperature and conductivity characteristics of the study area will be mapped. At the same time, the water sampler on the Trident will be used to collect water samples for analysis of contaminants. Contaminant analysis will be conducted onsite, or at a traditional laboratory. Areas of groundwater discharge are generally characterized by stronger thermal contrast and are also where groundwater-borne contaminants are most likely to be encountered. Alternatively, it may be the case that the groundwater discharge is highly dispersed before reaching the surface water. In this case, the Trident Probe should indicate either very weak or no contrast, and the contaminant levels should be significantly attenuated relative to the onshore levels. Areas of focused and diffuse groundwater discharge will be confirmed by measuring seepage flux using the UltraSeep system. An on-board global positioning system (GPS) linked to a geographical information system (GIS) will be used to plot and analyze results of the Trident Probe survey in real-time. Using principles outlined in the Triad Approach (e.g., real time data acquisition, systematic planning, and management of data uncertainty), areas of potential groundwater and contaminant discharge will be mapped out in a timely and cost-effective manner.

After completion of the Trident Probe survey, the UltraSeep system will be deployed to quantify the groundwater and contaminant flux into the wetlands. Stations will be selected for evaluation based on results of the Trident survey. The stations will represent a gradation in the expected level of groundwater discharge at the site. The UltraSeep will be deployed at these stations over a 24-hour

period during which groundwater discharge/recharge rates will be measured, and discharge samples will be collected. Samples will be characterized for groundwater-borne contaminants to determine whether the contaminants are discharging into the surface water at unacceptable levels. The UltraSeep system will provide a quantitative assessment of the rate of groundwater discharge to the surface water, and if present, the associated contaminant loading. The system will also be capable of distinguishing between areas of low and high discharge and areas where contaminants are present or not.

6.2.2 Alternative 1: No Action

The NCP requires that a no-action alternative be considered as a "baseline" for the evaluation of other alternatives. The no-action alternative does not include any remedial action or LUCs, but does include groundwater monitoring. Groundwater monitoring shall be performed pursuant to 62-780.750, FAC, *Post Active Remediation Monitoring*. The sampling requirements include:

- At least one well sampled at the downgradient edge of the plume.
- At least one well sample in the area(s) of highest groundwater contamination.
- Groundwater sampled quarterly, or at approved interval.
- Samples analyzed for contaminants present before the initiation of active remediation.

Using this standard, six monitoring wells are selected as candidates for long-term monitoring. The candidate monitoring wells were selected based on the groundwater CTL exceedances for metals, SVOCs, and VOCs, which are shown in Figures 4-9, 4-16, and 4-19. The candidate monitoring wells and analytical parameters are given in Table 6-2. Long-term monitoring would be conducted for 30 years.

Table 6-2
Candidate Monitoring Wells and Analytical Parameters for Long-Term Monitoring

Monitoring Well	Analytical Parameters	Monitoring Well	Analytical Parameters
11GS47	VOCs, SVOCs, metals	27GS19	VOCs, SVOCs
11GS52	VOCs, metals	30GS06	VOCs, SVOCs, metals
11GI12	VOCs	30GI170	VOCs

Implementability

Although not a remedy component, the NCP requires any alternative that leaves contamination onsite be reevaluated every 5 years to ensure its adequacy. This evaluation would include the spatial and temporal analyses of groundwater data to assess whether there are increasing, decreasing, or stationary trends in the concentrations of groundwater contaminants. This evaluation would be used to recommend continuation, increases, or decreases in the number of samples and types of analyses required to reevaluate the no-action alternative in subsequent 5-year reviews. Because 5-year reviews are considered in the media-specific RAAs for soil, they are not also estimated here.

Effectiveness

The no-action alternative is not effective at protecting human health. Although the surficial zone of the sand and gravel aquifer currently has no beneficial use, groundwater contamination may continue to exceed ingestion criteria, as shown in Figures 4-9, 4-16, and 4-19. Groundwater may discharge to the adjacent wetlands at concentrations exceeding the Class III surface water standards, as shown in Figure 4-20. Class III surface water criteria are protective of recreational use and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife.

Cost

The groundwater no-action alternative does not include conducting 5-year reviews because it would be redundant with the estimate for the soil no-action alternative shown in Section 6.1.1. The groundwater no-action alternative does include quarterly groundwater sampling of six monitoring wells with quality control samples. These monitoring wells would be sampled using a low-flow sampling protocol and analyzed for the parameters listed in Table 6-2. The RACER summary costs for the groundwater no-action alternative are given in Appendix C. The cost summary reports include 1) the site cost over time and 2) the long-term groundwater monitoring cost detail. The annual cost of groundwater monitoring is $55,244, multiplied by the escalation factor. The present value cost is calculated by discounting the site costs over time at a 6% discount rate. The present value cost of the groundwater no-action alternative is $1,003,984.

6.2.3 Alternative 2: Land Use Controls

This alternative would include the evaluation of the groundwater and the GSI to determine whether alternative groundwater CTLs are appropriate for OU 2 groundwater. The groundwater currently has no beneficial use and the many of the natural chemical constituents exceed the secondary drinking water standards. This may permit the groundwater to be classified as groundwater of low yield or poor quality, which would increase most groundwater CTLs by an order of magnitude. Additionally, LUCs would be established to reduce the exposure to groundwater, which would permit the groundwater plume to be managed at the LUC boundary or surface water boundary.

Implementability

If the groundwater is determined to be of poor quality, default CTLs for groundwater of low yield or poor quality would apply. Although this determination would reduce the number of exceedances, the groundwater would still have exceedances of the default CTLs for groundwater of low yield or poor quality. Thus, alternative groundwater CTLs would need to be established pursuit to Risk Management Options Level III, 62-780.680(3)(c). Alternative groundwater CTLs can be calculated using a lifetime excess cancer risk level of 1.0E-6 and a hazard index of 1 or less, which can be achieved by establishing LUCs to restrict the current and projected uses of the OU 2 groundwater. These alternative groundwater CTLs are appropriate as long as groundwater does not, and will not affect a freshwater or marine surface water, as stipulated in 62-780.680(2)(c)2. The GSI investigation, as described in Section 6.2.1, could be used to satisfy these criteria if:

- A hyporheic zone is identified in groundwater adjacent to the surface waters, based on conductivity and temperature demarcation, that minimizes groundwater infiltration and enhances contaminant attenuation processes; and

- Groundwater concentrations do not exceed Class III surface water CTLs in the hyporheic zone, if identified, or in monitoring wells installed adjacent to surface water.

At the LUC boundary, groundwater would need to be compliant with groundwater CTLs, or if appropriate, groundwater of low yield or poor quality CTLs.

NAS Pensacola currently operates as a C/I facility and the base is not proposed for closure. Thus, C/I status can be achieved through the implementation of LUC agreements to limit site access and property use. The LUC agreements would need to specifically restrict the use of groundwater. The groundwater is not used as a potable water supply and the groundwater exceeds secondary drinking water standards. Although potable water is not drawn from the groundwater, NAS Pensacola has three potable water wells that are used as a backup water supply for fire suppression. The LUC agreements would need to specifically address the groundwater to restrict potable water usage and to sufficiently limit occupational exposures. Annual compliance with the LUC agreements may be necessary. In the event that the property was transferred and onsite contamination remains above applicable requirements, the Navy would be required to deed restrict OU 2 as C/I property. The Navy has qualified planners and attorneys who can develop and implement proper LUCs for OU 2.

Although not a remedy component, the NCP requires any alternative that leaves contamination onsite be reevaluated every 5 years to ensure its adequacy. Therefore, the Navy would be required to perform a 5-year review to assess the adequacy of the LUCs alternative.

Effectiveness

The LUCs alternative would not provide any additional effectiveness for the current use scenario, but would provide long-term effectiveness by restricting future use and access. By limiting use and access, the groundwater would not be expected to exceed alternative CTLs. New monitoring locations adjacent to surface waters would be used to confirm that groundwater does not adversely affect surface water.

Cost

The groundwater LUCs alternative includes the GSI investigation, described in Section 6.2.1, and the determination of alternative groundwater CTLs using a focus risk assessment. The establishment of LUCs is redundant with the soil RAAs, described in Sections 6.1.2 to 6.1.5, and additional LUC agreements addressing groundwater are immaterial for cost estimation. The groundwater LUCs alternative also includes quarterly sampling of six groundwater wells to confirm

compliance with the Risk Management Options III criteria and the post active remediation monitoring requirements, as specified in 62-780.750, until the no further action criteria are satisfied. The RACER cost summary reports for the groundwater LUCs alternative are given in Appendix C. The cost summary reports include 1) the site cost over time, 2) the GSI investigation cost detail, 3) the focused risk assessment cost detail, and 4) the long-term groundwater monitoring cost detail. The estimated cost of GSI investigation is $155,392 and the estimated cost for the focused risk assessment is $13,386. The annual cost of groundwater monitoring is $55,244, multiplied by the escalation factor. When discounted at 6%, the total present value of the groundwater LUCs alternative is $1,175,293.

6.2.4 Alternative 3: Monitored Natural Attenuation

Many chemicals of concern may attenuate by natural processes, including dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials. The predominant groundwater CTL exceedances are VOCs emanating from Sites 11 and 30, which are shown in Figure 4-19. An evaluation of the VOC data may indicate that the chlorinated ethenes are biodegrading. Tetrachloroethene is a highly oxidized electron acceptor that can be reductively dechlorinated sequentially to trichloroethene, dichloroethene isomers, and ethene (USEPA, 1998b). Highly oxidized chlorinated ethenes are usually reduced through cometabolic processes during the microbial consumption of organic carbon, including the biodegradation of highly reduced organics, such as benzene, toluene, ethylbenzene, and xylenes (BTEX). Both oxidized and reduced VOCs are present at Site 30. Upgradient from Wetland 5A, highly oxidized chlorinated ethenes predominant, such as in monitoring wells 27GS19 and 30GS46. Some wells contain both oxidized and reduced VOCs, such as monitoring wells 27GS18, 27GS19, and 27GS04, which may be favorable for the degradation of the chlorinated ethenes through cometabolism. In downgradient wells, highly oxidized chlorinated ethenes are not observed. For example, in 30GS06, some BTEX species exist, but chlorinated ethenes do not exceed GCTLs. In monitoring well 30GS18, which is closest to Wetland 5A, vinyl chloride is the only VOC to exceed GCTLs, and its exceedance is marginal. A similar pattern is observed adjacent to the Yacht Basin. For example, in monitoring well 11GS47, the biodegradation of BTEX compounds may have cometabolized the chlorinated ethenes, because vinyl chloride is the only chlorinated ethene to exceed GCTLs. The biodegradation of chlorinated

ethenes is also observed to a lesser degree near Site 11. The number and magnitude of VOC exceedances generally decreased or remained stable from 1993 to 2003 (EnSafe, 2005). Several of the OU2 monitoring wells were sampled for MNA parameters in 2003 (EnSafe, 2005). OU2 groundwater generally exists under iron and sulfate reducing conditions and is favorable for reductive dechlorination, based on a geochemical ranking system provided in *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water* (EPA, 1998b).

As shown in Figure 4-16, most of the SVOC exceedances exceeded the GCTLs by less than an order of magnitude, which means degradation may be achievable through physical means. Additionally, naphthalene and methylnaphthalene are the predominant SVOCs that exceed GCTLs, and these SVOCs are generally amenable to biodegradation. The more recalcitrant SVOCs, such as the pentachlorophenol exceedance in 30GS06, barely exceed the GCTL. The number and magnitude of SVOC exceedances generally decreased or remained stable from 1993 to 2003 (EnSafe, 2005).

As shown in Figure 4-9, there are relatively few GCTL exceedances of potential anthropogenic metals, such as barium, cadmium, chromium, and lead, and none of these metals exceed the GCTL by more than a factor of 3. These metal exceedances may be naturally attenuated through physical means. As shown in Figure 4-8, iron and manganese are the only other metals to exceed GCTLs. These metals are naturally occurring and may not be indicative of contamination. The high concentrations of iron and manganese may indicate that there are strong reducing conditions in the groundwater near Sites 11 and 30, which will be favorable for chlorinated ethane reduction and chromium reduction.

Implementability

MNA is technically and administratively feasible provided that the relevant regulatory criteria are satisfied. MNA is an allowable strategy for site rehabilitation, and its applicability is described in Chapter 62-780.690, FAC. The GSI investigation described in Section 6.2.1 will be used to assess whether groundwater is contributing to surface water and sediment contamination in Wetlands 5A, 5B, 7, and 64.

MNA is allowable provided that the following relevant criteria are met:

- Free product is not present or free product removal is not technologically feasible and no fire or explosive hazard exists as a result of a release of non-aqueous phase liquids;
- The rate of natural attenuation in groundwater exceeds the rate at which contaminants are leached from the soil;
- The groundwater plume does not migrate beyond temporary compliance points;
- The physical, chemical, and biological characteristics of each contaminant and its transformation products is amenable to natural attenuation; and
- The available data show an overall decrease in the contamination.

As specified in 62-780.690(3), where surface water is or may be exposed to contaminated groundwater (based on monitoring well data, groundwater flow rate and direction, or fate and transport modeling), the point of measuring compliance with the surface water standards shall be in the groundwater from the landward side immediately adjacent to the surface water body. The GSI investigation described in Section 6.2.1 will be used for evaluating this criterion and selecting points of compliance. Permanent monitoring locations at the GSI will be selected based on results from the GSI investigation.

MNA will require the development of a monitoring program. Groundwater should be monitored in the source area and at the points of compliance for the purpose of evaluating natural attenuation. The monitoring wells would be gauged and sampled for MNA parameters no more than quarterly, and an annual evaluation would be performed to verify the progress of site rehabilitation. Sampling and evaluation reports would be submitted to USEPA and FDEP within 60 days of each event.

Although not a remedy component, the NCP requires any alternative that leaves contamination onsite be reevaluated every 5 years to ensure its adequacy. Additionally, per Navy guidance, the performance of remedial/ removal systems that leave contamination onsite shall be evaluated at least annually to measure progress toward the remedial action objective (U.S. Navy, 2003). This evaluation would include the spatial and temporal analyses of groundwater data to assess whether there are increasing, decreasing, or stationary trends in the concentrations of groundwater contaminants. This evaluation would be used to recommend continuation, increases, or decreases in the number of samples and types of analyses required to reevaluate the MNA alternative in subsequent 5-year reviews. Because 5-year reviews are considered in the media-specific RAAs for soil, they are not also estimated here.

Effectiveness

Based on the evaluation of the GCTL exceedances, MNA may be an effective means of remediating groundwater contamination. The effectiveness of MNA would be continually monitored and annual evaluations would be made to determine its continued viability. In the event that MNA did not achieve its objectives, an active remediation alternative would need to be pursued. MNA may continue after active remediation. MNA would continue until the No Further Action criteria of subsections 62-780.680(1), (2), and (3) are satisfied for two consecutive sampling events, or for four consecutive sampling events following active remediation.

Cost

The MNA alternative includes the installation of five point-of-compliance wells, which would be installed adjacent to surface water near Wetland 5A, 5B, 7, 8, and 64. Point-of-compliance wells will be monitored quarterly as a component of the long-term groundwater monitoring. Three source area monitoring wells will be monitored annually for MNA parameters and an evaluation report would be prepared and submitted to the FDEP. The RACER summary costs for the MNA alternative are given in Appendix C. The cost summary reports include 1) the site cost over time, 2) the GSI investigation cost detail, 3) the MNA cost detail, and 4) the long-term groundwater monitoring cost detail. The estimated cost of installing the point-of-compliance monitoring wells is $15,035, and the annual cost of MNA sampling and reporting is $22,999, multiplied by the

escalation factor. When discounted at 6%, the total present value of the MNA alternative is $1,598,950.

6.2.5 Alternative 4: Riparian Corridors

Riparian corridors are an application of phytoremediation. Phytoremediation processes are reviewed in Section 6.1.4. In a groundwater remedy, phytoremediation is typically applied as a riparian corridor and/or used for hydraulic control. These two applications are summarized as follows:

- *Hydraulic control* is the use of plants to remove groundwater through uptake and consumption in order to contain or control the migration of contaminants.

- *Riparian corridors/buffer strips* are generally applied along streams and river banks to control and remediate surface water runoff and groundwater contamination moving into the river. They may incorporate certain aspects of hydraulic control, phytodegradation, rhizodegradation, phytovolatilization, and perhaps phytoextraction.

Because the rooting depths of most crops are 1 to 4 feet, groundwater remedies predominantly use trees, which have been shown capable of remediating groundwater with water table depths of less than 30 feet. Riparian corridors are constructed by planting fast growing phreatophyte trees, including cottonwoods and poplars, in closely spaced trenched-rows. Typically, the riparian corridor consists of a triple row of trees and has a minimum width of 30 feet.

The riparian corridor alternative would not directly address groundwater exceedances in the industrial, developed areas of OU 2. In these areas, groundwater contamination would be permitted to naturally attenuate. Riparian corridors would be planted along the banks of the adjacent wetlands near Sites 11 and 30. The intended purpose of the riparian corridors would be to protect the surface water receptors by treating and removing groundwater contamination and by potentially limiting the infiltration of groundwater into surface water by transpiring the groundwater into the trees.

The riparian corridors alternative includes post-active remediation monitoring, as specified in the no-action alternative in Section 6.2.2.

Implementability

The construction of riparian corridors is technically and administratively feasible along the wetlands adjacent to Sites 11 and 30. The areas to be remediated are readily accessible, and water table is high. Furthermore, these areas have limited site development potential, ensuring that this remedy can be applied as a long-term remedy.

The riparian corridor alternative would include pilot testing to determine the appropriate species of tree and soil amendments. Because there are at least eight species of poplar indigenous to North America and because of their ability to form hybrids, it is expected that poplars can be cultivated in Pensacola. Trees are typically planted at a closely spaced interval in three parallel trenches. Because of the high water table, the trees may not need to be irrigated to become established. The riparian corridor would be closely monitored the first year to assure that the trees become established. In subsequent years, inspections would be performed to monitor the health of the trees and the effectiveness the remedy. The effectiveness of the riparian corridors at satisfying the RAOs must be continually monitored.

Although not a remedy component, the NCP requires any alternative that leaves contamination onsite be reevaluated every 5 years to ensure its adequacy. Additionally, per Navy guidance, the performance of remedial/removal systems that leave contamination onsite shall be evaluated at least annually to measure progress toward the remedial action objective (U.S. Navy, 2003). This evaluation would include the spatial and temporal analyses of groundwater data to assess whether there are increasing, decreasing, or stationary trends in the concentrations of groundwater contaminants. This evaluation would be used to recommend continuation, increases, or decreases in the number of samples and types of analyses required to reevaluate the groundwater pumping alternative in subsequent 5-year reviews. Because 5-year reviews are considered in the media-specific RAAs for soil, they are not also estimated here.

Effectiveness

Riparian corridors are a relatively new technology and they have mainly been used to remediate water soluble nutrients and pesticides. Poplars have been applied to mineralize atrazine and degrade chlorinated solvents. The effectiveness of this technology might be limited to easily assimilated and metabolized compounds, however.

Phreatophytes are particularly suited for hydraulic control. Young poplars were estimated to transpire 8 gallons per day (gpd), 5-year old poplars can transpire 25 to 50 gpd, and mature phreatophyte trees can transpire 200 to 400 gpd (EPA/600/R-99/107). Because the shallow aquifer has such a high hydraulic conductivity, however, riparian corridors would have limited capability of hydraulically controlling the aquifer — the geometric mean of hydraulic conductivity in shallow OU 2 wells was 167.7 ft/day, as reported in the RI.

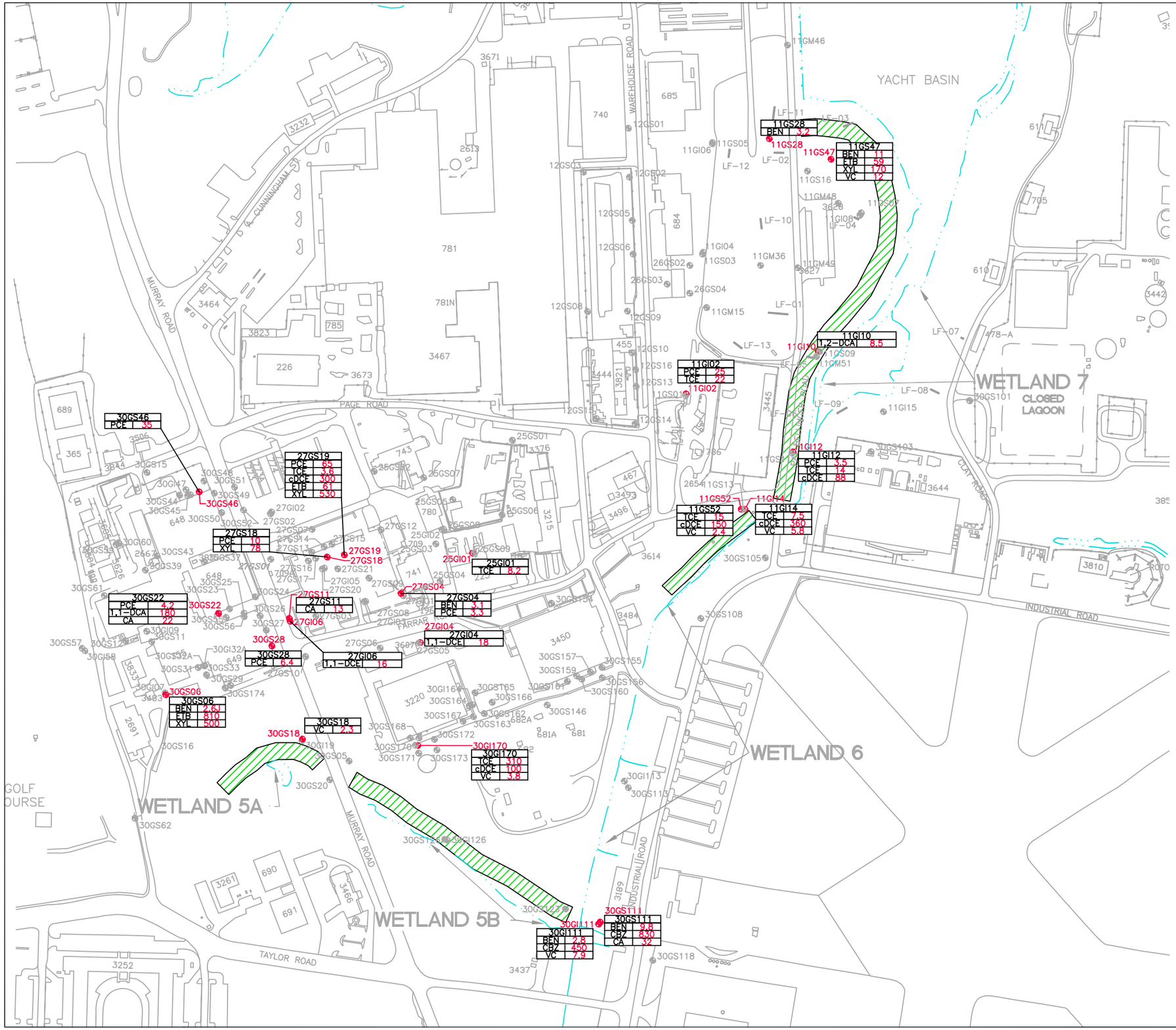
Riparian corridors are not immediately effective. Although poplars are fast growing trees, they would probably take a year to become established. Thus, the riparian corridor alternative effectiveness increases with time. Many of the trees, however, will not reach maturity due to overcrowding, competition, and disease. Young trees may also be prone to damage by animals. Poplar trees also have a relatively short lifespan of approximately 20 years.

Riparian corridors have a secondary advantage of stabilizing the stream bank and preventing erosion. They also greatly improve the aquatic and terrestrial habitats.

Because the riparian corridors would be constructed adjacent to surface water receptors, the short-term exposure to site workers would be limited. The site worker exposure risks would be minimized through the use of proper PPE. Because earthwork would be performed adjacent to surface water bodies, it would be necessary to construct silt fences along the riparian corridors.

Cost

Figure 6-6 shows the locations of the proposed riparian corridors. The total length of the riparian corridors is 3,240 ft and the width is 60 ft. Before construction, these 4.5 acres would be cleared



LEGEND

- SURFACE WATER BODY
- 743 BUILDING
- PROPOSED RIPARIAN CORRIDOR
- LF-10 TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 30GS155 SHALLOW OR INTERMEDIATE MONITORING WELL
- 30GS111 SHALLOW GROUNDWATER MONITORING WELL LOCATIONS/IDs WITH SAMPLE EXCEEDING THE GROUNDWATER CTL

SAMPLE ID	
PARAMETER KEY	CONCENTRATION

PARAMETER KEY

VOC	FLORIDA GCTL (ppb)
Benzene (BEN)	1
Chlorobenzene (CBZ)	100
Chloroethane (CA)	13
Chloroform (CF)	76
1,1-Dichloroethane (1,1-DCA)	76
1,2-Dichloroethane (1,2-DCA)	3
1,1-Dichloroethene (1,1-DCE)	7
cis-1,2-Dichloroethene (cDCE)	70
Ethylbenzene (ETB)	30
Tetrachloroethene (PCE)	3
Trichloroethene (TCE)	3
Toluene (TOL)	40
Vinyl Chloride (VC)	1
Xylenes [Total] (XYL)	20

NOTES

1. ALL CONCENTRATIONS ARE IN PARTS PER BILLION (PPB)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:
   - GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - GI = INTERMEDIATE GORUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE

160 0 160
SCALE FEET

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PENSACOLA, FLORIDA

FIGURE 6-6
GROUNDWATER ALTERNATIVE 2
LOCATIONS OF RIPARIAN CORRIDORS

Dr by: K. WOOSLEY	Proj. Code: 0059-001	
Ck by: C. TRIPP	App by: A. HARRIS	Sheet 1
Date: 11/06/05	DWG Name: 0059001B050	Of 1

and grubbed to remove existing vegetation. The riparian corridors would be constructed by planting 1,674 3-ft whip trees and installing an irrigation system. The whips would be expected to quickly become established when properly fertilized while planting and when irrigated. Ten 2-inch monitoring wells would be constructed to a 15-ft depth to facilitate performance monitoring of the riparian corridors. Soil and groundwater samples would be collected annually and analyzed for VOCs and MNA parameters for 30 years. The riparian corridor would also be inspected annually to assess the health of the trees. The results of the sampling and inspection would be used to complete the annual performance reviews (as specified in U.S. Navy, 2003).

The RACER summary costs for the riparian corridor alternative are given in Appendix C. The cost summary reports include 1) the site cost over time, 2) the GSI investigation cost detail, 3) the construction and operation cost detail, 4) the design cost summary, and 5) the long-term groundwater monitoring cost detail. The first year cost of the riparian corridors alternative is $413,731, which includes the GSI investigation; the design, construction, first-year operation, and performance sampling of the riparian corridor; and the long-term groundwater sampling. Performance and long-term groundwater sampling would continue for 30 years. When discounted at 6%, the total present value of the riparian corridors alternative is $2,061,272.

6.2.6 Alternative 5: Permeable Reactive Barrier and Riparian Corridors

Although riparian corridors would be protective of adjacent surface waters, they would not be applied to meet groundwater CTLs away from the adjacent wetlands. In Alternative 5, PRBs are added as a complementary component of Alternative 4, which treats the chlorinated solvent plume extending from the southeast corner of the Building 649 complex. Thus, Alternative 5 includes all of the components of Alternative 4, plus the construction of a PRB.

Zero-valent iron (ZVI) PRBs are typically applied to remediate dilute plumes of chlorinated solvents, or other oxidized contaminants, and are not typically used for source zone treatment. As chlorinated solvents interact with the PRB, the ZVI serves as a reductant for the reductive dechlorination of the chlorinated solvents, which oxidizes the iron. TCE degrades by the competing pathways of sequential hydrogenolysis and reductive β-elimination. In sequential

hydrogenolysis, TCE degrades to DCE isomers, which may then degrade to vinyl chloride and ethene. In reductive β-elimination, ZVI may degrade TCE to chloroacetylene (H–C≡C–Cl), then to acetylene (H–C≡C–H), then to ethene. The reductive β-elimination intermediate products are likely to be short-lived. PRBs should be designed to provide sufficient contaminant residence time for intermediate products, such as *cis*-1,2-DCE and vinyl chloride, to fully degrade to ethene. ZVI PRBs also have a secondary treatment mechanism. Several redox reactions produce hydroxide ions, which can raise the pH to more than 9 and promote the precipitation of many metal species. In poorly buffered groundwater, the pH has been reported to increase to 11.

In addition to providing sufficient residence time for contaminant degradation, PRBs have the contrasting objective of being a preferential conduit for contaminated groundwater flow. PRBs should ideally have a higher hydraulic conductivity than the surrounding formation. When the hydraulic conductivity of the PRB is less than the aquifer, groundwater may be preferentially directed around, under, or over the barrier. Groundwater flow under PRBs can be averted by keying the PRB into an underlying confining layer, which is estimated to exist at 25 to 40 ft bgl near Site 30. Nevertheless, the hydraulic conductivity of the aquifer is very high (the geometric mean of the hydraulic conductivity in shallow OU 2 wells was 167.7 ft/day) and the competency of the lower confining layer is unknown. Additionally, the hydraulic conductivity of the PRB is likely to degrade due to the precipitation of metals and the potential build-up of hydrogen gas, which is formed by the reaction of ZVI and water, but which would be moderated by biological activity. Because of these concerns, in their PRB design guidance, Gavaskar et al., (2000) recommend that the PRB should be at least 5 times as permeable as the surrounding aquifer.

PRBs are frequently constructed as funnel-and-gate systems, where impermeable funnels direct groundwater through reactive ZVI permeable gates. When properly designed, the impermeable funnels increase the groundwater head and direct groundwater through the permeable gates at an increased velocity. Although this configuration can reduce the material costs for PRB construction, it is probably not appropriate at OU 2. Without a competent aquitard below the contaminated groundwater, the impermeable funnels would not direct groundwater through the PRB gates. Given the high hydraulic conductivity of the formation, the construction of a sufficiently permeable PRB

would be difficult. Because of these constraints, the PRB would probably need to be constructed across the entire downgradient edge of contaminated zone and be keyed into the underlying confining zone.

The PRB and riparian corridors alternative includes post-active remediation monitoring, as specified in the no-action alternative in Section 6.2.2.

Implementability

The construction of a PRB is technically and administratively feasible near the Building 649 complex. The preferred location for the PRB is immediately downgradient of the Building 649 complex, along an equal potentiometric line, upgradient of Wetland 5A. This location extends across Murray Road and probably intersects underground utilities. If the PRB is constructed under Murray Road, the road would need to be temporarily closed and repaved. The PRB could either be designed around the underground utilities or the utilities could be re-routed. In addition to the construction of an impermeable barrier at the top of the PRB, the ground surface may need to be re-contoured to limit the infiltration of surface water into the PRB.

The PRB could be constructed by number of methods, including excavation and slurry trenching, deep soil mixing, and high pressure jetting. The construction method would be selected in the design, and would be dependent on the hydraulic and soil properties, the desired reactivity, the redundancy of downgradient protection, the presence and persistence of utilities, and the relative construction cost. PRBs are conventionally constructed in an excavated trench that is filled with bentonite slurry. As the trench is advanced, reactive media is added to displace the slurry, such that approximately 300 ft of slurry mixture is reused for an elongated trench. This method may not be feasible, however, because flowing sands may collapse the slurry trench and the presence and persistence of underground utilities may make this method difficult to implement. Although deep soil mixing and high pressure jetting are less invasive methods of emplacement, they emplace less reactive media and do not ensure continuity of the PRB.

Once constructed, PRBs require minimal maintenance. The maintenance requirements would be limited to effectiveness monitoring, which may be used to evaluate the longevity of the PRB. Although the PRB would have a limited lifespan due to decreased reactivity and permeability, there is insufficient precedence to determine exactly how long the PRB would remain sufficiently effective and when it should be replaced. The PRB would be expected to be effective for a minimum of 10 to 20 years, however. During this period, many pore volumes of groundwater would pass through the PRB and the remaining contamination would presumably decrease due to attenuation processes. Thus, PRB replacement is not anticipated.

Although not a remedy component, the NCP requires any alternative that leaves contamination onsite be reevaluated every 5 years to ensure its adequacy. Additionally, per Navy guidance, the performance of remedial/removal systems that leave contamination onsite shall be evaluated at least annually to measure progress toward the remedial action objective (U.S. Navy, 2003). This evaluation would include the spatial and temporal analyses of groundwater data to assess whether there are increasing, decreasing, or stationary trends in the concentrations of groundwater contaminants. This evaluation would be used to recommend continuation, increases, or decreases in the number of samples and types of analyses required to reevaluate the groundwater pumping alternative in subsequent 5-year reviews. Because 5-year reviews are considered in the media-specific RAAs for soil, they are not also estimated here.

Effectiveness

The construction of a ZVI PRB would provide an additional level of effectiveness than riparian corridors alone. Although riparian corridors are protective of surface waters, they do not address groundwater CTL exceedances away from the adjacent wetlands. Furthermore, riparian corridors require time to reach their maximum effectiveness and the effectiveness is uncertain. In contrast, PRBs are immediately effective at treating passing groundwater. Thus, the construction of a PRB would passively treat the most contaminated groundwater and provide an additional level of protection for surface waters.

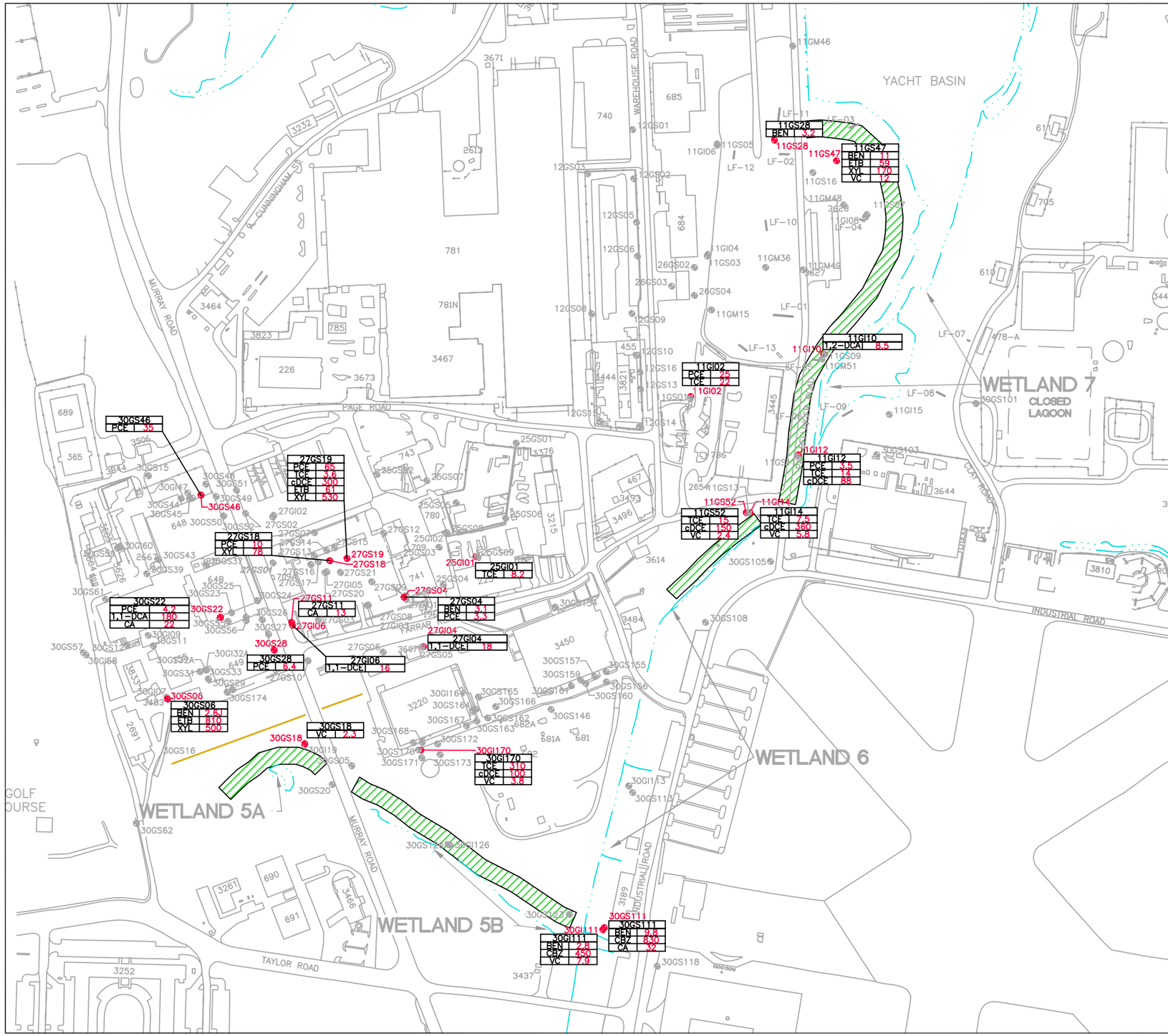
Although ZVI PRBs are effective at reducing the concentrations of many of the COPCs, they produce undesirable groundwater quality immediately downgradient of the PRB. The undesirable effects include increased pH, decreased dissolved oxygen, and ferrous iron leaching. Although these effects are generally limited to the groundwater immediately downgradient of the PRB, the aquifer resiliency is highly site-specific. These conditions would not be expected to mobilize contamination, but would stress the microbes and make the downgradient zone unfavorable for the oxidation and biodegradation of reduced hydrocarbons, such as BTEX compounds. If the riparian corridor is situated downgradient of the PRB, it would amend the adverse effects, if any, before the groundwater is discharged to surface water.

Although the construction of the PRB would result in a short-term risk to site construction workers, this risk would be minimized through the use of proper PPE. Although earthwork may result in a temporary increase in erosion to Wetland 5A, appropriate measures would be taken to minimize erosion. These measures may include silt fencing and hay bails, temporary and permanent run-on and runoff control, and re-seeding.

Cost

Figure 6-7 shows the locations of the proposed PRB and riparian corridors. The riparian corridor details and costs in Alternative 5 are identical to Alternative 4, and are not repeated in this section. In this cost estimate, the PRB would be constructed using a conventional method of excavating a trench, securing it with a bentonite slurry, and displacing the slurry with reactive media. The PRB would be 720 ft long, 40 ft deep, and 2.5 ft wide. The lower 30 ft of the PRB would be constructed of 50% iron fillings and 50% pea gravel and the top 10 ft of the PRB would be constructed of montmorillonite clay. Fifteen 2-inch monitoring wells would be constructed to a 40-ft depth on the downgradient side of the PRB to facilitate performance monitoring. Groundwater samples would be collected annually and analyzed for VOCs. The analytical results would be used to complete the annual performance review (as specified in U.S. Navy, 2003).

The RACER summary costs for the PRB and riparian corridor alternative are given in Appendix C. The cost summary reports include 1) the site cost over time, 2) the GSI investigation cost detail,



LEGEND

- SURFACE WATER BODY
- 743 BUILDING
- PROPOSED RIPARIAN CORRIDOR
- PROPOSED PERMEABLE REACTIVE BARRIER
- LF-10 TRENCH LOCATIONS/IDs
- FENCE LINE
- ROADS
- SIDEWALKS
- 30GS155 SHALLOW OR INTERMEDIATE MONITORING WELL
- 30GS111 SHALLOW GROUNDWATER MONITORING WELL LOCATIONS/IDs WITH SAMPLE EXCEEDING THE GROUNDWATER CTL

SAMPLE ID	
PARAMETER KEY	CONCENTRATION

PARAMETER KEY

VOC	FLORIDA GCTL (ppb)
Benzene (BEN)	1
Chlorobenzene (CBZ)	100
Chloroethane (CA)	13
Chloroform (CF)	76
1,1-Dichloroethane (1,1-DCA)	76
1,2-Dichloroethane (1,2-DCA)	3
1,1-Dichloroethene (1,1-DCE)	7
cis-1,2-Dichloroethene (cDCE)	70
Ethylbenzene (ETB)	30
Tetrachloroethene (PCE)	3
Trichloroethene (TCE)	3
Toluene (TOL)	40
Vinyl Chloride (VC)	1
Xylenes [Total] (XYL)	20

NOTES

1. ALL CONCENTRATIONS ARE IN PARTS PER BILLION (PPB)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:
   - GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
   - GI = INTERMEDIATE GORUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE

160 0 160
SCALE FEET

NAVFAC Naval Facilities Engineering Command SOUTHERN DIVISION

FEASIBILITY STUDY
OPERABLE UNIT 2
NAS PENSACOLA
PENSACOLA, FLORIDA

FIGURE 6-7
GROUNDWATER ALTERNATIVE 3
LOCATIONS OF RIPARIAN CORRIDORS
AND PERMEABLE REACTIVE BARRIER

Dr by: K. WOOSLEY	Proj. Code: 0059-001	
Ck by: C. TRIPP	App by: A. HARRIS	Sheet 1
Date: 11/09/05	DWG Name: 0059001B051	Of 1

3) the construction and operation cost detail, 4) the design cost summary, and 5) the long-term groundwater monitoring cost detail. The first year cost of the PRB and riparian corridors alternative is $2,816,423, which includes the GSI investigation; the design, construction, first-year operation, and performance sampling of the PRB and riparian corridors; and the long-term groundwater sampling. Performance and long-term groundwater sampling would continue for 30 years. When discounted at 6%, the total present value of the PRB and riparian corridors alternative is $4,929,829.

6.2.7 Alternative 6: Groundwater Pumping and Discharge to FOTW

Groundwater pumping is a conventional method for remediating groundwater and includes the processes of containment, removal, and treatment. Extraction wells are installed near contaminant hotspots to remove groundwater contamination. Pumping also has the capability of hydraulically containing groundwater contamination, which may prevent the seepage of contaminated groundwater into adjacent surface waters. Extracted groundwater is then treated and disposed.

The high permeability of the surficial sand and gravel aquifer may make the groundwater pumping alternative impracticable. In the RI, the geometric mean of the hydraulic conductivity was 167.7 ft/day for the shallow aquifer. When the hydraulic conductivity is large, the well yield is large and the radius of influence is limited. The well yield in fully penetrating wells in unconfined aquifers can be estimated using the Thiem equation for unconfined aquifers (Bouwer, 1978):

$$Q = \frac{\pi K\left(h_2^2 - h_1^2\right)}{\ln\left(r_2 / r_1\right)}$$

In this equation, Q is the pumping rate, K is the hydraulic conductivity, r_1 and h_1 are the radius of well (3-inch) and the height of water above the bottom of the formation during pumping, and r_2 and h_2 are the assumed radius (50-ft) to the undisturbed water table and the undisturbed water table elevation (35-ft saturated thickness used). Although this calculation does not include well losses, these may reduce the estimated well yield by 20 to 30% for well-constructed extraction wells. In the surficial sand and gravel aquifer, the well yield is pump-constrained, as opposed to formation-constrained. Solutions to the Thiem equation for unconfined flow indicate that a 35.6 gpm pumping rate is needed to induce a 1-ft drawdown in the aquifer adjacent to the

extraction well, a 70.2 gpm pumping rate is needed to induce a 2 ft drawdown, and 103.8 gpm pumping rate is needed to induce a 3-ft drawdown.

The radius of influence for the extraction well can be estimated using Boulton's equation for unconfined flow (Bouwer, 1978):

$$s = \frac{Q}{2\pi KH}\left(1 + C_k\right)V\left(t', r'\right)$$

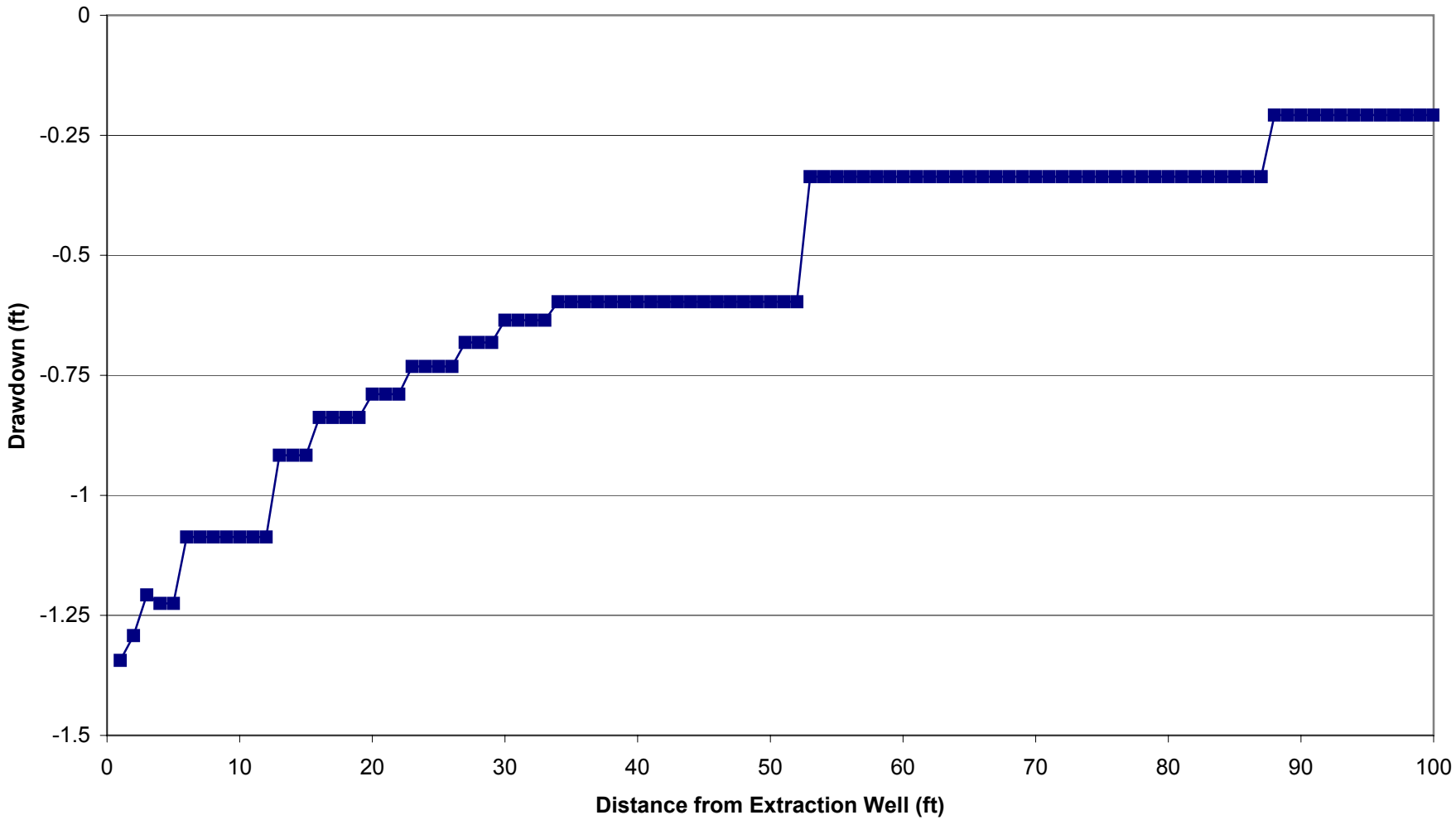
$$t' = \frac{Kt}{SH}$$

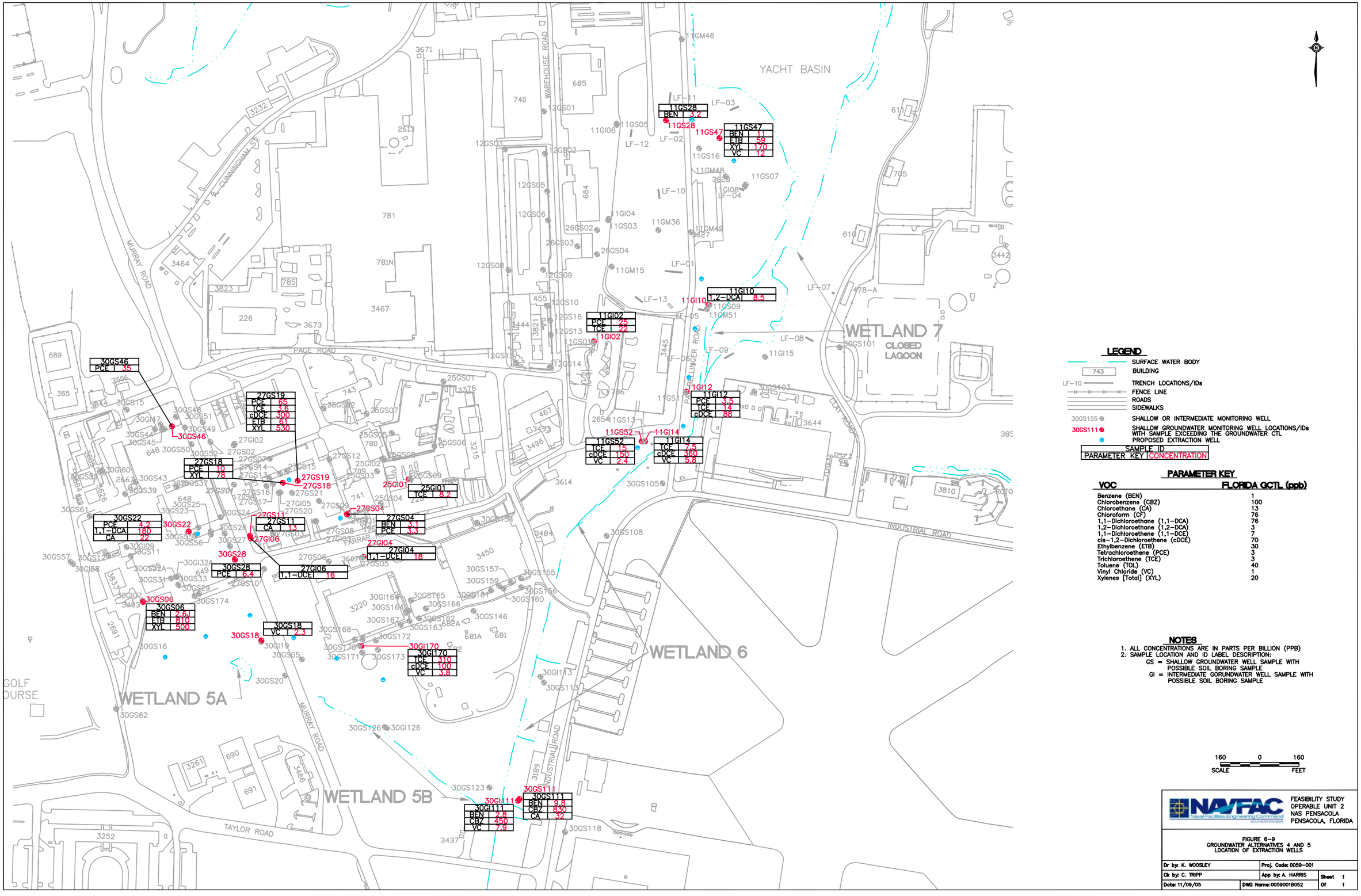
$$r' = \frac{r}{H}$$

In this equation, s is the drawdown at radius r, H is the static water level, C_k is a correction factor that is a function of r', $V(t',r')$ is Boulton's well function, S is the storativity, and t is the elapsed pumping time. This equation is valid when the water height in the well is greater the 0.5H. Figure 6-8 shows the solution to Boulton's equation after 7 days for unconfined flow when the extraction rate is 70 gpm. The discontinuity in this solution is a consequence of using the discrete solution to Bouton's well function, as given in Bouwer (1978). This solution yields a 0.60-ft drawdown 52 ft from the extraction well and a 0.34-ft drawdown 87 ft from the extraction well after 7 days of continuous pumping at 70 gpm.

In the conceptual evaluation of the groundwater pumping alternatives, groundwater contamination is addressed by pumping groundwater at a 70 gpm pump rate from multiple 6-inch extraction wells, which are presumed to have 100-ft radii of influence. The extraction well network would consist of 13 extraction wells, constructed to 25 ft bgl, on the downgradient perimeter of OU 2 to address groundwater discharging to surface water, and 3 extraction wells, constructed to 25 ft bgl, to treat the VOC source area in the Building 649 complex. Extraction wells would be spaced at an approximately 200-ft interval, which is estimated to hydraulically contain groundwater. The extraction well locations are shown in Figure 6-9, which are superimposed on the Phase III VOC GCTL exceedances, shown in Figure 4-19. As shown in Figure 4-16, there were limited Phase III SVOC GCTL exceedances, and these occurred in wells with VOC exceedances. Because monitoring wells 30GS111 and 30GI111 occur on the opposite side of Wetland 6, SVOC

Figure 6-8: Estimated Radius of Influence of 6-inch Extraction Well in Shallow Groundwater at OU 2 When Pumped at 70 GPM for 7 Days Solution to Boulton's Equation for Unconfined Flow of a Fully Penetrating Well




YACHT BASIN
WETLAND 7
CLOSED LAGOON
WETLAND 6
WETLAND 5A
WETLAND 5B
GOLF COURSE
WAREHOUSE ROAD
MURRAY ROAD
PAGE ROAD
A. CUNNINGHAM
PLANTER ROAD
CLAY ROAD
INDUSTRIAL ROAD
TAYLOR ROAD
11GS28 BEN 3.2
11GS47 BEN 11 ETB 59 XYL 170 VC 12
11GI10 1,2-DCA 8.5
11GI02 PCE 25 TCE 22
11GI12 PCE 3.5 TCE 14 cDCE 88
11GS52 TCE 75 cDCE 150 VC 2.4
11GI14 TCE 7.5 cDCE 360 VC 5.8
30GS46 PCE 35
27GS19 PCE 65 TCE 3.6 cDCE 300 ETB 61 XYL 530
27GS18 PCE 10 XYL 78
25GI01 TCE 8.2
30GS22 PCE 4.2 1,1-DCA 180 CA 22
27GS11 CA 13
27GS04 BEN 3.1 PCE 3.3
27GI04 1,1-DCE 18
27GI06 1,1-DCE 16
30GS28 PCE 6.4
30GS06 BEN 2.6J ETB 810 XYL 500
30GS18 VC 2.3
30GI170 TCE 310 cDCE 100 VC 3.8
30GI111 BEN 2.8 CBZ 450 VC 7.9
30GS111 BEN 9.8 CBZ 830 CA 32
LEGEND
SURFACE WATER BODY
BUILDING
TRENCH LOCATIONS/IDs
FENCE LINE
ROADS
SIDEWALKS
SHALLOW OR INTERMEDIATE MONITORING WELL
SHALLOW GROUNDWATER MONITORING WELL LOCATIONS/IDs WITH SAMPLE EXCEEDING THE GROUNDWATER CTL
PROPOSED EXTRACTION WELL
SAMPLE ID
PARAMETER KEY CONCENTRATION
PARAMETER KEY
VOC FLORIDA GCTL (ppb)
Benzene (BEN) 1
Chlorobenzene (CBZ) 100
Chloroethane (CA) 13
Chloroform (CF) 76
1,1-Dichloroethane (1,1-DCA) 76
1,2-Dichloroethane (1,2-DCA) 3
1,1-Dichloroethene (1,1-DCE) 7
cis-1,2-Dichloroethene (cDCE) 70
Ethylbenzene (ETB) 30
Tetrachloroethene (PCE) 3
Trichloroethene (TCE) 3
Toluene (TOL) 40
Vinyl Chloride (VC) 1
Xylenes [Total] (XYL) 20
NOTES
1. ALL CONCENTRATIONS ARE IN PARTS PER BILLION (PPB)
2. SAMPLE LOCATION AND ID LABEL DESCRIPTION:
GS = SHALLOW GROUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
GI = INTERMEDIATE GORUNDWATER WELL SAMPLE WITH POSSIBLE SOIL BORING SAMPLE
160 0 160
SCALE FEET
NAVFAC Naval Facilities Engineering Command SOUTHERN DIVISION
FEASIBILITY STUDY
OPERABLE UNIT 2
NAS PENSACOLA
PENSACOLA, FLORIDA
FIGURE 6-9
GROUNDWATER ALTERNATIVES 4 AND 5
LOCATION OF EXTRACTION WELLS
Dr by: K. WOOSLEY
Proj. Code: 0059-001
Ck by: C. TRIPP
App by: A. HARRIS
Sheet 1
Date: 11/09/05
DWG Name: 0059001B052
Of 1

and VOC exceedances in these monitoring wells are not addressed in this remedy. The extraction well network would address the GCTL exceedances for barium, cadmium, chromium, and lead, which are shown in Figure 4-9, with the exception of marginal lead exceedance in monitoring well 30GS126, which is adjacent to Wetland 5B. The extraction well network would not address exceedances of secondary drinking water standards for inorganics, specifically aluminum, iron, and manganese, which are shown in Figure 4-8. Secondary drinking water standard exceedances are presumed to be attributed to natural background conditions.

Alternatives 6 and 7 differ only in the groundwater disposal option. In Alternative 6, groundwater is discharged directly to the FOTW, whereas in Alternative 7, groundwater is treated and discharged to the adjacent wetlands. Although Alternative 6 is favorable, the quality and quantity of extracted groundwater may exceed the FOTW's pretreatment standards or capacity. In other NAS Pensacola remediation activities, the FOTW has both accepted and rejected extracted wastewater for treatment. If a sufficient percentage of brackish groundwater is extracted, the salinity of the water may be detrimental to the activated sludge at the FOTW. In Alternative 6, extracted groundwater would be routed through multiple trunk lines, and discharged to the FOTW through the sanitary sewer system.

The groundwater pumping alternatives include post-active remediation monitoring, as specified in the no-action alternative in Section 6.2.2.

Implementability

The construction of the extraction well network and piping for FOTW discharge to the sanitary sewer is technically feasible at OU 2. However, it is not known whether the extracted groundwater would exceed the quality and quantity restrictions for FOTW disposal. In the conceptual groundwater pumping scenario, 16 extraction wells would be constructed and continuously pumped at 70 gpm. This produces at total continuous discharge of 1,120 gpm. This discharge quantity may exceed the treatment capacity of the FOTW. Additionally, four of the extraction wells are constructed within 150 ft of the tidally-influenced Yacht Basin, and these wells may produce brackish water, which may be prohibited from the FOTW discharge. Groundwater extraction and discharge to the FOTW may also cause an impact on the water budget of the adjacent wetlands.

The Navy is predisposed against the installation of new pump-and-treat remedies. The predisposition is because pump-and-treat remedies typically become long-term remedies, have trouble meeting the remedial action objectives, and are rarely optimized for maximum performance. The following is an excerpt from the *Navy/Marine Corps Policy for Optimizing Remedial and Removal Actions At All Installation Restoration and Munitions Response Program Sites* (U.S. Navy, 2003):

> ***Special Technical Issue:*** Since 1998, Navy, other DoD Components, and the Environmental Protection Agency (EPA) have been conducting evaluations of the effectiveness of "pump and treat" systems to address groundwater contamination. Consensus of all parties is that pump and treat systems are rarely the optimal alternative for groundwater response actions. Therefore, any plans to install new pump and treat systems on Navy and Marine Corps installations requires approval from Headquarters (HQ) at the Naval Facilities Engineering Command (NAVFAC). This requirement applies to all "pump and treat" systems (remedial and removal actions) where groundwater is removed from the sub-surface by pumping or other means, treated above ground in any way, and discharged in any way (i.e., off site disposal, sewer systems, re-injected, etc.) In order to receive the NAVFAC HQ approval, the IR Manager shall forward a summary of the site background, the conceptual site model (CSM), the remedial action objectives, a listing of the technologies screened for the site, a summary of the alternatives analysis, and a statement of why "pump and treat" is the most appropriate technology to be used at the site, including a life cycle cost analysis (net present value and total site cost) and exit strategy. NAVFAC HQ will provide a written approval/dis-approval response to the IR Manager based on review of this submittal.

Although this does not preclude the application of a pump-and-treat remedy, it increases the burden for its implementation.

Groundwater pumping may become a *de facto* long-term remedy if remedial goals are not met. The operation of the groundwater pumps can be automated and telemetry installed to facilitate minimal O&M.

Groundwater monitoring must be continued after the termination of treatment, if applicable. A minimum of four groundwater sampling events are required and site rehabilitation shall be considered complete when the No Further Action criteria of 62-780.680(2), FAC, have been met for at least the last two sampling events [62-780.750(4)(f), FAC]. Because it is assumed that the groundwater pumping alternatives are *de facto* long-term remedies, however, groundwater monitoring is assumed for 30 years.

Although not a remedy component, the NCP requires any alternative that leaves contamination onsite be reevaluated every 5 years to ensure its adequacy. Additionally, per Navy guidance, the performance of remedial/ removal systems that leave contamination onsite shall be evaluated at least annually to measure progress toward the remedial action objective (U.S. Navy, 2003). This evaluation would include the spatial and temporal analyses of groundwater data to assess whether there are increasing, decreasing, or stationary trends in the concentrations of groundwater contaminants. This evaluation would be used to recommend continuation, increases, or decreases in the number of samples and types of analyses required to reevaluate the groundwater pumping alternative in subsequent 5-year reviews. Because 5-year reviews are considered in the media-specific RAAs for soil, they are not also estimated here.

Effectiveness

The groundwater pumping alternatives are effective for the containment, removal, and treatment of contamination groundwater. The 13 extraction wells proposed along the wetlands would prevent contaminated groundwater from discharging to the wetlands, and are thus protective of Class III surface waters. The three extraction wells proposed in the Building 649 complex would be used to remove the source area contamination, and would thus be protective of the future beneficial use of groundwater.

Cost

Figure 6-9 shows the locations of the 16 proposed extraction wells. The extraction wells are 6-inch PVC wells constructed to a depth of 25 ft. Groundwater is pumped from the wells into subsurface conveyance piping. The conveyance piping from the 16 extraction wells to the sanitary sewer is estimated to include 3,000 ft of pressure-rated piping. Because 13 of the extraction wells are located at topographic lows along the waterfront, this estimate includes two prefabricated 800,000 gpd lift stations. The cost estimate includes O&M for 30 years. O&M activities include maintenance of the 16 groundwater pumps and two lift stations and the collection of monthly compliance samples for FOTW discharge.

The RACER summary costs for the groundwater pumping and FOTW discharge alternative are given in Appendix C. The cost summary reports include 1) the site cost over time, 2) the GSI investigation cost detail, 3) the construction cost detail, 4) the design cost summary, 5) the O&M cost detail, and 6) the long-term groundwater monitoring cost detail. The first year cost of the groundwater pumping and FOTW discharge alternative is $1,153,716, which includes the GSI investigation; the design, construction, O&M, and compliance sampling; and the long-term groundwater sampling. O&M, compliance sampling, and long-term groundwater sampling would continue for 30 years. When discounted at 6%, the total present value of the groundwater pumping and FOTW discharge alternative is $3,501,880.

6.2.8 Alternative 7: Groundwater Pumping, Treatment, and Discharge to Wetlands

The groundwater pumping scenario in Alternative 7 is identical to Alternative 6, and is not repeated in this section. Alternative 7 differs in the disposal option for the extracted groundwater. Because the extracted groundwater may exceed the quality and quantity criteria for the FOTW, an independent treatment and disposal option is developed. Extracted groundwater would be primarily contaminated with VOCs, but may also need treatment for SVOC and metal exceedances. The treatment scenario developed in this alternative includes air stripping as primary treatment and GAC as secondary treatment. Air stripping is a conventional method for removing chlorinated solvents and BTEX from extracted groundwater. Air stripping may also have limited effectiveness for SVOC and metals treatment, possibly through scaling processes. GAC would be required as

secondary treatment, however, to remove residual SVOCs, VOCs, and metals from the waste stream. After primary treatment, extracted groundwater would be routed through sequential GAC canisters and the water quality would be measured from a sample port in between the GAC canisters. This sample location permits contaminant breakthrough to be observed and for appropriate measures, such as GAC replacement, to be performed. GAC replenishment and disposal would be performed offsite. After primary and secondary treatment, the treated groundwater would be discharged to the adjacent wetlands as a NPDES permitted discharge.

Although vapor treatment may be required for the air stripper, preliminary calculations indicate that vapor treatment is not necessary. In 62-210.300(3)(a)38, FAC, brownfield site remediation is exempted from permitting when the total VOCs in the air emissions from all onsite remediation equipment does not exceed 13.7 pounds per day. When VOCs are stripped from 1,120 gpm of groundwater, the average VOC concentration in the groundwater would have to exceed 1,020 µg/l to exceed the 13.7 pounds per day criteria. As shown in Figure 4-19, the total VOC concentration exceeded this criterion in only one monitoring well — 30GS06 — which had a total VOC concentration of 1,310 µg/l. Because extracted groundwater is received from 16 wells and commingled before treatment, the air stripping unit would not be anticipated to exceed the criteria for air permitting.

Implementability

The groundwater pumping, treatment, and discharge to wetlands alternative is technically feasible at OU 2. The operation of the groundwater pumps, the air strippers, and the GAC canisters can be automated and telemetry installed to facilitate minimal O&M. Although this treatment system could be designed for minimal O&M, air strippers are prone to scaling from iron oxidation. Sequestering agents may be used to minimize scaling. Monthly O&M may be required to inspect the treatment system, replenish the sequestering agent, acid-wash the air stripper, and replace the GAC canister, as needed. Monthly maintenance may also be required to collect compliance samples for the discharge monitoring reports, as specified in the NPDES permit.

As discussed in Section 6.2.7, the Navy is predisposed against the installation of new pump-and-treat systems and an additional level of scrutiny is required. Groundwater pumping may become a *de facto* long-term remedy if remedial goals are not met.

Groundwater monitoring must be continued after the termination of treatment, if applicable. A minimum of four groundwater sampling events are required and site rehabilitation shall be considered complete when the No Further Action criteria of 62-780.680(2), FAC, have been met for at least the last two sampling events [62-780.750(4)(f), FAC]. Because it is assumed that the groundwater pumping alternatives are *de facto* long-term remedies, however, groundwater monitoring is assumed for 30 years.

Although not a remedy component, the NCP requires any alternative that leaves contamination onsite be reevaluated every 5 years to ensure its adequacy. Additionally, per Navy guidance, the performance of remedial/ removal systems that leave contamination onsite shall be evaluated at least annually to measure progress toward the remedial action objective (U.S. Navy, 2003). This evaluation would include the spatial and temporal analyses of groundwater data to assess whether there are increasing, decreasing, or stationary trends in the concentrations of groundwater contaminants. This evaluation would be used to recommend continuation, increases, or decreases in the number of samples and types of analyses required to reevaluate the groundwater pumping alternative in subsequent 5-year reviews. Because 5-year reviews are considered in the media-specific RAAs for soil, they are not also estimated here.

Effectiveness

The groundwater pumping alternatives are effective for the containment, removal, and treatment of contamination groundwater. The 13 extraction wells proposed along the wetlands would prevent contaminated groundwater from discharging to the wetlands, and are thus protective of Class III surface waters. The 3 extraction wells proposed in the Building 649 complex would be used to remove the source area contamination, and would thus be protective of the future beneficial use of groundwater.

Discharging the extracted groundwater to the wetlands would help maintain the existing water balance. As considered, approximately 1,120 gpm of groundwater would be extracted from the shallow sand and gravel aquifer. Most of this groundwater would normally discharge to the wetlands, and the pumping in extraction wells adjacent to the wetlands may actually drain Wetlands 5A and 5B. Thus, by discharging treated groundwater to the wetlands, the continued water balance of the wetlands would be maintained. This would protect the existing flora and fauna in the adjacent Wetlands 5A and 5B.

Cost

The groundwater pumping and conveyance aspects of Alternative 7 are identical to Alternative 6, and are not repeated in this section. Alternative 7 also includes air stripping and GAC treatment systems for the 1,120 gpm flow. The component details for the treatment system are provided in the RACER cost estimates in Appendix C. The cost estimate includes O&M for 30 years. O&M activities include maintenance of the 16 groundwater pumps and two lift stations, maintenance of the air stripping and GAC treatment systems, and the collection of monthly compliance samples for NPDES discharge and vapor discharge from the air stripper.

The RACER summary costs for the groundwater pumping, treatment, and NPDES discharge alternative are given in Appendix C. The cost summary reports include 1) the site cost over time, 2) the GSI investigation cost detail, 3) the construction cost detail, 4) the design cost summary, 5) the O&M cost detail, and 6) the long-term groundwater monitoring cost detail. The first year cost of the groundwater pumping, treatment, and NPDES discharge alternative is $2,521,620, which includes the GSI investigation; the design, construction, O&M, and compliance sampling; and the long-term groundwater sampling. O&M, compliance sampling, and long-term groundwater sampling would continue for 30 years. When discounted at 6%, the total present value of the groundwater pumping, treatment, and NPDES discharge alternative is $12,683,467.