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FINAL FOCUSED FEASIBILITY STUDY
NAS PENSACOLA SITE 1

NAVAL AIR STATION PENSACOLA
PENSACOLA, FLORIDA

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19. Abstract

This Focused Feasibility Study (FFS) develops, evaluates, and compares four remedial action alternatives that may be used to mitigate hazards and threats to human health and the environment at Site 1 at Naval Air Station (NAS) Pensacola. The FFS addresses soil and groundwater contamination as recommended in the ***Final Remedial Investigation Report for Site 1, Naval Air Station Pensacola, Pensacola, Florida*** (EnSafe/Allen & Hoshall, January **1996)** (FU).

The FFS evaluates the RI, the baseline risk assessment **(BRA),** and potential applicable, relevant, or appropriate requirements (ARARs) to develop preliminary remediation goals (PRGs) for Site 1. The BRA did not identify any risk to current or future workers onsite above the 1×10^{-6} threshold; no further action would be required for protection of human health under an industrial scenario. When a residential scenario is evaluated, surface soil still posed no unacceptable risk, however, exposure to the shallow/intermediate groundwater presented an unacceptable risk and hazard via the ingestion and inhalation exposure pathways. PRGs were assembled for Site 1 that are protective of human health under a residential scenario and of the environment.

Based on the USEPA guidance document ***Presumptive Remedy for CERCU Municipal Landfill Sires*** four alternatives are developed and screened in this FFS:

- No action
- Natural attenuation. This alternative is not the same as 'no action." Under this alternative, contaminated **soil and** water will be left in place. Institutional controls would be implemented at the site to limit access. Groundwater would be monitored and the base master plan would be amended **to** prevent consumption of any water exceeding remedial goals. Natural attenuation would include in-depth modeling and evaluation of contaminant degradation rates to determine feasibility. In addition, a sampling and analysis program must be conducted throughout the process to confirm that degradation is proceeding at rates consistent with meeting cleanup objectives.
- Capping, including design and construction of a low-permeability surface cap over the entire landfill area to reduce leachate generation and infiltration into groundwater. Under this alternative the groundwater would be monitored and expected to meet remedial goals through natural intrinsic processes.
- Groundwater containment with pumping and treatment. In this alternative the contaminated groundwater will be actively contained and treated through a pump-and-treat system. Two subalternatives will be considered, 1) treatment with constructed wetlands and 2) treatment with air stripping. Under this alternative the groundwater would be monitored and expected to meet remedial goals in time.

These alternatives are initially evaluated using the three screening criteria of implementability, effectiveness, and cost. Then, as per the ***National Contingency Plan*** (NCP), a detailed analysis of alternatives is performed on all four alternatives. using the criteria of long-term effectiveness; short-term effectiveness; reduction of toxicity, mobility, or volume; impiementability; cost; compliance with ARARs; overall protection of human health and the environment; state acceptance; and community acceptance.

A comparative analysis of the four alternatives a summarized below:

Threshold Criteria: If **an** industrial-use scenario is applied at Site 1 through institutional controls under the natural attenuation alternative, no further actions are required to protect human health. If a residential-use scenario is applied, both the capping and ***pump*** **and** treat alternatives are protective of human health.

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ABBREVIATIONS AND ACRONYMS

ARAR	Applicable or Relevant and Appropriate Requirement
bls	below land surface
BNA	Base-neutral/acid extractable organic compounds
BRA	Baseline Risk Assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CG	Cleanup Goals
cm/sec	centimeters per second
COC	Contaminants of concern
E&E	Ecology & Environment, Inc.
FDEP	Florida Department of Environmental Protection
FFS	Focused Feasibility Study
FGGC	Florida Groundwater Guidance Concentrations
ft/day	feet per day
ft^3	cubic feet
H&S	Health and safety
IAS	Initial Assessment Study
lb	pound
MCL	Maximum Contaminant Level
NACIP	Navy Assessment and Control of Installation Pollutants
NAS	Naval Air Station
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEESA	Naval Environmental and Engineering Support Activity (since renamed)
O&M	Operations and maintenance
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
PCB	Polychlorinated biphenyls
PRG	Preliminary remediation goals
PVC	Polyvinyl chloride
PWC	Public Works Center
RI	Remedial Investigation
ROD	Record of Decision
TBC	To Be Considered
USEPA	U.S. Environmental Protection Agency
VOC	Volatile organic compounds

EXECUTIVE SUMMARY

This Focused Feasibility Study (FFS) develops, evaluates, and compares four remedial action alternatives that may be used to mitigate hazards and threats to human health and the environment at Site 1 at Naval Air Station (NAS) Pensacola. The FFS addresses soil and groundwater contamination as recommended in the *Final Remedial Investigation Report for Site 1, Naval Air Station Pensacola, Pensacola, Florida* (EnSafe/Allen & Hoshall, January 1996) (RI).

The FFS evaluates the RI, the baseline risk assessment (BRA), and potential applicable, relevant, or appropriate requirements (ARARs) to develop preliminary remediation goals (PRGs) for Site 1. The BRA did not identify any risk to current or future workers onsite above the $1x10^{-6}$ threshold; no further action would be required for protection of human health under an industrial scenario. When a residential scenario is evaluated, surface soil still posed no unacceptable risk, however, exposure to the shallow/intermediate groundwater presented an unacceptable risk and hazard via the ingestion and inhalation exposure pathways. PRGs were assembled for Site 1 that are protective of human health under a residential scenario and of the environment.

Based on the USEPA guidance document *Presumptive Remedy for CERCLA Municipal Landfill Sites* four alternatives are developed and screened in this **FFS:**

- No action.

- Natural attenuation. This alternative is not the same as "no action." Under this alternative, contaminated soil and water will be left in place. Institutional controls would be implemented at the site to limit access. Groundwater would be monitored, land use restrictions will be implemented that limit land use to industrial and/or recreational use, while groundwater use beneath and downgradient of the landfill will be restricted. A sampling and analysis program must be conducted throughout the process to confirm that degradation is proceeding at rates consistent with meeting cleanup objectives.

- Capping, including design and construction of a low-permeability surface cap over the entire landfill area to reduce leachate generation and infiltration into groundwater. Under this alternative the groundwater would be monitored and expected to meet remedial goals through natural intrinsic processes.

- Groundwater containment with pumping and treatment. In this alternative the contaminated groundwater will be actively contained and treated through a pump-and-treat system. Two subalternatives will be considered, 1) treatment with constructed wetlands and **2)** treatment with air stripping. Under this alternative the groundwater would be monitored and expected to meet remedial goals in time.

These alternatives are initially evaluated using the three screening criteria of implementability, effectiveness, and cost. Then, as per the ***National Contingency Plan*** (NCP), a detailed analysis of alternatives is performed on all four alternatives, using the criteria of long-term effectiveness; short-term effectiveness; reduction of toxicity, mobility, or volume; implementability; cost; compliance with ARARs; overall protection of human health and the environment; state acceptance; and community acceptance.

A comparative analysis of the four alternatives a summarized below:

Threshold Criteria: If an industrial-use scenario is applied at Site 1 through institutional controls under the natural attenuation alternative, no further actions are required to protect human health. If a residential-use scenario is applied, both the capping and pump and treat alternatives are protective of human health.

Balancing Criteria: If an industrial-use scenario is applied at Site 1 through institutional controls under the natural attenuation alternative, no further actions are required to protect human health. If residential issues are considered, capping and groundwater containment provide more long-term effectiveness than no-action or natural attenuation. Short-term impacts from capping are greater than for the other three alternatives but are controllable. All

alternatives are implementable, with capping having the highest cost and natural attenuation having the lowest cost of alternatives 2, 3, and **4.**

Modifying Criteria: These criteria will be addressed during the FFS review period and the public comment period for the ROD.

1.0 INTRODUCTION

1.1 Purpose and Organization

This Focused Feasibility Study (FFS) will develop, evaluate, and compare remedial action alternatives that may be used to mitigate hazards and threats to human health and the environment as a result of soil and groundwater contamination at Site 1, also referred to as Operable Unit 1, at Naval Air Station (NAS) Pensacola.

This FFS is being performed under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and the Superfund Amendments and Reauthorization Act of 1986 based upon findings reported in the ***Final Remedial Investigation Report, Naval Air Station Pensacola, Site I*** **(RI; E/A&H, 1996).**

This FFS report is organized in the format suggested in Office of Solid Waste and Emergency Response (OSWER) Directive **9355.3-01,** ***Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*** (Interim Final, October **1988).** Because of the limited number of alternatives indicated by the OSWER Directive **9355.3-11,** ***Conducting Remedial Investigations/Feasibility Studies for CERCLA Municipal Landfill Sites*** (February 1991), an abbreviated feasibility study format was adopted, as described below:

- **Section 1, Site Background, PRGs —** This section presents background information regarding the RI, baseline **risk** assessment **(BRA),** and preliminary remediation goals (PRGs). Remedial volumes identified using **PRGs** are presented.

- **Section 2, Description of Remedial Alternatives —** This section presents the remedial alternatives. The remedial elements of each alternative are discussed, along with their implementability, effectiveness, and cost.

- **Section 3, Detailed Analysis of Alternatives** — This section analyzes the alternatives per the nine criteria outlined in the ***National Oil and Hazardous Substances Pollution Contingency Plan; Final Rule*** (EPA/540/1-89/002, December 1989) (NCP). This analysis is the foundation of future decision-making for the site.

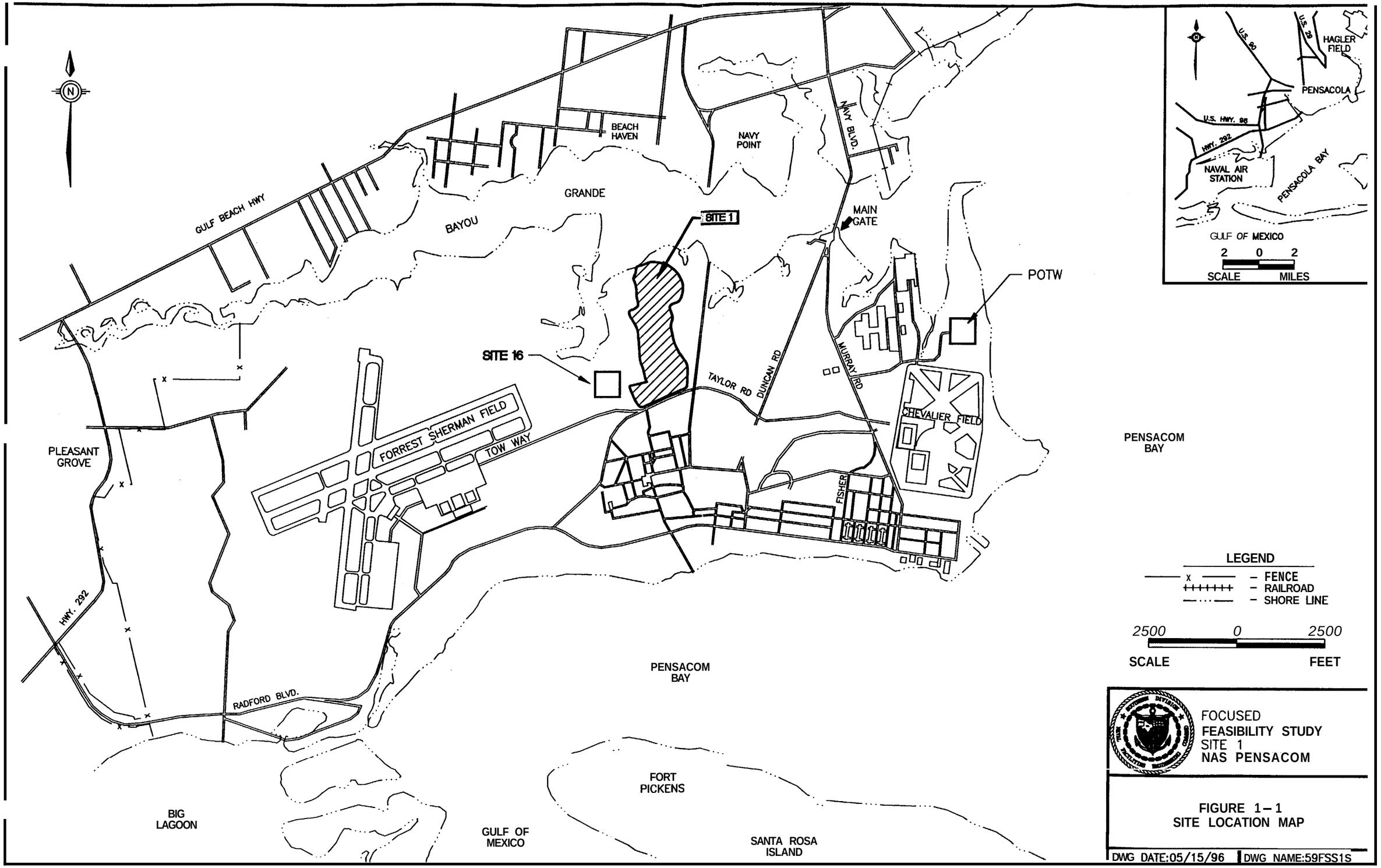
- **Section 4, Comparative Analysis of Alternatives** — This section provides decision-makers with a concise comparative format that highlights differences between the alternatives.

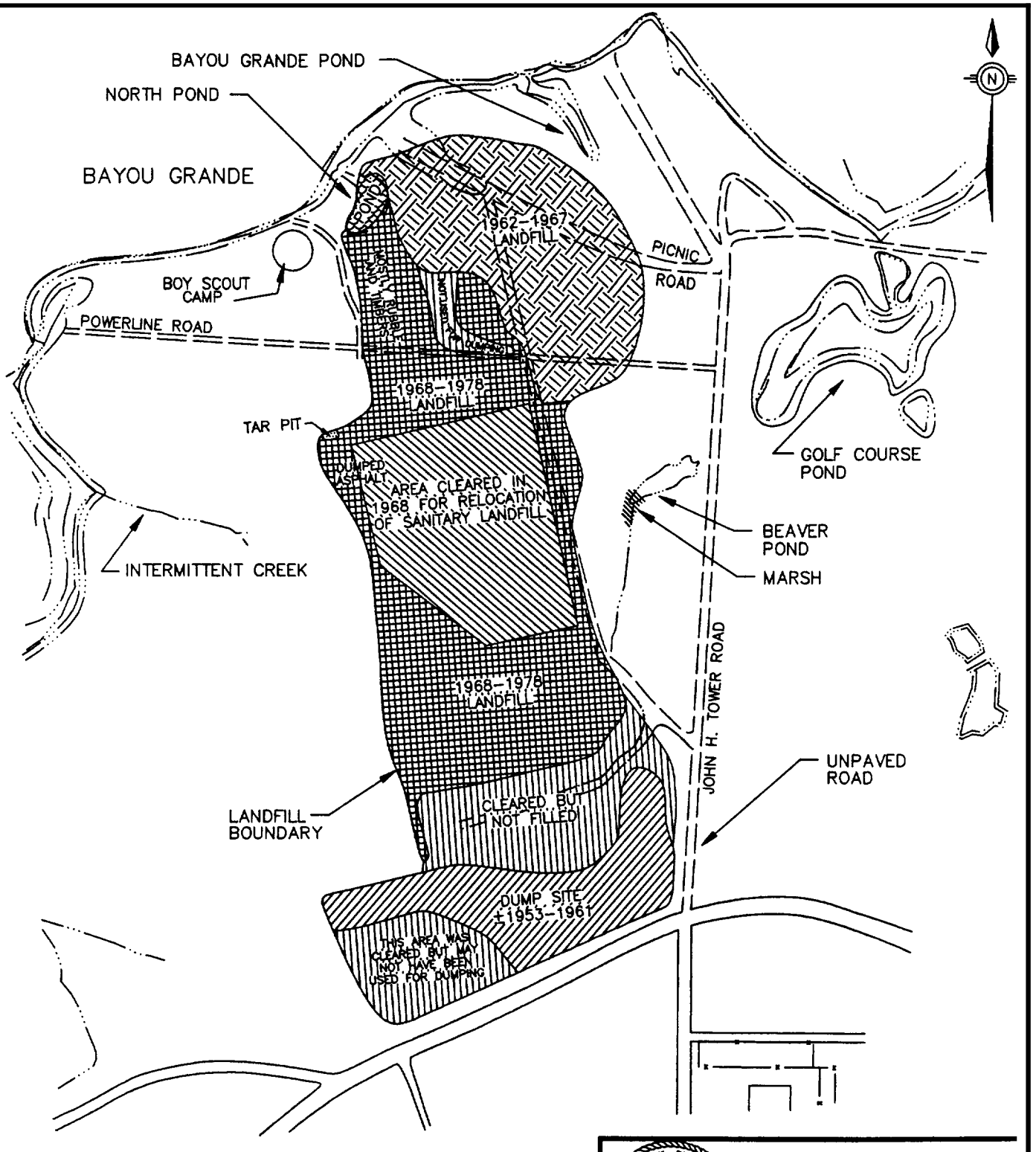
1.2 Background Information

The following section summarizes the findings of the RI. For more detail concerning the methods and results of the RI, refer to the RI report. .

1.2.1 Site Description

Site 1, the sanitary landfill, as shown on Figures 1-1 and 1-2, comprises an inactive landfill and land surrounding it (approximately 85 acres). The landfill is at an elevation of 8 to 20 feet above mean sea level and is densely vegetated with 15- to 25-foot tall planted pines and natural scrub vegetation. Situated within the north central portion of NAS Pensacola, Site 1 is approximately 0.5 mile east of Forrest Sherman Airfield. The site is bordered by an inland water body (Bayou Grande) to the north, by the A.C. Read Golf Course to the east, and by areas of natural scrub vegetation to the west and south. Bayou Grande has been classified by the Florida Department of Environmental Protection (FDEP) as a Class III water body, indicating its use for recreation and maintaining a well-balanced fish and wildlife population (FDEP, 1992a). Taylor Road lies approximately 200 feet south of the site, beyond the scrub vegetation.


N
GULF BEACH HWY
BEACH HAVEN
NAVY POINT
NAVY BLVD.
GRANDE
BAYOU
SITE 1
MAIN GATE
POTW
SITE 16
TAYLOR RD
DUNCAN RD
MURRAY RD
CHEVALIER FIELD
FORREST SHERMAN FIELD
TOW WAY
FISHER
PLEASANT GROVE
HWY. 292
RADFORD BLVD.
PENSACOM BAY
PENSACOM BAY
FORT PICKENS
BIG LAGOON
GULF OF MEXICO
SANTA ROSA ISLAND
U.S. 90
U.S. 29
HAGLER FIELD
PENSACOLA
U.S. HWY. 98
HWY. 292
NAVAL AIR STATION
PENSACOLA BAY
GULF OF MEXICO
2 0 2
SCALE MILES
LEGEND
– FENCE
– RAILROAD
– SHORE LINE
2500 0 2500
SCALE FEET
FOCUSED
FEASIBILITY STUDY
SITE 1
NAS PENSACOM
FIGURE 1 – 1
SITE LOCATION MAP
DWG DATE:05/15/96
DWG NAME:59FSS1S



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SCALE FEET

SOURCE: E&E 1991/NAVFAC DRAWING NUMBER 5205053

FOCUSED FEASIBILITY STUDY
SITE 1
NAS PENSACOLA

FIGURE 1-2
SITE MAP

DWG DATE: 05/15/96 | DWG NAME: 059SMFS2

Developed areas near the site include a Boy Scout camp, a nature trail, an NAS Pensacola picnic area, and recreational use Buildings 3553 and 3487, all immediately north of the landfill. Also in this generally developed area are two tidal-inlet ponds with associated wetlands. Other wetland areas are west and east of the landfill, most of which are associated with marshy intermittent creeks. These creeks appear to provide surface/groundwater-seep drainage from the general landfill area to Bayou Grande. The nearest residential area (base housing) is approximately 1,000 feet south of Site 1. Site 16, a brush disposal area and formerly a brush-burning location, is approximately 600 feet west-southwest of the site.

1.2.2 Site History

During the early 1950s and continuing until 1976, a variety of domestic and industrial wastes generated from NAS Pensacola and other outlying Navy facilities were disposed at Site 1. A partial list of wastes and quantities disposed at the site include the following, as taken from the 1983 Naval Energy and Environmental Support Activity (NEESA) Initial Assessment Study (IAS):

- Ketone-soaked rags
- Polychlorinated biphenyl (PCB)- and transformer oil-soaked rags (6,500 cubic feet [ft^3])
- Paint chips
- Paint sludge from water wall paint booth (170,000 pounds [lbs])
- Paint sludge (5,200 gallons)
- Dry air-filter pads from paint booths (11,963 ft^3)

- Compressed air cylinders **(200)**
- Asbestos from building demolition
- Wood soaked with plating solutions **(1,667 ft³)**
- Pesticide rinsate
- Garbage (64,800 tons)
- Wastes from outlying facilities: Corry, Ellison, Saufley, Baron, and Whiting
- Containers from paints, pesticides, oils, strippers, plating chemicals, solvents, thinners, etc.
- Mercury

As shown on Figure **1-2,** previous investigation documents and NAS Pensacola Public Works Center (PWC) drawings indicate disposal activities moved from one portion of the site to another during the time the landfill was active (NEESA, **1983).** The southernmost portion of the site, used during the **1950s,** is the landfill's oldest-known section. In the early **1960s,** waste disposal was moved approximately 3,000 feet north, to the northernmost portion of the site. Additionally, an area along the northwestern border of the site also was reportedly filled with construction rubble during the **1950s** and **1960s.** During the late **1960s** and until the closure of the landfill, waste was disposed in its central portion. During the earlier years of disposal at Site 1, wastes commonly were burned before burial; however, **this** practice ended in the late **1960s** due to residents' concern over air pollution in nearby areas. The landfill officially closed October 1, **1976.**

1.2.3 Chronology of Events and Previous Investigations

The following chronology of events and previous investigations at Site 1 provides a basis for understanding the history and focus of the remedial investigation/feasibility study.

1974 — Discovery of Landfill Leachate Discharge

In 1974, landfill leachate was discharging from an abandoned drainage field into a nearby golf course pond. At that time, the drainage outlet was plugged, causing the water table to rise and leachate to seep from the surface. As a result, an investigation was performed in 1974 and 1975 during which seven galvanized-steel monitoring wells were installed and sampled. Groundwater sample analysis indicated the presence of phenol and several metals (G&M 1984). This investigation (Crawford 1975, unavailable for review) reportedly concluded shallow groundwater flowed to the north toward Bayou Grande and groundwater was contaminated in the upper portion of the Sand-and-Gravel Aquifer near the landfill (NEESA 1983).

1983 — Initial Assessment Study

An IAS was performed by NEESA (since renamed) under the Navy Assessment and Control of Installation Pollutants (NACIP) program. As the first phase of the NACIP program, the IAS's purpose was to identify and assess sites posing a threat to human health or the environment due to contamination from hazardous materials operations. This study included reviewing facility records and aerial photographs, interviewing facility personnel, and conducting field surveys. During the survey, limited sampling of landfill leachate and site ponds sediment was performed. Sample analysis detected concentrations of cadmium, chromium, mercury, nickel, and lead in sediments, and cadmium and mercury in the leachate (NEESA, 1983). The survey concluded Site 1 presented a threat to human health and the environment and therefore was recommended for further investigation to include a confirmation study, Phase II of the NACIP program.

1984 — Verification Study

Part I of the NACIP confirmation study, the verification study, was performed by Geraghty & Miller, Inc. to confirm whether groundwater contaminants were present at sites recommended for study in the IAS (G&M, 1984). During this study, eight shallow 2-inch polyvinyl chloride (PVC) monitoring wells were installed and sampled. Groundwater samples were analyzed for volatile organic compounds (VOCs), base-neutral/acid extractable organic compounds (BNAs), pesticides, PCBs, metals, cyanide, and field parameters. Analytical results indicated that shallow groundwater beneath the landfill had been affected by past disposal practices. VOCs were detected in all groundwater samples collected. The highest concentrations of organic compounds, most of which were VOCs, were detected in samples from the central portion of the site. Only trace concentrations of BNAs were detected. No PCBs or pesticides were present at concentrations above method detection limits. All detected metals concentrations were below FDEP 1984 drinking water standards. Water levels measured in the study indicated shallow groundwater flows north, northwest, and northeast toward surface water bodies, where it discharges to the bayou, site ponds, and tidal inlets.

1986 — Characterization Study

Part II of the NACIP confirmation study, the characterization study, was performed by G&M to determine the nature and extent of contamination at verification study sites requiring additional analysis (G&M, 1986). During this investigation, five additional shallow monitoring wells (GM-38 through GM-42) and three deep wells (GM-43 through GM-45) were installed. Groundwater samples were collected from all new wells and the eight verification study wells. Groundwater samples from the new wells were analyzed for the United States Environmental Protection Agency's (USEPA) list of organic priority pollutants, including VOCs, BNAs, pesticides, and PCBs. Samples collected from the previously installed wells were analyzed for VOCs only. No metals analysis was performed for either well group. Samples collected from 12 of the 16 wells contained one or more VOCs. Additionally, two samples collected from deep wells exhibited VOC contamination. However, the presence of certain VOCs during the

characterization study was not consistent with the results of the verification study (e.g., vinyl chloride only detected during characterization, methylene chloride detected only during verification). BNAs, pesticides, or PCBs were not detected during the characterization study. Water level elevation data again confirmed the generally northward flow of shallow groundwater toward site surface water bodies. However, deep well water levels indicated a slight gradient to the south (G&M, 1986).

1991 — Contamination Assessment/Remedial Activities Investigation

Phase I of a Contamination Assessment/Remedial Activities Investigation was performed by Ecology and Environment, Inc. (E&E, 1991a), to identify principal areas and primary contaminants of concern (COCs) at Site 1 and to provide recommendations for subsequent phases of investigation. Various preliminary surveys were performed which included: site reconnaissance survey, aerial photography analysis, radiation survey, surface emissions survey, and a geophysical survey. Additionally, site surface water, sediment, surface soil, and groundwater were sampled for laboratory analysis. Groundwater samples were collected from 15 G&M monitoring wells along with 28 temporary shallow monitoring wells. Sediment, surface water, and surface soil samples were analyzed for a suite of screening parameters, including VOCs, polynuclear aromatic hydrocarbons, phenols, pesticides, total PCBs, total recoverable petroleum hydrocarbons, and metals (water samples analyzed unfiltered). Samples collected from existing G&M wells were analyzed according to USEPA Contract Laboratory Program protocol for the full Target Analyte List/Target Compound List plus gross alpha radioactivity. Samples from temporary wells were analyzed for the screening parameters suite. Complete discussions of the investigation are in the corresponding 1991 Interim Data Report (E&E, 1991b). The following passage summarizes E&E's investigation result conclusions.

Site Reconnaissance Survey — Numerous disturbed areas indicating fill activities or leachate migration were identified across the site. A collapsed/depression feature with remains of metal containers, an oozing tar-like substance, and elevated organic vapor concentrations was identified

in the northwest comer of the 1950s fill area. An area of exposed medical and industrial waste was identified in the southwestern comer of the 1970s fill area. A linear pit containing a black, tar-like material was identified in the northwestern comer of the 1970s fill area. This pit measured approximately 40 feet by 15 feet and contained approximately 1.5 feet of material. A construction rubble field was identified south of North Pond extending south across Powerline Road to the vicinity of well GM-33. Various discolored water/leachate seeps and areas of soil and/or vegetation staining were identified in site wetland areas (intermittent streams, ponds, and tidal inlets).

Aerial Photography Analysis — Reviewing historical aerial photos generally confirmed the progression of landfill activities, which began in the site's southern portion during the 1950s, moved to the northern portion in the early 1960s, and were concluded in the central portion from the late 1960s through 1976. Additionally, numerous areas of disturbance associated with landfill activities were noted from these photos. Specifically, three dark areas, one of which corresponds to the location of the tar pit, were identified on a 1970s photo along the western extent of the 1970s fill area. An apparently low, linear marshy area also was identified on a 1970s photo, corresponding to the construction rubble field. Also, a sizeable dark irregular feature measuring approximately **200** feet by 75 feet was observed in the center of the 1970s fill area on a 1973 photo (E&E, 1991b).

Surface Emissions and Radiation Surveys — Elevated organic vapor concentrations ranging from 1.0 to 20.0 parts per million above background were detected at five locations. The highest concentration was detected at the collapse/depression feature in the 1950s fill area. The survey detected no significant concentrations of surface radiation (E&E, 1991b).

Geophysical Survey — *An* electron magnetometer (EM-31) and metal detector (EM-34) were used to perform the survey. Overall, the survey's results indicated subsurface ferrometalic materials are present at relatively shallow depths (20 feet below land surface [bls] or less) across

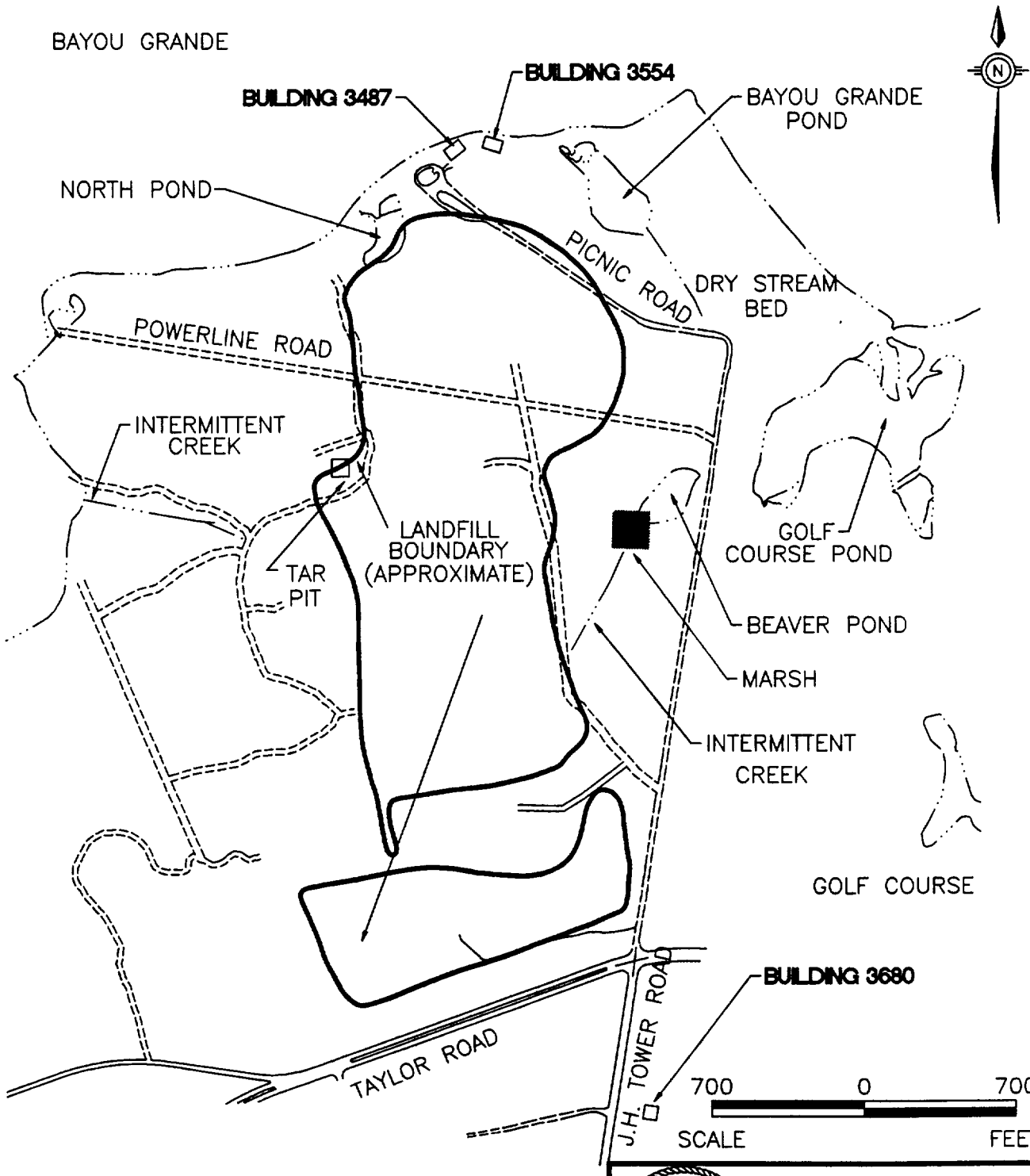
most of the landfill, primarily within the landfill boundary determined by aerial photos and site reconnaissance. Deeper anomalous **EM-34** readings collected north, west, and east of the landfill may be attributable to landfill leachate migration toward the bayou in a lower portion of the surficial zone of the Sand-and-Gravel Aquifer. However, these deeper anomalies also may reflect saline water intrusion and/or more conductive lithologies present below the base of the surficial zone (E&E, 1991b).

1.2.4 Surface Water Movement and Site Drainage

The generally high soil permeabilities around Site 1 limit substantial contamination transfer via surface water flow. Precipitation infiltrates directly into the subsurface, constituting a source of recharge to the surficial aquifer. During the RI, overland flow was not observed within the landfill boundary. Two intermittent creeks lie within wetlands outside the landfill, as shown on Figure 1-3. One creek approximately 50 to 100 feet east of the landfill's central portion depending upon precipitation amounts) channels intermittent flow northeastward to the beaver pond. The other originates approximately 500 feet west of the landfill's central portion and channels intermittent flow northwestward to Bayou Grande. Neither has been observed to receive direct surface water runoff from the landfill, but rather are apparently fed by groundwater seepage when the water table is high. A third dry stream bed is in the site's northern portion, immediately south and leading to Bayou Grande Pond. No surface water was in this stream during the investigation.

1.2.5 Site-Specific Stratigraphy

Site 1 investigations have been limited to the Sand-and-Gravel Aquifer. Borings have been completed in the surficial zone, low permeability zone, and the upper portion of the main producing zone. Boring logs indicate the surficial zone is composed primarily of buff white to brown to gray, fine- to medium-grained quartz sand, extending to approximately **27** feet bls along the northern portion of the site, and approximately ***60*** feet bls along the southern portion.



LEGEND

- COASTLINE/SURFACE WATER FEATURE
- UNPAVED ROADS
- LANDFILL BOUNDARY

FOCUSED FEASIBILITY STUDY
SITE 1
NAS PENSACOLA

FIGURE 1-3
SITE 1- SURFACE WATER FEATURES

DWG DATE: 05/15/96 DWG NAME: 059VOCE4

Beneath the surficial zone, the low permeability zone has been encountered in all borings extended to the anticipated depth of interception. The low permeability zone ranges from approximately 8 to 40 feet thick (G&M, 1986). Boring logs indicate the stratum to be composed of gray to dark gray clays and silty, sandy clays, containing seams of fine- to coarse-grained sand, as well as shell and wood fragments (G&M, 1986). The main producing zone has been encountered beneath the low permeability zone on Site 1 at approximately 48 feet bls along the northern portion to 100 feet bls along the southern portion. Boring logs indicate the upper portion of the zone is composed of white to gray, fine- to medium-grained sand with minor silt content (G&M, 1986).

1.2.6 Water Level Elevations and Tidal Effects

Generally, water level elevations in shallow and intermediate depth wells mimic local topography across the site, sloping north toward the bayou. Contrastingly, deep well water level elevations do not follow topography, but rather slope generally to the south across the site, toward the Gulf of Mexico. All deep water level elevations were significantly higher than the elevation of the top of the confining clay, indicating the deep interval is confined across the site.

Notable variations in water levels (.03 foot or greater) from low to high tide were observed at wells within approximately 300 feet of the shoreline of sizable surface water features.

Surface water flow was observed between the golf course pond and the bayou, and between north pond and the bayou during the tidal cycle. Surface water was observed flowing into these ponds at high tide and from these ponds during low tide. However, flow was not observed between Bayou Grande Pond and the bayou during the study because a berm composed of sand and silty pond sediment effectively closed off the pond's inlet channel.

1.2.7 Groundwater Flow

Groundwater in the shallow and intermediate well depths flows in essentially the same pattern, indicating that these two depth intervals should be considered part of the same general flow system. Shallow and intermediate depth groundwater flows in an overall northward direction during both low and high tide, with components of flow to the north-northwest, northwest, and northeast toward Bayou Grande and other surface water features. This flow pattern generally mimics site topography, which is characteristic of unconfined surficial aquifers with high transmissivities.

Based on the limited water level data for the deep interval (e.g., only three deep wells exist at Site 1), the potential for groundwater flow in this depth interval **is** generally to the south toward Pensacola Bay and the Gulf of Mexico.

1.2.8 Vertical Permeabilities

Vertical permeabilities of the unsaturated soil samples from **2** to 5 feet bls ranged from **2.923 X** 10^{-2} centimeters per second (cm/sec) to **9.793** X 10^{-2} cm/sec (or **82.87** feet per day [Wday] to **277.63** Wday). Vertical permeabilities of two low permeability zone clayey material samples from approximately **40** feet bls ranged from **6.524** X 10^{-7} cm/sec to **8.19 X** 10^{-7} cdsec (or .0018 Wday to .0023 ft/day).

According to Fetter (1988), sediments with permeabilities of 10^{-5} cdsec or less can be considered **confining** units. The extremely low permeabilities found in the clay material of the low permeability zone indicate the potential is extremely low for groundwater movement through the clay.

1.3 Remedial Objectives

In developing remedial objectives for the FS, four issues were addressed:

- The spatial distribution of contamination, as presented in the RI.
- A BRA, including human health and ecological assessments.
- Chemical-specific applicable and relevant or appropriate requirements (ARARs), where applicable.
- Potential groundwater contamination by contaminant residuals in site soil.

1.3.1 RI Assessment

The Site 1 RI dated January 1996 concluded soil inside the landfill boundary has been impacted by past activities there. Buried waste in the landfill has been characterized as containing detectable concentrations of all analyzed parameter groups (inorganics, volatiles, semivolatiles, pesticides and PCBs). Given the age of the landfill (approximately 20 to 40 years), only minimal concentrations of waste constituents are expected to be leaching to underlying groundwater. Surface soil quality outside the landfill boundary appears to be generally comparable to reference soil conditions. However, surface soil within the boundary appears to have been impacted by landfill activities, resulting in elevated concentrations of inorganic and organic constituents.

The nature and extent of landfill-impacted groundwater have been evaluated onsite. Relatively low concentrations of inorganic and organic constituents are present in the surficial zone (shallow and intermediate well depths) beneath the site. Groundwater analytical results from samples collected in 1993 (with Teflon bailers) compared with those collected in 1994 (via quiescent sampling techniques) indicate 1993 analytical results were significantly affected

(biased) due to sample turbidity. Based on **1994** analytical results, the greatest impact from inorganics to shallow and intermediate groundwater quality appears to be limited to the center of the site, along the landfill's eastern, western, and northwestern boundaries. Except for aluminum, iron, and manganese (indicated by reference data to naturally occur at elevated concentrations), inorganic concentrations exceeding ARARs are generally limited to areas within and around the landfill perimeter.

Organic constituents have consistently been detected at relatively low (near Maximum Contaminant Levels/Florida Groundwater Guidance Concentrations [MCL/FGGC]) concentrations in surficial groundwater. Consistent with the distribution of elevated inorganics, the highest concentrations of organics were detected in the center of the site and along the eastern and western boundaries. Relatively lower organic concentrations extend downgradient from the landfill to areas along Bayou Grande's coastline, adjacent wetlands, and east-northeast beneath the golf course. However, no elevated inorganics or organics (except for a single low pesticide concentration) were detected in samples collected from the most downgradient monitoring well across the golf course opposite the landfill. This indicates the extent of organic-impacted groundwater migrating east-northeast from the landfill is limited to the area beneath the adjacent golf course. **As** with inorganics, organic concentrations exceeding ARARs are generally limited to areas within and around the landfill's perimeter.

Based on deep well sample results, groundwater quality within the main producing zone beneath the site does not appear to have been affected by site activities.

In Wetland 1, both benchmark values for lead were exceeded for surface water and sediment. However, risk from lead in Wetland **1** sediment is low. In Wetlands **3** and 18, several SSVs were exceeded by wetland sediment and surface water. In Wetland **16** only the surface water standard for iron in saltwater was exceeded. **A** more detailed risk assessment of Site **1** wetlands will be made during the Site **41** investigation.

1.3.2 BRA

The human health risk associated with exposure to environmental media at NASP Site 1 was assessed for hypothetical current child trespassers, a potential site worker, and potential site residents. The exposure media considered in these assessments included surface soil (0 to 1 foot deep interval), subsurface soil (all depth intervals samples), shallow/intermediate groundwater, and deep groundwater. It was determined that the risk and/or hazard associated with exposure to all environmental media (and combinations thereof) did not exceed USEPA and FDEP's risk and hazard thresholds for the trespassing child and the potential site worker scenarios. Based on these findings, no COCs were identified relative to these receptor groups. Site 1 groundwater is not currently used as a potable water source or for any industrial uses. Therefore, current receptors were not evaluated with respect to this medium.

The hypothetical future site resident was evaluated with respect to soil and groundwater using a surface soil data set and two separate groundwater data sets. Surface soil data consist of samples collected from the surface, and the two groundwater data sets consisted of data from the combined shallow/intermediate and deep groundwater depths. Exposure to the shallow/intermediate groundwater presented an unacceptable risk and hazard via the ingestion and inhalation exposure pathways.

For surface soils, beryllium was reported at a concentration which represents greater than 1E-6 risk. However, **this** beryllium was reported at a location between fill areas at Site 1 and was reported in only one sample of **27** collected. Risk estimated without beryllium does not exceed 1E-6. Therefore, no soil COCs were identified for the hypothetical future site resident.

The combined shallow/intermediate groundwater pathway hazard indices (ingestion and inhalation exposures) for the future site resident child and adult were estimated to be **3** and 7, respectively. The combined potential groundwater carcinogenic risk for ingestion and inhalation of groundwater was computed to be 4E-4. The primary noncarcinogenic COCs for groundwater

ingestion are arsenic, barium, benzene, cadmium, chlorobenzene, manganese, nickel, vinyl chloride, and zinc. Arsenic accounts for most of the hazard index, followed by benzene, chlorobenzene, and manganese. The primary carcinogenic COCs identified for ingestion of groundwater include arsenic, vinyl chloride, and benzene. Arsenic was the primary contributor to the estimated risk. Arsenic contributes 70% of the total combined carcinogenic risk for the site resident, followed by vinyl chloride and benzene, which contribute approximately 21% and 0.6% of the risk, respectively. The maximum concentration detected for arsenic was below the USEPA and FDEP primary MCLs.

The deep groundwater pathway hazard indices (ingestion only) for the future site resident child and adult were calculated as 1 and 0.5, respectively. Since no VOCs were detected in deep groundwater, risk and/or hazard via the inhalation pathway was not computed. Manganese was the sole contributor to the hazard via ingestion of deep groundwater.

A preliminary assessment was performed using the currently available data for Site 1 surface water and sediment. These were assessed assuming an adolescent child (age 7-16) trespasser (swimming/wading) scenario. Based on the maximum concentrations reported for all wetlands sampled, surface water risk and hazard were estimated to be 9E-7 and 0.05 for the combined incidental ingestion and inhalation exposure pathways. Sediment exposure was estimated for the incidental ingestion and dermal contact exposure pathways, which resulted in combined risk and hazard estimates of 1E-7 and 0.002, respectively. The preliminary risk and hazard estimates did not exceed USEPA and FDEP risk and hazard thresholds of 1E-6 and 1.

Ecological risks at Site 1 were determined to be inconsequential for flora and fauna from contaminated soil. Based on a review of the factors that may affect availability of chemicals, and a critical assessment of the concentrations observed during the 1994 sampling activity, no appreciable ecological effects are expected from groundwater discharge to wetlands near Site 1

1.3.3 Chemical-Specific ARARs and TBCs

Where appropriate, chemical-specific ARARs will be considered in developing remedial objectives for the site. Appendix A lists all ARARs. MCLs, in accordance with the NCP, are ARARs in groundwater. Five parameters exceeded MCLs onsite during the 1994 sampling event: benzene, chromium, chlorobenzene, nickel, and vinyl chloride.

Secondary MCLs and FGGCs (June 1994) are considered ARARs by the State of Florida. Four groundwater contaminants exceeded secondary MCLs during the 1994 sampling event: aluminum, iron, manganese, and xylene. Five parameters exceeded FGGCs during the 1994 sampling event: arsenic, bromoform, cadmium, naphthalene, 1,1,2,2-tetrachloroethane.

Also to be considered (TBC) are the FDEP Soil Cleanup Goals. Other chemical-specific ARARs that might impact the selection and screening of technologies include land-ban criteria, which will be considered in the technologies discussion, if appropriate.

1.3.4 Protection of Groundwater Assessment

The potential for groundwater contamination due to site compounds was also assessed by comparing contaminant concentrations in soil with guidance concentrations protective of groundwater (as identified in FDEP's Soil Cleanup Goals). As discussed above, these concentrations are TBC criteria for the site. Fourteen compounds were identified as exceeding guidance concentrations when soil concentrations were compared to the leaching criterion.

Type A	Type B	Type C
naphthalene	ethylbenzene	tetrachlorethene
xylene	toluene	2,4-dinitrotoluene
	1,4-dichlorobenzene	4-methylphenol
	1,2-dichlorobenzene	bis(2-chlorethyl)ether
	pentachlorophenol	
	2,4-dimethylphenol	
	2-methylphenol	
	dieldrin	

Type **A** compounds were defined as contaminants in soil exceeding FDEP cleanup goals (CGs) for leachability in soil and promulgated MCLs, Florida secondary MCLs, or FGGCs in groundwater beneath Site **1** (based on **1994** groundwater samples).

Type B compounds were present in both soil and groundwater. They exceeded FDEP's CGs for leachability in soil, but were below MCLs, Florida secondary MCLs, or FGGCs in groundwater (based on **1994** groundwater samples).

Type C compounds were present in soil, but not detected in groundwater (based on **1994** groundwater samples).

1.3.5 Remedial Objectives

Tables **1-1** and **1-2** present the preliminary contaminant-specific remedial goals discussed above. These tables indicate whether goals are ARARs or TBC criteria.

Table 1-1
Preliminary TBC Contaminant-Specific Remediation Goals for Soil at Site 1

Parameters	PRG (µg/kg)	Number of Exceedances	Basis
Naphthalene	100	4	Florida Guidance leachability
Xylene	100	2	Florida Guidance leachability

Note:
µg/kg = Micrograms per kilogram

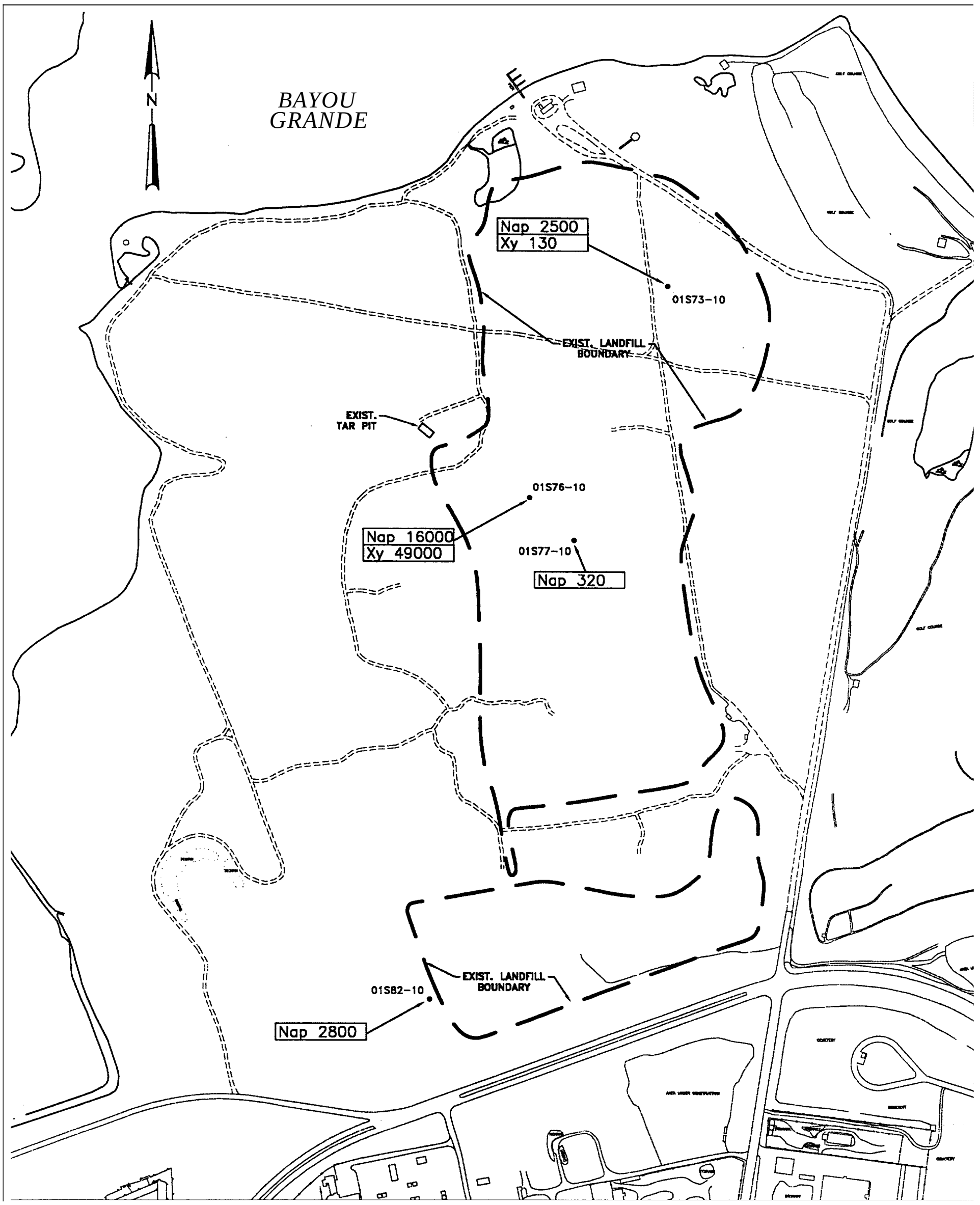
Table 1-2
Preliminary ARAR Contaminant Specific Remediation Goals for Groundwater at Site 1

Parameters	PRG (µg/L)	Number of Exceedances	Basis
Aluminum	200	8	Secondary MCL
Cadmium	5	1	FGGC
Chromium	100	1	Primary MCL
Iron	300	22	Secondary MCL
Manganese	50	20	Secondary MCL
Nickel	100	1	Primary MCL
Benzene	1	14	Primary MCL
Bromoform	4	1	FGGC
Chlorobenzene	100	2	Primary MCL
Naphthalene	6.8	4	FGGC
1,1,2,2-Tetrachloroethene	0.2	2	FGGC
Vinyl Chloride	1	6	Primary MCL
Xylene	20	3	Secondary MCL

Note:
µg/l = Micrograms per liter

Parameters identified in Table 1-1 contaminated soil was present in four locations across Site 1, as Figure 1-4 shows.

In the USEPA guidance document *Conducting Remedial Investigations/Feasibility Studies for CERCLA Municipal Landfill Sites,* hot spots are defined as highly toxic/or highly mobile material that presents a potential principal threat to human health or the environment. Excavation or treatment of hot spots is generally practical where the waste type or mixture of wastes is in a discrete, accessible location of a landfill. A hot spot should be large enough that its remediation would significantly reduce the risk posed by the overall site, but small enough that it is



LEGEND

- • Shallow soil boring
- Unpaved road

Nap 2800	Naphthalene
Xy 49000	Xylene

** All concentrations in $\mu g/L$

GRAPHIC SCALE

400 0 200 400 800

(IN FEET)
1 inch = 400 ft.

FOCUSED FEASABILITY STUDY
SITE 1
NAS PENSACOIA

FIGURE 1-4

PRELIMINARY CONTAMINANT REMEDIATION GOAL EXCEEDANCES IN SOIL

DWG DATE: 5/13/96 | DWG NAME: 1FIG1

reasonable to consider removal or treatment. It generally may be appropriate to consider excavation and/or treatment of landfill contents where a low to moderate volume of toxic/waste poses a principal threat to human health and the environment. The sampling strategy developed for the RI was designed to generally characterize the site rather than delineate hot spots. Because of this sampling strategy, it cannot be determined if areas designated as hot spots are discrete areas or widespread. It would be questionable whether any risk would be reduced by removing material from Site 1.

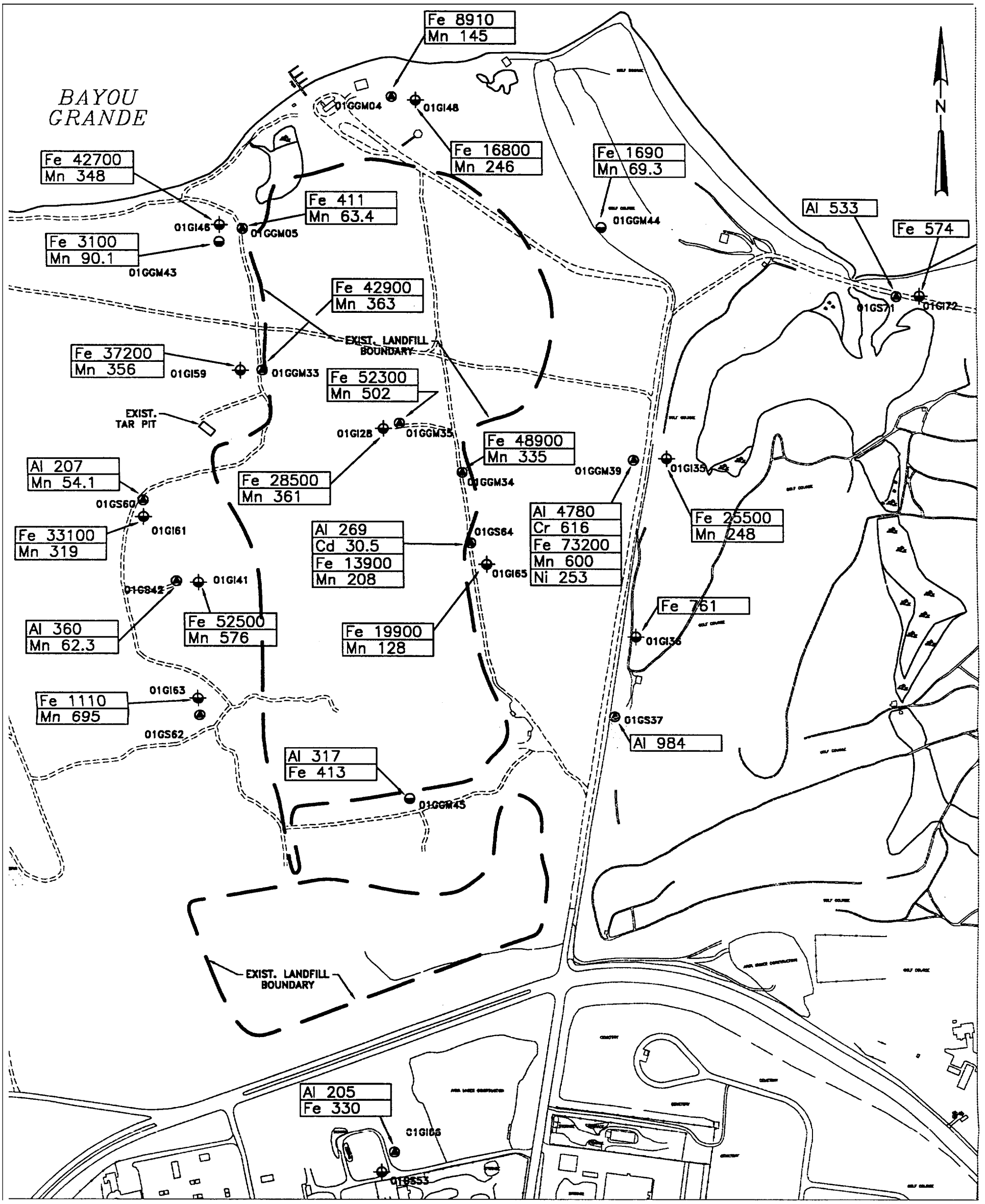
The tar pit is the area of an approximately 15-foot by 40-foot trench containing a tar-like substance. This area is being recommended for removal due to the physical hazard to humans and animals being trapped by the sticky substance, not because of chemical toxicity.

Figures 1-5 and 1-6 shows the groundwater samples exceeding PRGs based on 1994 sampling data, as described in Table 1-2. This contamination is beneath Site 1 and to the east, north, and west of the site. Table 1-3 presents the remedial objectives for Site 1.

Table 1-3
Site 1 — Remedial Objectives

Media	Objective	Location	Volume	Rationale
Soil	Protect fauna from physical danger of tar pit.	Northwest portion of landfill.	33 yd^3	Tar-like substance presents a physical danger to fauna (TBC).
Waste	Protect groundwater from leachable compounds.	Entire landfill.	±700,000 yd^3	Entire waste component may be leaching contaminants to groundwater (TBC).
Groundwater	Restore site groundwater to MCLs and prevent further contamination of shallow/intermediate groundwater.	Central, northern, western, and eastern portions of Site 1.	210 million gallons	Groundwater exceeding MCLs (ARAR).

Note:
yd^3 – Cubic yards



LEGEND

- Shallow monitoring well
- Deep monitoring well
- Intermediate monitoring well
- Unpaved road

GRAPHIC SCALE

40 0 200 400 80

(IN FEET)
1 inch = 400 ft.

** All concentrations in µg/L

Al 4780	Aluminum
Cd 30.5	Cadmium
Cr 616	Chromium
Fe 73200	Iron
Mn 600	Manganese
Ni 253	Nickel

FOCUSED FEASABILITY STUDY
SITE 1
NAS PENSACOIA

FIGURE 1-5

INORGANIC PRELIMINARY CONTAMINANT REMEDIATION GOAL EXCEEDANCES IN GROUNDWATER

DWG DATE: 5/13/96 | DWG NAME: 1FIG2

BAYOU GRANDE

N

Br 4.0
Tet 6.0

01GGM04
01GI48
B 1
B 3
Vc 12
01GI46
01GGM05
01GGM43
01GGM44
B 6
Nap 8
Tet 2.0
EXIST. LANDFILL BOUNDARY
01GS71
01GI72
01GI59
01GGM33
B 2
EXIST. TAR PIT
01GI28
01GGM35
B 12
Nap 9
01GGM39
01GI35
B 9
Nap 38
Xy 27
01GGM34
01GS60
01GI61
Vc 4.0
Xy 43
B 5
Vc 3.0
B 3
01GS64
B 7
Vc 2.0
01GI65
01GS42
01GI41
B 10
Vc 7.0
B 33
CB 120
B 80
CB 110
Nap 7
Vc 3
01GI36
01GI63
B 6
01GS62
01GS37
B 12
Xy 110
01GGM45
EXIST. LANDFILL BOUNDARY

LEGEND

- Shallow monitoring well
- Deep monitoring well
- Intermediate monitoring well
- Unpaved road

B 80	Benzene
Br 4.0	Bromoform
CB 110	Chlorobenzene
Nap 38	Naphthalene
Tet 2.0	1,1,2,2-Tetrachloroethane
Vc 3.0	Vinyl Chloride
Xy 27	Xylene

** All concentrations in µg/L

GRAPHIC SCALE

400 0 200 400 800

(IN FEET)
1 inch = 400 ft.

FOCUSED FEASABILITY STUDY
SITE 1
NAS PENSACOIA

FIGURE 1-6

ORGANIC PRELIMINARY CONTAMINANT REMEDIATION GOAL EXCEEDANCES IN GROUNDWATER

DWG DATE: 5/13/96 | DWG NAME: 1FIG3

1.4 Preliminary Technology Screening

As stated in the USEPA guidance document on presumptive remedies for municipal landfills, "Section 300.430(a)(iii)(B) of the **NCP** contains the expectation that engineering controls, such as containment, will be used for waste that poses a relatively low long-term threat or where treatment is impracticable. The preamble to the NCP identifies municipal landfills as a type of site where treatment of the waste may be impracticable because of the size and heterogeneity of the contents (*55* FR 8704). Waste in Comprehensive Environmental Response, Compensation, and Liability Act landfills usually is present in large volumes and is a heterogeneous mixture of municipal waste frequently co-disposed with industrial and/or hazardous waste. EPA generally considers containment to be the appropriate response action, or the 'presumptive remedy,' for the source areas of municipal landfill sites.

The components of the presumptive remedy are:

- Landfill cap
- Source area groundwater control to contain any contaminant plume
- Leachate collection and treatment
- Landfill gas collection and treatment
- Institutional controls to supplement engineering controls

The guidance document also states that "an active response is not required **if** groundwater contaminant concentrations exceed chemical-specific standards but the site risk is within the USEPA's acceptable risk range (1E-4 through 1E-6). For example, if it **is** determined that the release of contaminants from a particular landfill is declining, and concentrations of one or more groundwater contaminants are at or barely exceed chemical-specific standards, the agency may decide not to implement an active response. Such a decision might be based on the understanding that the landfill is no longer acting as a source of groundwater contamination, and that the landfill does not present an unacceptable risk from any other exposure pathway."

Remedial technologies applicable to specific-site conditions at Site 1 are:

- Low-permeability surface cap
- Vertical barriers
- Excavation and offsite disposal
- Natural attenuation
- Low temperature thermal desorption
- Solidification/stabilization
- Constructed wetlands
- Air stripping
- Bioreactors

Table 1-4 discusses these treatment technologies, their objectives, implementability, effectiveness, and cost. The following table is consistent with technology-screening techniques presented in the NCP and USEPA guidance because it includes containment, removal, disposal, and treatment options.

Implementability encompasses both the technical and administrative feasibility of implementing a technology. Technical implementability is used to initially eliminate technology types and process options that are clearly ineffective or unworkable. The readily available information from the RI site characterization is used to screen out technologies and process options. Administrative implementability emphasizes the institutional aspects of implementability, 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.

Table 1-4
Technology Screening for Site 1

Technology	Objectives	Implementability	Effectiveness	cost
Low-Permeability Surface Cap	Capping is a containment technology that will limit human contact with soil and reduce infiltration of rainwater through contaminated waste.	This technology is implementable at Site 1. The site must be cleared and grubbed before installing the cap and this process could temporarily increase risk to workers onsite.	This technology is effective at reducing contact, ingestion, or inhalation risks. Capping also significantly reduces leachate generation by infiltrating rainwater. The cap must be maintained for at least 30 years.	High capital cost, low O&M cost.
Vertical Barriers	Subsurface barriers, such as a vertically excavated trench filled with slurry, form a barrier to restrict groundwater flow and contain contaminated leachate.	Implementability is questionable at Site 1. The vertical barriers must be keyed into an impermeable layer to be effective. The depth to the clay layer beneath Site 1 is near the limits of this technology, making implementation infeasible.	This technology is effective in preventing groundwater migration from the site; however, it must be used in conjunction with a surface cap or a water management system must be in place to prevent the failure of the vertical bamers.	High capital cost, low to moderate O&M cost.
Excavation and Offsite Disposal	Excavation is a removal technology. Excavation of "hot spots" can eliminate risk to human health and the environment. Per CERCLA guidance, excavation and offsite disposal is a last resort at landfill sites.	This technology is implementable at Site 1; however, it is not feasible. Hot spots may be excavated only if their removal would significantly reduce the risk onsite and if they are small enough to be reasonable to remove Site 1 meets neither requirement.	This technology is very effective at removing contaminated media. Risk to human health and the environment would remain approximately the same as before the "hot spot" removal.	Moderate to high Cost of this alternative depends on the method of disposal following excavation.

Table 1-4
Technology Screening for Site 1

Technology	Objectives	Implementability	Effectiveness	cost
Natural Attenuation	Natural attenuation is not a technology but more of a management philosophy. Natural subsurface processes such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials are allowed to reduce contaminants to acceptable concentrations.	Natural attenuation is implementable at Site 1. Natural attenuation should only be used in low-risk situations, such as Site 1 (no receptors) because contaminant migration is a risk.	Biodegradation can be slow; however, given time it is expected that the contaminants will naturally attenuate to concentrations below the remedial goals for Site 1. An accurate model developed during remedial design can give a more precise estimate of time to meet remedial goals.	Low capital costs, low O&M costs.
Low Temperature Thermal Desorption	Wastes are heated from 200° to 600°F to volatilize water and organic contaminants. A vacuum system transports the offgas to a gas treatment system. This is a physical separation process and is not designed to destroy organics.	This technology is implementable at Site 1. The waste must be screened and separated prior to desorption but this is all fully available and fully developed technology. The waste must be excavated to implement this technology, making it infeasible at Site 1.	This technology is effective at removing the volatile contaminants from the wastestream. It is somewhat less effective at removing semivolatile components without increasing the temperature of the treatment, which would increase energy consumption and costs. This technology would not affect inorganic contaminants.	Moderate to high capital cost, low O&M cost.
Solidification/Stabilization	Contaminants are physically bound or encased within a stabilized mass, or chemical reactions are induced with stabilizing agents. The contaminants are not removed nor destroyed but their mobility is reduced.	This technology is implementable at Site 1, however it is not feasible. Some processes may significantly increase the volume of the waste, makiig replacement difficult. Some contaminants are incompatible with the process and treatability studies may be required.	This technology is effective at reducing the mobility of inorganic contaminants. It has limited effectiveness at treating semivolatile organic compounds and is ineffective at treating volatile organic compounds, making it infeasible at Site 1. Environmental conditions may affect long-term effectiveness.	Moderate to high capital cost, low O&M cost.

Table 1-4
Technology Screening for Site 1

Technology	Objectives	Implementability	Effectiveness	cost
Constructed Wetlands	Constructed wetlands is a technology for treating the contaminated leachate and groundwater generated at Site 1. Wetlands treat the water through biological processes, physical processes, and volume reduction through evapo-transpirative processes.	Constructed wetlands are implementable at Site 1. This technology is land intensive, but adequate land is available near Site 1.	Constructed wetlands are being used in other landfills to treat leachate. Contaminant concentrations should be lowered to acceptable levels for discharge of the effluent to surface water or infiltration onsite. Start-up can be slow, sometimes taking more than one growing season for a system to perform to design capacity.	Moderate to high capital cost, low to moderate O&M costs.
Air Stripping	Air stripping is a technology for treating contaminated leachate and groundwater generated at Site 1. Volatile organics are partitioned from water by greatly increasing the surface area of the water exposed to air. Types of aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration.	Air stripping is implementable at Site 1. Potential exists for inorganic or biological fouling of equipment or clogging of the stripping column packing material due to inorganics in the groundwater. Air strippers must be taken out of service and packing materials acid-washed.	Volatile contaminants should be reduced to below remedial goals. Semivolatile contaminants will be reduced, but may not meet remedial goals. Inorganics will not be affected unless some form of pretreatment is implemented.	Moderate capital cost, moderate to high O&M cost.

Table 1-4
Technology Screening for Site 1

Technology	Objectives	Implementability	Effectiveness	Cod
Bioreactor	Bioreactor is a technology for treating contaminated leachate and groundwater generated at Site 1. Contaminants in extracted groundwater are put into contact with microorganisms through 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.	Bioreactor is not technically implementable at Site 1 due to the low contaminant concentration in the groundwater. This is a well-developed technology that has been used for many years to treat municipal wastewater. Equipment and materials are readily available.	Biological reactors can destroy organic contaminants. However biochemical oxygen demand loading must be high enough to support the growth of the microbes. The low level of organic contaminants present in Site 1 groundwater would not be sufficient to support the growth of microbes. With the addition of supplemental nutrients, it is unlikely that the target contaminants would be reduced to an acceptable level. A bioreactor is considered technically infeasible at Site 1.	High capital costs, high O&M costs.
Hydraulic Barriers	A series of wells is used to pump groundwater creating a hydraulic barrier and preventing groundwater from migrating off site.	Groundwater recovery is technically implementable at Site 1. This is a well developed technology that has been used for many years and would require minimal pilot testing to determine final designs.	Hydraulic barriers have been used effectively at many sites to contain and in some cases recover groundwater plumes. The groundwater must be treated after recovery and can add significantly to the cost.	Moderate capital costs, moderate O&M costs.

The effectiveness screening evaluation is based on how effective each technology would be in protecting human health and the environment. Each should be evaluated as to its effectiveness in providing protection and reducing toxicity, mobility, or volume of contamination. Both short- and long-term components of effectiveness should be evaluated; short-term refers to the construction and implementation period and long-term refers to the period after the remedial action is complete.

Costs play 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 as to whether costs are high, low, or medium relative to other process options.

Using the implementability, effectiveness, and cost criteria discussed in this table to screen remedial technologies, it is clear that excavation and offsite disposal is neither required nor desired for either technical or regulatory reasons; it is unlikely that excavation of any "hot spot" areas would significantly reduce the overall risk presented by the site. Due to the large size and heterogeneous mixture of waste in the landfill, it is technically impractical to consider excavating all of the waste. Excavation will not be included in the assembly of alternatives. Similarly, vertical barriers are screened from consideration due to technical reasons. The depth to clay beneath the site make it infeasible at Site 1. Low temperature thermal desorption is eliminated because the waste must be excavated to implement this technology, making it infeasible at Site 1. Because solidification/stabilization is not effective in treating VOCs it is eliminated from consideration. The bioreactor is technically infeasible because the low contaminant concentration in the groundwater would not support the microbed growth. If the nutrients for biological growth were supplemented, it is questionable whether an acceptable level of target contaminant reduction could be achieved; therefore, bioreactors are screened from consideration.

Low-permeability surface cap, natural attenuation, hydraulic barriers, constructed wetlands, and air stripping all satisfy the implementability, effectiveness, and cost criteria; these process options will be retained for the assembly of alternatives.

1.5 Focused Feasibility Study Alternatives

As described in the NCP, the primary objective of the feasibility study is to ensure that appropriate remedial alternatives are developed and evaluated such that relevant information concerning the remedial action options can be presented to decision-makers and the appropriate remedy selected. To accomplish this objective, the feasibility study is tasked with addressing only remedial measures appropriate to the scope and complexity of the project.

Because landfills share similar characteristics, they lend themselves to remediation by similar technologies. The NCP expects that containment technologies will generally be appropriate remedies for wastes that pose a relatively low-level threat or where treatment is impracticable. Containment has been identified as the most likely response action at these sites because (1) CERCLA municipal landfills are primarily composed of municipal and, to a lesser extent, hazardous waste; therefore, they often pose a low-level threat rather than a principal threat; and **(2)** the volume and heterogeneity of waste within CERCLA municipal landfills will often make treatment impractical. Consequently, because the alternatives are comparatively straightforward and may be evaluated immediately using the detailed analysis procedures, an **FFS** format is being used to address media of concern.

Tar pit excavation and disposal would occur in each remedial alternative evaluated except no action. Because removal of the tar pit is common to all alternatives it will not be considered during remedy selection.

The following remedial alternatives will be discussed:

- Alternative I — No Action. Consideration of this alternative is required under the NCP. Under the no action alternative, contaminated soil and water is left in place. This alternative poses no excess risk to current workers and site trespassers; risk to future child residents exceeds the 1×10^{-6} threshold. While contaminated soil continues to leach contaminants to groundwater, it is expected that current conditions represent worst-case scenarios over the next **30** years.

- Alternative II — Natural Attenuation. This alternative is not the same as "no action." Under this alternative, contaminated soil and water is left in place. Institutional controls are implemented at the site to limit access.. This alternative poses no excess risk to current workers and site trespassers; risk to future child residents are controlled institutionally during the process. Groundwater is monitored and institutional controls are implemented to prevent consumption of any water exceeding remedial goals. It is expected that current conditions represent worst-case scenarios and contaminant concentrations are attenuating with time. A sampling and analysis program must be conducted throughout the process to confirm that degradation is proceeding at rates consistent with meeting cleanup objectives.

- Alternative III — Capping. A low-permeability surface cap is placed over the approximately ***85*** acres that comprise the landfill. Storm water runoff controls are required. This alternative poses no unacceptable risk to current workers or site trespassers and no unacceptable risk for future child residents provided the cap does not fail. Surface cap installation entails minimal short-term **risk** to remediation workers since most highly contaminated soil is left in place while the surface cap is constructed. This risk is controlled through standard engineering dust suppression techniques and through use of personal protection equipment. The primary benefit in this alternative is reduced leachate

generation and infiltration into groundwater. Under this alternative, the groundwater is monitored and expected to meet remedial goals through natural attenuation over time, although capping will slow the natural degradation of the waste itself.

- Alternative IV — Groundwater Containment with Pumping and Treatment. In this alternative the contaminated groundwater is actively contained and treated through a pump-and-treat system. Two subalternatives will be considered.

  - Treatment with constructed wetlands.
  - Treatment with air stripping.

This alternative poses no unacceptable risk to current workers or site trespassers and no unacceptable risk for future child resident. Permits may need to be obtained for discharge of treated water or for air emissions from treatment.

2.0 ASSEMBLY OF ALTERNATIVES

This section presents the remedial alternatives for Site 1 developed using residential- and leachability-based PRGs. The remedial elements of each alternative are discussed, along with impacts on the community, associated costs, and implementation considerations.

2.1 Alternative 1: No Action

The NCP requires that a no-action alternative be considered as a "baseline" against which all other alternatives will be evaluated. In the no-action alternative, no remedial actions are taken to contain, remove, or treat soil contaminated above risk- or leachability-based cleanup goals. Soil remains in place and attenuates according to natural biotic and abiotic processes.

2.1.1 Alternative 1: Remedial Elements

No remedial elements are associated with the no-action alternative.

2.1.2 Alternative 1: Implementability

This alternative is technically feasible. No construction, operation, or maintenance is required. No technology-specific regulations apply. This alternative is administratively feasible. The no-action alternative has no special technical or capacity requirements.

2.1.3 Alternative 1: Effectiveness

The no-action alternative does not provide any additional effectiveness for the current use scenario as no risks to current or future workers are posed above the $1x10^{-6}$ threshold. The site is secured by Navy personnel; unauthorized personnel are not allowed near Site 1. This alternative does not meet the effectiveness criterion as it does not reduce future child exposures to groundwater.

The no-action alternative also does not meet the effectiveness criterion for protection of groundwater as it does not reduce the leachability of contaminants in soil and waste. Due to the

age of site constituents, it is unclear whether wastelsoil contaminated with leachable compounds will significantly impact the aquifer any more than the current scenario. Constituent concentrations are expected to decrease through natural biotic or abiotic attenuation processes, thus rendering the wastelsoil less threatening to groundwater with time.

This alternative does not reduce the toxicity, mobility, or volume of contaminants. No risks are posed during the short term (implementation phase). Once the no-action alternative is implemented, the only risks remaining are those to future child residents through exposure to groundwater; contaminated wastelsoil may threaten site groundwater.

2.1.4 Alternative 1: Cost

No cost is associated with the no-action alternative.

2.2 Alternative 2: Natural Attenuation

This alternative is not the same as "no action." Under this alternative, contaminated soil and water is left in place. Institutional controls are implemented at the site to limit access. This alternative poses no excess risk to current workers and site trespassers; risk to future child residents is controlled institutionally, consumption of any groundwater is prevented by placing restrictions on the use of groundwater beneath and downgradient of the landfill. Groundwater is monitored and the aquifers are modeled to predict the fate and transport of contaminants. It is expected that current conditions represent worst-case scenarios and contaminant concentrations are attenuating with time. A sampling and analysis program must be conducted throughout the process to confirm that degradation is proceeding at rates consistent with meeting cleanup objectives.

2.2.1 Alternative 2: Remedial Elements

The natural attenuation alternative includes initial fate and transport modeling to predict expected contaminant concentrations in groundwater and surface water over time. Additional groundwater sampling may be required to support this modeling. A groundwater monitoring program is implemented to monitor the progress of natural attenuation and to ensure protection of human health. Institutional controls are implemented to restrict land and groundwater use at Site 1. A fence is erected around the perimeter of the site and Navy security ensures no unauthorized personnel enter the site.

2.2.2 Alternative 2: Implementability

This alternative is technically feasible. No construction, operation, or maintenance is required. Groundwater monitoring can be carried out using existing monitoring wells and any additional ones required to meet Florida Administrative Code 62.701.510 requirements. No other technology-specific regulations apply.

This alternative is administratively feasible. No problems are anticipated in limiting land use, or restricting groundwater use beneath and downgradient of the landfill. Community acceptance must be obtained and may require some education for the general public on the difference between no action and natural attenuation.

2.2.3 Alternative 2: Effectiveness

Natural attenuation does not provide any additional effectiveness for the current use scenario as no risks to current or future workers are posed above the 1×10^{-6} threshold. This alternative is based on current use of the site as an industrial area and that this use will not change in the foreseeable future. Additionally, institutional controls will be put in place that state contaminants are present in surface soil and groundwater beneath the site at concentrations that exceed residential use criteria. The areas will be designated for industrial use only. Should use

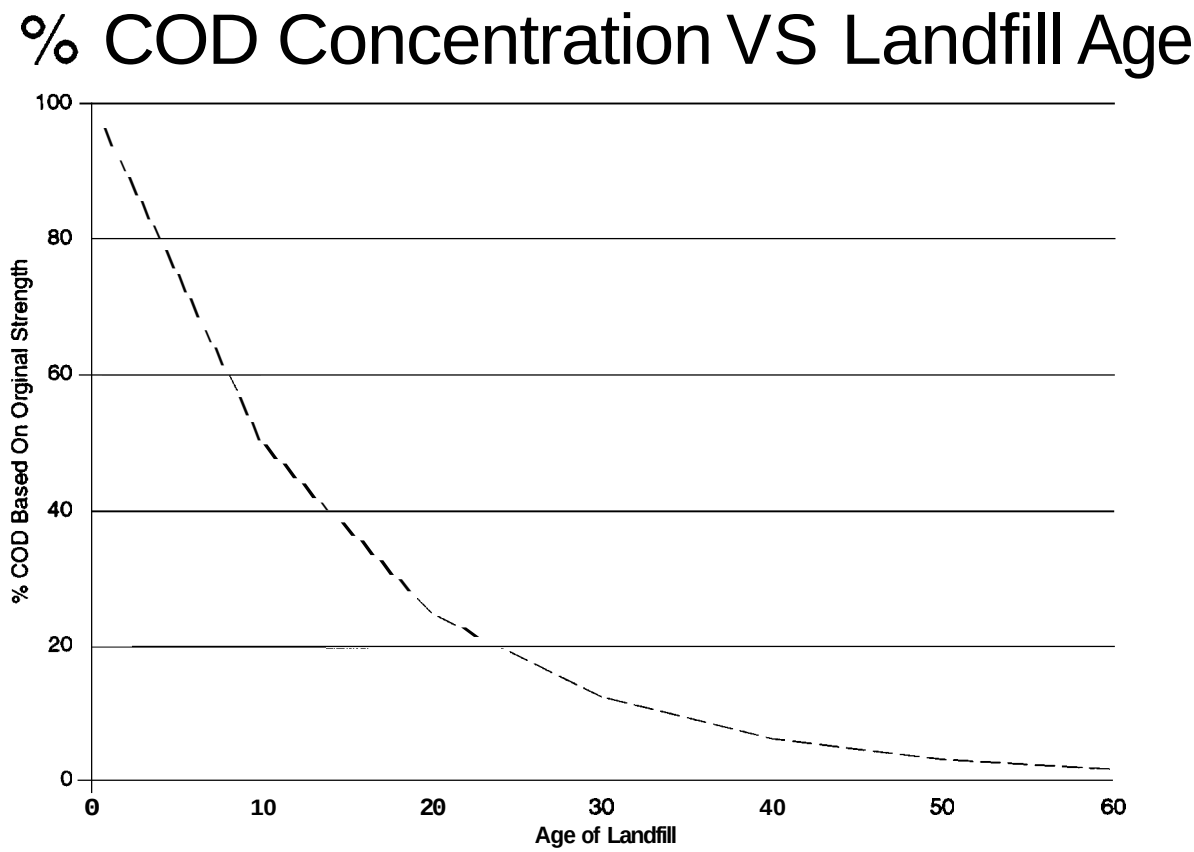
of Site 1 change, the site may need to be reevaluated. This alternative meets effectiveness criterion by administratively preventing a future child resident from exposure to the groundwater beneath the site.

This alternative also meets the effectiveness criterion for protection of groundwater as contaminant concentrations are expected to decrease through natural biotic and abiotic attenuation processes, thus rendering the waste less threatening to groundwater and improving groundwater quality to meet remedial goals with time.

Landfills have a distinct life cycle that proceeds in five distinct phases. The rate and characteristics of leachate produced and gas generated from a landfill vary from one phase to another and reflect the microbial processes taking place inside the landfill. The phases are initial adjustment phase, transition phase, acid formation phase, methane fermentation phase, and maturation phase (Reinhart, 1995). Comparing the biochemical oxygen demand and chemical oxygen demand concentrations in groundwater samples at Site 1 with those reported for other conventional landfills indicates that Site 1 is in the maturation stage. According to Reinhart during the maturation phase "biological activity shifts to relative dormancy. Gas production drops and leachate strength stays at much lower concentrations."

Studies have suggested that the COD half-life for conventional landfills to be approximately 10 years (Reinhart 1995). The age of the landfill at Site 1 varies from 20 years to more than 40 years. COD concentration generally mirrors the leachate organic strength. A plot of the COD concentration, using 100% as the initial concentration, versus the age of a generic landfill using a 10-year half-life, suggests that most of the contaminant mass at Site 1 may have already been leached from the landfill into the groundwater (Figure 2-1).

Figure 2-1


% COD Concentration VS Landfill Age
% COD Based On Orginal Strength
100
80
60
40
20
0
0
10
20
30
40
50
60
Age of Landfill

In-depth numerical modeling required to support a natural attenuation scenario for groundwater will be conducted during remedial design, due to the requirement of the modeling for a single-stage synoptic water quality sampling event upon which to base concentration calibration it cannot be done at this time. In the absence of this model, a trend analysis of groundwater data and a gross physico-chemical modeling of advective contaminant transport relative to the nearest surface water receptors is presented in support of the feasibility of the natural attenuation scenario.

Table **2-1** presents data for all commonly sampled wells from the **1984** event, and the **1994** event. For each well, the detected parameters and concentrations are listed for each event. Finally, **an** interpretive column in the table presents the direction of the parameter concentrations (up or down) over time. For a total of 21 parameters, only chlorobenzene concentrations increased between 1984 and **1994.** Clearly, this data indicates that overall water quality, as defined by these parameters, has improved even though a proactive groundwater remediation system was not in operation.

Table 2-1
Trend Analysis from 1984 Groundwater Samples to 1994 Groundwater Samples

Concentrations in μg/L	Year	GM-04	GM-05	GM-33	GM-34	GM-35	Trend
Chloromethane	1984	ND	ND	ND	ND	5.4	⇓
	1994	ND	ND	ND	ND	ND	
Chloroethane	1984	27	ND	ND	165	1.2	⇓
	1994	ND	ND	ND	ND	ND	
1,ldichloroethene	1984	ND	ND	ND	ND	0.9	⇓
	1994	ND	ND	ND	ND	ND	
1,1-dichloroethane	1984	ND	1	ND	ND	3.2	⇓
	1994	ND	ND	ND	ND	ND	
1,2-dichloroethene	1984	ND	55	ND	ND	1.7	⇓
	1994	ND	ND	ND	ND	ND	

Table 2-1
Trend Analysis from 1984 Groundwater Samples to 1994 Groundwater Samples

Concentrations in µg/L	Year	GM-04	GM-05	GM-33	GM-34	GM-35	Trend
1,1,1-trichloroethene	1984	59	ND	ND	44	ND	⇓
	1994	ND	ND	ND	ND	ND	
Trichloroethene	1984	ND	.7	ND	ND	ND	⇓
	1994	ND	ND	ND	ND	ND	
Chlorobenzene	1984	ND	ND	ND	ND	20	⇑
	1994	36	1	31	24	36	
2,4-dimethylphenol	1984	ND	ND	ND	ND	8.0	⇓
	1994	ND	ND	ND	ND	ND	
1,2-dichlorobenzene	1984	ND	ND	ND	3.0	5.0	⇓
	1994	ND	ND	ND	ND	4.0	
1,4-dichlorobenzene	1984	5.0	ND	15.0	9.0	10.0	⇓
	1994	4.0	ND	7.0	5.0	8.0	
Napthalene	1984	2.0	ND	8.0	8.0	47.0	⇓
	1994	ND	ND	ND	9.0	8.0	
Diethylphthalate	1984	ND	ND	2.0	ND	3.0	⇓
	1994	ND	ND	ND	ND	ND	
2 ethyl naphthalene	1984	NA	NA	NA	14.0	11.0	⇓
	1994	ND	ND	ND	ND	ND	
2,4-Dimethylphenol	1984	ND	ND	ND	ND	8.0	⇓
	1994	ND	ND	ND	ND	ND	
Cadmium	1984	ND	1.0	1.0	2.0	1.0	⇓
	1994	ND	ND	ND	ND	ND	
Chromium	1984	4.0	2.0	5.0	3.0	3.0	⇓
	1994	ND	ND	ND	ND	ND	
Lead	1984	20	ND	ND	20	20	⇓
	1994	ND	ND	ND	ND	ND	
Silver	1984	1	ND	2	31	ND	⇓
	1994	ND	ND	ND	ND	ND	
Nickel	1984	9	1	8	9	ND	⇓
	1994	ND	ND	ND	ND	ND	
Zinc	1984	8	13	9	365	12	⇓
	1994	ND	ND	ND	ND	7.5	

In further support of natural attenuation, the distance directly downgradient to the nearest surface water body from the wells exceeding a PRG closest to the surface water was measured and "average" half-lives were calculated for the compounds exceeding a PRG, and an "average" groundwater velocity for shallow and intermediate was calculated. Using this information, the travel time (assuming advection dominated transport) and adjusted concentration at discharge to the nearest water body (assuming degradation based on number of half-lives utilized during travel time) was calculated. All of the above information is presented in Table **2-2.** This analysis indicates that of the seven compounds looked at, only vinyl chloride and benzene is shown to exceed the PRGs. Notably, this analysis does not account for dispersion.

Keeping with the intent of the feasibility study, and utilizing the available data, it is clear that natural attenuation may be a reasonable alternative. At a minimum, the ultimately chosen alternative may incorporate at least some element of natural attenuation, to be selected with confidence through rigorous modeling and verified by periodic monitoring.

2.2.4 Alternative 2: *Cost*

Cost components for the natural attenuation alternative include the following:

- Fate and transport modeling
- Groundwater sampling
- Institutional controls
- Analysis and report compilation

Table **2-3** presents the costs associated with natural attenuation. In addition, costs associated with excavation and disposal of the tar pit would be associated with this alternative and all others except the no-action alternative. Table **2-4** presents the costs associated with the tar pit removal.

Table 2-2
Gross Physio-Chemical Modeling

Parameter	Closest Distance to water body	Concentration @ closest point (well ID/Depth)	Half-Life	Travel Time	Worst Case Concentration at Water Body	FPDWS
Benzene	**225'**	**3 ppb (01GI46/Intermediate)**	**365 days**	**132 days**	**2.5 ppb**	**1 ppb**
Bromoform	175'	4 ppb (01GGM04/Shallow)	210.5 days	67 days	3.4 ppb	4 ppb*
1,1,2,2-Tetrachloroethane	**175'**	**6 ppb (01GGM04/Shallow)**	**22 days**	**67 days**	**< 1 ppb**	**NS**
Vinyl Chloride	225'	12 ppb (01GI46/Intermediate)	1453 days	132 days	11.45 ppb	1 ppb
Chlorobenzene	**1050'**	**120 ppb (01GS42/Shallow)**	**218 days**	**404 days**	**34.5 ppb**	**100 ppb**
Naphthalene	1090'	38 ppb (01GI28/Intermediate)	129.5 days	641 days	1.3 ppb	6.8 ppb*
Xylene	**850'**	**43 ppb (01GI61/Intermediate)**	**189.5 days**	**500 days**	**7.31 ppb**	**20 ppb****

Notes:
* – Florida Groundwater Guidance Concentration
** – Florida Secondary Drinking Water Standard
NS – No standard
Exceedances only from 1994 Sampling
Half-life was the $\bar{x}$ of high and low
Travel time was calculated using the $\bar{x}$ of high and low values for groundwater velocity for shallow and intermediate depths.
Advection dominated; no dispersion accounted for; only retardation accounted for was through degradation rate.

Table 2-3
Natural Attenuation/Monitoring Costs

Action	Quantity	Cost per Unit	Total Cost
*Modeling	320 hrs	$94/hr	$30,080.
Groundwater sampling	32 samples semiannually; 6 QA/QC per sampling event	$1,000/sample	$76,000[a]
Groundwater analysis	76 samples per year	$610/sample	$46,360[b]
Well construction	15 new wells 20' deep 10' screens development	$1,487/well	$22,305[a]
*Institutional Controls			
1. Land and Groundwater Use Restrictions	1	$5,000 ea	$5,000[c]
2. Construct Fence	7,704'	$10.78/lf	$83,049[d]
3. Signs	77	$70.84 ea	$5,390[d]
Contingency	LS	30% Direct Cost	$43,750[a]
Engineering support/report preparation	LS	15% Direct Cost	$21,875[a]

Notes:

a	=	Cost based on experience with similar work.
b	=	Cost based on existing Navy laboratory contract cost.
c	=	Cost provided by NAS Pensacola engineering.
d	=	Costs from "Environmental Restoration: Assemblies Cost Book", ECHOS 1995.
lf	=	Linear feet
LS	=	Lump sum
QA/QC	=	Quality assurance/quality control
*	=	These costs are associated with Natural attenuation and would be excluded from monitoring only costs.

Table 2-4
Tar-Pit Removal Costs

Action	Quantity	Cost per Unit	Total Cost
Mobilization/demobilization	1	$2,000	$2,000[a]
Hazardous material excavation	67 yd^3	$10 per yd^3	$6,700[a]
Transportation to landfill	6 truck loads	$95 per truckload	$570[a]
Tipping fee	67.5 tons	$35 per ton	$2,360.
Contingency	LS	30% direct cost	$3,490
Engineering supportlreport preparation	LS	$70,000	$70,000[b]

Notes:
a – Based on previous removal action costs carried out by the Navy at NAS Pensacola.
b – Cost estimated by Bechtel Environmental, Inc.
yd^3 – Cubic yards
LS – Lump sum

2.3 Alternative 3: Capping

A low-permeability surface cap is placed over the approximately 85 acres that compose the landfill. The primary purpose of the cap is to limit the infiltration of rainwater through the waste interval, thus limiting leachate generation. Secondly, the cap prevents any exposure to potentially contaminated media by human and faunal visitors to the site.

2.3.1 Alternative 3: Remedial Elements

The cap consists of 24 inches of clay with a maximum permeability of 1×10^{-7} cm/sec centimeters overlain by 12 inches of sand as a drainage layer, topped by 18 inches of topsoil and grass to stabilize the soil. A 20 mm PVC liner is installed on top of the clay to further reduce percolation of water through the waste. The entire site is cleared, grubbed, and graded prior to cap installation. Storm water runoff is controlled by perimeter ditches that collect runoff and direct it away from the site. Under this alternative, the groundwater is monitored and with little

additional contamination, expected to meet remedial goals through natural attenuation over the. Regular maintenance activities are required, such as inspecting, mowing, and repairing the cap.

2.3.2 Alternative 3: Implementability

This alternative is both technically and administratively feasible at Site 1. Caps are regarded as reliable containment structures. Cap installation involves clearing and grubbing the site, which will destroy a mature pine forest, a significant habitat for many animals. During installation leachate generation may increase due to the removal of the vegetative cover, allowing for greater infiltration of rainwater.

The capping alternative is administratively feasible and is part of the presumptive remedy for CERCLA municipal landfills.

2.3.3 Alternative 3: Effectiveness

The capping alternative does not offer any additional effectiveness for current and future site workers, as no risks are posed above the 1×10^{-6} threshold. However, if the cap is maintained, the threat to groundwater and, therefore, future child residents should be lessened over time, but the current groundwater contamination would remain.

The Hydrologic Evaluation of Landfill Performance (USEPA/600/R-94/168a,9-94) computer program — a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of landfills — was used to compare the current conditions at Site 1 with the expected conditions if the site is capped with a low-permeability clay cap. The model was run using synthetic weather generated by the program based on past weather patterns in Mobile, Alabama. The results from three runs of the model are shown in Table 2-5. The first run modeled the landfill as it exists currently, the second run models the landfill with a cap consisting of 24" of clay, and the last models the same clay cap covered with a 20 mm PVC liner.

Table 2-5
Landfill HELP Model Comparison

	Runoff		Evapotranspiration		Leachate Generated	
Cap Type	Percent	Inches	Percent	Inches	Percent	Inches
No Cap	0	0	61	40	39	25
Clay Cap	17	4	65	42	18	12
Clay Cap with 20 mm PVC Liner	30	20	69	45	1	0.5

Note:
* Inches based on an average annual precipitation budget of 65 inches.

The clay cap reduces the leachate generated by the landfill by 64%, while installing a 20 mil PVC liner on top of the clay reduces the leachate further to only 2.5% of the original amount predicted for the existing landfill. Appendix B includes the input and output for the model runs.

2.3.4 Alternative 3: Cost

Cost components for the surface cap alternative include the following:

- Cap construction
- Groundwater monitoring
- Institutional controls
- Cap operation and maintenance activities
- Engineering support and report preparation

Table 2-6 presents the costs associated with the surface cap alternative.

Table 2-6
Surface Cap Costs

Action	Quantity	Cost per Unit	Total Cost
Clear & grub	85.2 acres	$2,100 per acre	$178,920[a]
Low permeability clay	274,934 yd^3	$16.10 per yd^3	$4,426,437.
20 Mil PVC geomembrane	3,711,312 ft^2	$0.26 per ft^2	$964,941[b]
Drainage sand	137,467 yd^3	$6.68 per yd^3	$918,280[b]
Topsoil from installation	206,200 yd^3	$6.31 per yd^3	$1,301,125[b]
Seed and till	85.2 acres	$1,488.73 per acre	$126,839[b]
Fertilize	85.2 acres	$105.22 per acre	$8,965[b]
Surface drainage perimeter ditch	7,704 ft	$9.28 per linear ft	$71,493[b]
6' chain-link Perimeter fence	7,704 ft	$10.78 per linear ft	$83,049[b]
Warning signs	77 (every 100')	70.84	$5,390[b]
Contingency	LS	30% Direct Cost	$2,425,631[b]
Engineering support/report preparation	LS	217000	$217,000[c]
Operation & Maintenance Cost			
Maintain vegetation	85.2 acres	$100/acre	$8,520[d]
Maintain drainage & cap	85.2 acres	$100/acre	$8,520[d]
Inspection	LS	$1,000 LS	$1,000[d]
Groundwater monitoring	76 samples/yr	$1,610/sample	$122,360[d]

Notes:
[a] — Costs based on vendor proposed costs
[b] — Costs from "Environmental Restoration: Assemblies Cost Book," ECHOS 1995
[c] — Cost estimated by Bechtel Environmental, Inc.
[d] — Cost based on experience with similar work
LS = Lump sum
ft^2 — Square feet
yd^3 — Cubic yards

2.4 Alternative 4: Groundwater Containment with Pumping and Treatment

In this alternative a groundwater extraction system is installed to capture the contaminated groundwater which will be treated ex-situ. The groundwater extraction system is shut down once the remedial goals for groundwater have been met. The main purpose of the system is to contain the contaminated groundwater, more so than to remediate the aquifer. The system is designed to 1) address specific areas that exhibited PRG exceedances within and downgradient of the landfill and 2) serve a dual function as a perimeter monitoring network; when monitoring detects exceedances of performance standards, the appropriate wells can be activated as extraction wells.

2.4.1 Alternative 4: Remedial Elements

Under this alternative, contaminated groundwater is contained by well-based extraction to create hydraulic barriers. The extracted groundwater can be treated by air stripping or through constructed wetlands. The treated groundwater is expected to meet remedial goals.

Based on areal extent of apparent onsite contamination in the surficial aquifer, and specific characteristics of the aquifer (hydraulic conductivity, aquifer thickness), a twenty-well recovery system is proposed for containment. The feasibility of groundwater extraction was projected as described in the following paragraphs.

To approximate the composite capture zone of the multiple-well system for the FFS, the groundwater flow regime during pumping of the system was modeled using the flow model Visual MODFLOW. The individual capture zones and verification of the composite capture zone were modeled using the reverse particle-tracking routine resident in the tracking model MODPATH. Appendix C includes the specific groundwater modeling report for the site.

The model indicated that 20 wells screened throughout the entire surficial aquifer, pumping at a combined 80 gallons per minute would capture one volume of contaminated groundwater in

5 years. The aquifer parameters used for these simulations are based on specific-capacity tests. These values will need to be verified, and the simulation refined and calibrated during the data acquisition and interpretation phase of remedial design, when actual field conditions during execution of a long-term aquifer test can be measured. The predictive design presented here is only intended to demonstrate the feasibility of contaminated groundwater extraction from the surficial aquifer and to provide a first estimate for preliminary design.

The two treatment processes undergoing detail analysis for this feasibility study are air stripping and constructed wetlands. In addition to the cost associated with the treatment processes, additional costs will be incurred for groundwater extraction, piping, and permitting.

Constructed Wetlands

Constructed wetlands are man-made systems that are designed, built, and operated to perform the functions of natural wetlands for treatment of contaminated water. Wetlands improve water quality through physical, chemical, and biological processes operating independently and also interactively. The removal mechanisms for suspended solids in the wetlands treatment system essentially fall under two processes. The first is sedimentation where the suspended solids ultimately settle to the bottom. Retention times and contact with plant materials enhance this process. Absorption of suspended solids also aids in this reduction process. Many chemical constituents tend to attach or sorb onto solids. Absorption combined with solids settling remove constituents from the water column that otherwise could remain. Increased water surface area for gas exchange improves dissolved oxygen content for decomposition of organic compounds and oxidation of many metallic ions. But the most important processes are similar to transformations occurring in conventional treatment plants. Wetlands like conventional treatment systems, simply provide suitable environments for abundant microbial populations. Wetland systems use larger treatment areas to establish stable, low maintenance systems providing environments for similar microbes, but may support additional types of microorganisms because of the diverse mixture of microenvironments. The latter, along with a larger

treatment area, frequently provides more complete reduction and lower discharge concentrations of water-borne pollutants.

The principal function of vegetation in wetlands systems is to create additional environments for microbial populations. Not only do the stems and leaves in the water column obstruct flow and facilitate sedimentation, they also provide substantial amounts of surface area for attachment of microbes — reactive surfaces. Plants also increase the amount of aerobic microbial environment in the substrate incidental to the unique adaption that allows wetlands plants to thrive in saturated soil. Most plants are unable to survive in water-logged soil because their roots cannot obtain oxygen in the anaerobic conditions rapidly created after inundation. However, hydrophytic or wet-growing plants have specialized structures in their leaves, stems, and roots somewhat analogous to a mass of breathing tubes that conduct atmospheric gases, including oxygen, down into the roots. Because the root hair outer covering is not a perfect seal, oxygen leaks out, creating a thin aerobic region around each root hair. In addition, the ability of vascular plants to absorb and concentrate heavy metals is well-documented.

Constructed wetlands provide an onsite treatment that requires little maintenance or power after a landfill is closed. They provide several characteristics that are beneficial for leachate treatment including large vegetative bio-mass, large adsorptive surfaces on sediments and plant material, aerobic/anaerobic interfaces, and diverse, active microbial populations. Plants also provide a more rapid decrease in leachate volume through transpiration than is provided by lagoons without plants.

Although an emerging technology, it is based on well-established processes and can be implemented, but requires substantial testing and planning. Also treated water must be discharged to surface water or reinjected into the underlying aquifer. The process of collecting the leachate from the groundwater eliminates contaminant migration. The technology will be retained for further evaluation as a treatment for groundwater.

Air Stripping

Air stripping is an established technology were volatile organics are partitioned from groundwater by greatly increasing the surface area of the contaminated water exposed to air. Types of aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration. In this FFS, tray aeration was chosen for implementation at Site 1. The following variables may limit the applicability and effectiveness of the process:

- Potential exists for inorganic or biological fouling of the equipment. Ferrous iron precipitates as insoluble ferrous hydroxide species upon aeration. Air strippers must be taken out of service and packing materials acid-washed.

- Consideration should be given to the Henry's Law constant of the VOCs in the water stream.

- Compounds with low volatility at ambient temperature may require pre-heating the groundwater.

A pretreatment process using sodium hydroxide to raise the pH and precipitate metals from the water will be included in the treatment train for air stripping. The water will then be treated with air stripping and the waste residuals will be disposed of offsite through a licensed treatment, storage, and disposal facility.

This technology is an established technology and can be implemented with a minimum of testing. Treated water must be discharged to surface water or reinjected into the underlying aquifer. The process of extracting groundwater eliminates contaminant migration. The technology will be retained for further evaluation as a treatment for groundwater.

2.4.2 Alternative 4: Implementability

This alternative is both technically and administratively feasible at Site 1. With 8 wells screened through the entire depth of the surficial aquifer, the contaminated water identified in the RI can be captured. Both treatment processes are technically feasible.

The constructed wetland alternative requires setting aside a rather large area of land to be converted to wetlands. The wetland are constructed on top of the landfill within the capture zone of the extraction wells. This ensures that any water infiltrating through the bottom of the wetlands is contained by the treatment system. If a cap is installed, the clay functions as the bottom of the constructed wetlands, reducing their cost. Wetlands have been successfully used to treat landfill leachate to acceptable discharge limits at another area landfill. Because wetlands are an emerging technology and no set design criteria have been developed, a pilot-scale study will be required prior to implementation at Site 1.

Air stripping would effectively remove volatile contaminants from the water. A model developed by Carbon Air Corporation, STAT 180 Version 2.4, models the contaminant removal in a low profile air stripper. The output from this model indicated that the volatile contaminants present at Site 1 would be removed to below PRGs.

The containment and treatment of groundwater alternative is administratively feasible and groundwater containment is part of the presumptive remedy for CERCLA municipal landfills. The air stripping subalternative requires calculating the air emissions and completing all other requirements for air permitting. The constructed wetlands provide valuable habitat for wildlife.

2.4.3 Alternative 4: Effectiveness

The groundwater extraction and treatment alternative does not offer any additional effectiveness for current and future site workers, as no risks are posed above the 1×10^{-6} threshold. However the threat to groundwater and, therefore, future child residents should be eliminated over time,

but it is difficult to estimate the amount of water that must be treated and the time required for aquifer restoration due to contaminant retardation in the aquifer. It is estimated to take from 5 years to 10 years to extract the contaminated groundwater identified in the RI report. Air stripping effectively removes the volatile contaminants from the groundwater to concentrations below drinking water standards; however, inorganic contaminants would not be effectively removed in this technology. With pH adjustment and clarification preceding air stripping, the most metals should be removed. Artificial wetlands have been applied in the past to landfill leachate treatment and have successfully removed both inorganic and organic contaminants; however, as an emerging technology its effectiveness cannot be determined without a pilot study.

2.4.4 Alternative 4: Cost

The costs for groundwater containment and treatment can be divided into extraction component (the same for natural wetlands or air stripping) and treatment costs. The containment system is based on preliminary data and modeling for feasibility purposes and cannot be considered a final design. The cost for groundwater containment, treatment through air stripping and treatment through constructed wetlands are presented in Tables 2-7, 2-8, and 2-9 respectively.

Table 2-7
Groundwater Containment Costs

Action	Quantity	Cost per Unit	Total Cost
Pumping tests	1	$78,000	$78,000[a]
Extraction well construction	20 Wells	$4,770/Well	$95,400[b]
Pumps and switches	20 Pumps	$2,675/pump	$53,500[c]
Piping and connections	14,250 lf	$10.34/lf	$147,349
Excavation and backfill	4,749 cy	$8.07/lf	$38,324[b]
Continency	LS	30% of Direct Cost	$123,770
Engineering support/report preparation	LS	$217,000	$217,000[f]
Annual Operation and Maintenance Cost			
Maintenance	12 months	$280 per month	$3360[d]
Electricity	65,400kwhr	$.0737 per kwhr	$4,820[e]
Replacement pumps	4 pumps	$450 per pump	$1800[b]
Monitoring	76 samples	$1,610/sample	$122,360[a]

Notes:

[a] = Costs based on previous work carried out by EnSafe.
[b] = Costs from "Environmental Restoration: Assemblies Cost Book," ECHOS 1995.
[c] = Costs from "Environmental Restoration: Assemblies Cost Book," ECHOS, 1995 and on vendors' proposed costs.
[d] = Costs based on one technician @ $35 per hr one day per month.
[e] = Costs based on 20, 0.5 horsepower pumps running 24 hours a day 365 days per year.
[f] = Cost estimate by Bechtel Environmental, Inc. This cost would be included in the Engineering Support/Report Prep costs for surface capping if they were carried out simultaneously.
kwhr = Kilowatt hour
cy = Cubic yards
LS = Lump sum
lf = Linear feet

Table 2-8
Air Stripping Costs

Action	Quantity	Cost per Unit	Total Cost
Low profile air stripper	1	$22,970	$22,970[a]
Installation of air stripper	1	$8,000	$8,000[a]
Controls (remote capability)	1	$7.000	$7,000[a]
Concrete slab	1	$1,000	$1,000[b]
Permitting	1	$5,000	$5,000[a]
Acid wash system	1	$8,800	$8,800[a]
Heavy metal removal system	1	$96,750	$96,750[a]
Contingency	LS	30% of Direct Cost	$44,856
Engineering supportlreport preparation	LS	$217,000	$217,000[f]
Annual Operation and Maintenance Cost			
Electricity	75,170 kwhr	$0.0737 per kwhr	$5,540[c]
HCl acid	2,9540 lbs	$0.0975 per lb	$2,880.
Disposal of spent acid	2,9540 lbs	$0.69 per lb	$20,380[e]
NaOH base	7,300 lb per year	$0.1475 per lb	$1,0801
Waste sludge disposal	47,961 lbs per year	$0.70 per lb	$33,570[e]
Labor	233 hrs	$35 per hr	$8,155[d]
Engineering supportlreport preparation	Annual	15%	$10,740

Notes:

[a] = Costs based on vendor proposed costs
[b] = Costs from "Environmental Restoration: Assemblies Cost Book," ECHOS 1995.
[c] = Costs based on electricity for 650 cubic feet per minute blower and 1 0.5 horsepower discharge pump running 24 hours per day, 365 days per year.
[d] = Costs based on 15-minutedaily inspection, four hour week waste handling and one eight hour day per month maintenance.
[e] = Costs based on current NAS Pensacola PWC waste disposal contract.
[f] = Cost estimates by Bechtel Environmental, Inc. This cost would be included in the engineering supportlreport preparation costs for surface capping if they were both carried out simultaneously.
LS = Lump sum

Table 2-9
Constructed Wetlands Costs

Action	Quantity	Cost per Unit	Total Cost
Clear and grub*	1.86 acres	$2,100 per acre	$3,906[a]
Grading	8983 yd^2	$0.88 per yd^2	$7,910[b]
Berm construction	15,600 LF	$23.15 per lf	$361,140[b]
Clay*	4492 CY	$16.10 per yd^3	$72,321[b]
40 mm PVC liner*	283,650 ft^2	$0.26 per ft^2	$141,825[b]
Soil	22,692 cy	$6.79 cy	$154,080[b]
Gravel	180 CY	$20.17 cy	$3,630[b]
Piping	1500 LF	$10.03 lf	$15,045[b]
Plants	1.86 Acres	$7500 per acre	$13,950.
Pilot study	1	$93,000 each	$93,000[b]
Contingency	LS	30% of Direct Cost	$260,042
Engineering support/report preparation	LS	$217,000	$217,000[d]
Annual Operation and Maintenance Cost			
Maintain vegetation	.93 acres	$7,500 per acre	$6,975
Maintain berms	1.86	$200 per acre	$372
Analytical	48 samples	$610 per sample	$29,280[b]
Labor	296 hrs	$35 per Hour	$10,360[c]
Engineering support/report preparation	Annual	15% O&M	$6,990

Notes:

[a] – Costs based on vendor proposed costs.
[b] – Costs from "Environmental Restoration: Assemblies Cost Book," ECHOS 1995.
[c] – Costs based on technician collecting samples two days per month and a daily two-hour inspection.
[d] – Cost estimated by Bechtel Environmental, Inc. This cost would be included in the Engineering support/report prep costs for surface capping if they were both carried out simultaneously.
lf – Linear feet
LS – Lump sum
yd^2 – Square yards
* These costs would not be incurred if wetlands were incorporated as part of the cap design.

3.0 DETAILED ANALYSIS OF ALTERNATIVES

In **this** section, the remedial alternatives selected in Section 2 are examined with respect to the requirements stipulated in CERCLA as amended, the NCP, Office of Solid Waste and Emergency Response (OSWER) Directive Number 9355.9-19 (***Superfund Selection of Remedy,*** Interim, December 24, 1986), and factors described in OSWER Directive Number 9355.3-01 ***(Conducting Remedial Investigations and Feasibility Studies Under CERCLA***, Interim Final, October 1988).

3.1 Evaluation Process

The detailed analysis of alternatives consists of analyzing and presenting relevant information needed to allow decision-makers to select a site remedy; it is not intended to replace the decision-making process. During the detailed analysis, each alternative is assessed against the evaluation criteria described in the OSWER Directive Number 9355.3-01 and all other alternatives. The results of the assessment are arrayed to compare the alternatives and identify the key tradeoffs among them. This approach to analyzing alternatives is designed to provide decision-makers with sufficient information to adequately compare the alternatives, select an appropriate remedy for a site, and demonstrate satisfaction of the CERCLA remedy selection requirements of the remedial action decision.

Nine evaluation criteria have been developed to address the CERCLA requirements and considerations, and to address the additional technical and policy considerations that have proven to be important for selecting among remedial alternatives. These evaluation criteria serve as the basis for conducting the detailed analyses during the FFS and for subsequently selecting an appropriate remedial action. The evaluation criteria are:

- Short-term effectiveness
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume

- Implementability
- cost
- Compliance with ARARs
- Overall protection of human health and the environment
- State acceptance
- Community acceptance

Each remedial alternative is evaluated with respect to the above criteria, as described in the following sections. At the completion of all detailed analyses, a section is included in which the statutory factors and criteria listed above are compared for each alternative to assist in selecting a remedy.

3.1.1 Short-Term Effectiveness

The short-term effectiveness of a remedial alternative is evaluated relative to its effect on human health and the environment during implementation of the remedial action. The short-term effectiveness assessment is based on four key factors:

- Risks that occur 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 implementing the remedial action.
- Time until remedial response objectives are achieved.

3.1.2 Long-Term Effectiveness and Permanence

The evaluation of alternatives under this criterion addresses the results of a remedial action in terms of the risk remaining onsite 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 magnitude of residual risk and the adequacy and reliability of controls should be addressed for each alternative.

Magnitude of Residual Risk

This factor assesses the residual risk remaining from untreated waste or treatment residuals at the conclusion of remedial activities. The potential for this risk may be measured by numerical standards such as cancer risk levels or the volume or concentration of contaminants in waste, media, or treatment residuals remaining onsite.

Adequacy and Reliability of Controls

This factor assesses the adequacy and suitability of any controls that are used to manage treatment residuals or untreated wastes that remain onsite. This may include an assessment of containment systems and institutional controls to determine if they are sufficient to ensure that any exposure to human and environmental receptors is within protective levels.

3.1.3 Reduction of Toxicity, Mobility, or Volume

This evaluation criterion addresses the statutory preference for remedial actions that employ treatment technologies that permanently and significantly reduce the toxicity, mobility, or volume of the hazardous substances.

The evaluation should consider the following specific factors:

- Treatment processes, the remedies they will employ, and the materials they will treat.
- Amount of hazardous materials that will be destroyed or treated, including how principal threat(s) will be addressed.
- Degree of expected reduction in toxicity, mobility, or volume, measured as a percentage of reduction (or order of magnitude) when possible.
- Degree to which the treatment will be irreversible.
- 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.

3.1.4 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. This criterion involves analyzing the factors discussed below.

Technical Feasibility

- **Construction and Operation:** This factor assesses the technical difficulties and unknowns associated with constructing and operating a technology.
- **Reliability of Technology:** The reliability of an alternative focuses on the likelihood that technical problems associated with implementation will lead to schedule delays.

- **Ease of Undertaking Remedial Action:** The ease of implementing the remedial action discusses future remedial actions that may need to be undertaken and the difficulty implementing these actions.

- **Monitoring Considerations:** This consideration addresses the ability to monitor the effectiveness of the remedy, including an evaluation of the exposure risks if monitoring is insufficient to detect a system failure.

Administrative Feasibility

Administrative feasibility involves activities needed to coordinate with other offices and agencies.

Availability of Services and Materials

- **Offsite Treatment:** Availability of adequate offsite treatment, storage capacity, and disposal services.

- **Equipment and Specialists:** Availability of necessary equipment and specialists, and provisions to ensure any necessary additional resources.

- **Services and Materials:** Availability **of** services and materials, plus the potential for obtaining competitive bids, which may be particularly important for innovative technologies.

- **Prospective Technologies:** Availability of prospective technologies.

3.1.5 Cost

A detailed cost estimate is developed for each remedial alternative based on engineering analyses, estimates by suppliers of necessary technology, and costs for similar actions (such as excavation) at similar sites. Costs are expressed in 1996 dollars. The cost estimate for a

remedial alternative consists of four principal elements: capital cost, O&M cost, costs for evaluation reports, and present worth analysis. Capital costs include direct and indirect costs.

Direct Cost

The costs of equipment, labor, and materials are used to develop, construct, and implement a remedial action.

Indirect Cost

Indirect costs include the costs of engineering, financial, and other services that are not actually part of construction but are required to implement a remedial alternative. The percentage applied to the direct cost varies with the degree of difficulty associated with construction and/or implementation of the alternative.

In this FFS, the indirect costs include:

- Health and safety (H&S) items
- Permitting and legal fees
- Bid and scope contingencies
- Engineering design and services

Annual Operation and Maintenance 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 water treatment facility), equipment replacement costs, and long-term monitoring costs.

Evaluation Reports Costs

This refers to the costs associated with reports prepared every five years to evaluate the results of monitoring activities.

Present Worth Analysis

Present worth analysis is applied to these following-year costs to allow comparison of remedial alternatives on the basis of a single cost representing an amount that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the remedial action over its planned life. A 30-year performance period is assumed for present worth analyses as applicable for the particular alternative. A discount rate of 5% is assumed for base calculations. An increase in the discount rate would be reflected as a decrease in the present worth of the alternative. The Superfund CASHOUT computer model was used to calculate the present value of cleanup costs, which are tabulated in Appendix D. The study estimate costs provided for the alternatives are intended to reflect actual costs with an accuracy of minus 30% to plus 50%, in accordance with USEPA guidelines.

3.1.6 Compliance with ARARs

This evaluation criterion is used to determine whether each alternative will meet all of its federal and state ARARs that have been identified in previous stages of the remedial process. The detailed analysis should identify which requirements are applicable or relevant and appropriate to an alternative. Chemical-, location-, and action-specific ARARs should be addressed for each alternative during the detailed analysis. 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). Appendix A lists ARARs.

3.1.7 Overall Protection of Human Health and the Environment

This evaluation criterion provides 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.

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

3.1.8 State Acceptance

This assessment evaluates the technical and administrative issues and concerns the state may have regarding each alternative. This criterion is largely satisfied through state involvement in the entire remedial process, including review of the FFS. The U.S. Navy, the lead agency at Site 1, will work with FDEP in implementing the chosen alternative.

3.1.9 Community Acceptance

This assessment evaluates the issues and concerns the public may have regarding each of the alternatives. As with state acceptance, this criterion will be addressed in the Record of Decision (ROD) when comments on the FFS have been received.

3.2 Evaluation of Selected Alternatives

The following sections present a detailed analysis of each alternative presented in Section 2.

3.2.1 No Action

The "no action" alternative for Site 1 involves no active remedial effort. No actions will be taken to contain, remove, or treat soil contaminated above risk- or leachability-based cleanup goals. Soil will remain in place and will attenuate according to natural biotic and abiotic processes.

Short-Term Effectiveness

Short-term effectiveness assesses the effects of an alternative on human health and the environment while implementing the remedial alternative. No implementation concerns are associated with the "no action" alternative. This alternative may be implemented immediately.

Long-Term Effectiveness and Permanence

Degradation of site contaminants is left to natural attenuation processes in this alternative, and the long-term effectiveness of the "no action" alternative is minimal. Current risk levels would attenuate slowly. The volume and concentrations of contaminated soil and groundwater will remain unchanged except for natural attenuation. The "no action" alternative does not reduce the magnitude of residual risk. This alternative lacks treatment actions that would provide permanence.

Any controls which are currently in place at the site — which include military security and limited access to the site — will remain. These controls are considered minimal for protecting human health given the current and projected land use onsite.

Reduction of Toxicity, Mobility, and Volume

The "no action" alternative does not reduce the mobility or volume of contaminants at Site 1. Toxicity is reduced slowly through natural attenuation. Contaminants will remain in place onsite; no treatment is effected during remedial actions. However, intrinsic remediation processes (either biotic or abiotic degradation) will continue. Intrinsic remediation is considered irreversible. Contaminated groundwater that is not being contained and remediated will continue to migrate.

Implementability

The "no action" alternative is technically feasible and easily implemented. No construction, operation, or reliability issues are associated with this alternative. Current site controls —

including military security and limited access to personnel — have historically been reliable access controls. No administrative coordination is required for implementation of the "no action" alternative. The "no action" alternative will not require offsite services, materials, specialists, or innovative technologies.

cost

No costs are associated with the "no action" alternative.

Compliance with ARARs

The "no action" alternative does not comply with the chemical-specific ARAR developed in the BRA. The "no action" alternative does not trigger any location- or action-specific ARARs. Contaminated groundwater that is not contained would continue to be above the ARARs. This alternative does not comply with FAC 62-736.500 which requires warning signs around site perimeter.

Overall Protection of Human Health and the Environment

The no "action" alternative does not afford any long-term effectiveness and permanence under a residential scenario beyond natural degradation of constituents. No short-term impacts are associated with this alternative. This alternative does not reduce the mobility or volume of contaminants at Site 1. This alternative does not comply with chemical-specific ARARs and TBC criteria as groundwater continues to migrate and could theoretically be consumed. Therefore, the "no action" alternative does not protect human health or the environment.

State Acceptance

FDEP has been involved with the USEPA in the entire remedial process. FDEP will have the opportunity to review and comment on this FFS.

Community Acceptance

Community acceptance for the "no action" alternative will be established after the public comment period for the FFS.

3.2.2 Natural Attenuation

Under this alternative, contaminated soil and water are left in place. The natural attenuation alternative includes initial fate and transport modeling to predict expected contaminant concentrations over time. Additional groundwater sampling may also be required in support of this modeling. A groundwater monitoring program is implemented to monitor the progress of natural attenuation and to ensure human health is protected. Institutional controls would be implemented with land use restrictions that limit land use to industrial/or recreational use, with groundwater use beneath and downgradient of the landfill restricted. A fence, with appropriate signage, would enclose the site to limit access.

Short-Term Effectiveness

No implementation concerns are associated with the natural attenuation alternative. This alternative may be executed as soon as land use restrictions and groundwater restrictions can be put in place.

Long-Term Effectiveness and Permanence

The natural attenuation alternative eliminates residual risk to future child residents by designating Site 1 as an industrial area and preventing it from being used for residential purposes. This alternative meets the effective criterion for protection of groundwater as contaminant concentrations are expected to decrease through natural biotic and abiotic attenuation processes, thus rendering the waste less threatening to groundwater and improving groundwater quality to meet remedial goals with time. The consumption of contaminated groundwater will be controlled institutionally and groundwater will be monitored until remedial goals are met.

Any controls which are currently in place onsite — including military security and limited access to the site — will remain. A perimeter fence with warning signs will be installed, further

limiting access. These controls are considered reliable for protecting human health given the current and projected land use onsite.

Reduction of Toxicity, Mobility, and Volume

The natural attenuation alternative does not reduce the mobility or volume through treatment, and does not satisfy the statutory preference for treatment as a principal element. Contaminants will remain in place onsite; no treatment is effected during remedial actions. However, intrinsic remediation processes (either biotic or abiotic degradation) will continue and toxicity is expected to reduce slowly with time. Intrinsic remediation is considered irreversible. Contaminated groundwater that is not being contained and remediated will be monitored and will reach remedial goals with time.

Implementability

The natural attenuation alternative is technically feasible and easily implemented. A fence would be built to limit site access and additional monitoring wells installed for groundwater monitoring. No other construction, operation, or maintenance issues are associated with this alternative. Current site controls — including military security and limited access to personnel — have historically been reliable access controls. No administrative coordination is required to implement the natural attenuation alternative. The natural attenuation alternative will not require offsite services, materials, specialists, or innovative technologies other than what is needed for the fence installation, monitoring well installation, and tar pit disposal.

Cost

Cost components for the natural attenuation alternative include the following:

- Fate and transport modeling
- Groundwater sampling
- Institutional controls
- Analysis and report compilation

Costs associated with natural attenuation are detailed in Section **2.** Direct capital costs for the alternative is approximately **$145,830.** The indirect costs for engineering servicesheport preparation is **$21,875.** Assuming a **30%**contingency, total direct and indirect capital costs are **$211,455.** Annual operating and maintenance costs for natural attenuation are **$140,710.** The total present value for Alternative 2, therefore, is **$3,040,617** (assuming a **5%** discount rate over **30** years. Additional costs will be incurred by excavating and disposing of contaminated soil in the tar pit area. Total direct costs for excavation and disposal are estimated to be **$1 1,630.** Indirect costs, including engineering services/report preparation and contingencies **(30**%) **,** are **$73,490.**

Compliance with ARARs

The natural attenuation alternative complies with the chemical-specific ARAR developed in the BRA. Groundwater is expected to reach remedial goals with time through natural processes; however, the time frame to reach these goals is expected to exceed **30** years.

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

Under an industrial scenario, the natural attenuation alternative addresses the long-term effectiveness and permanence criterion by preventing exposure to the contaminant source. If Site **1** remains industrial, no further actions will be required to protect human health. The contaminated soil will be left onsite indefinitely, attenuating through natural biotic or abiotic means (intrinsic remediation). No short-term impacts are associated with this alternative. This alternative is expected to comply with chemical-specific ARARs with time, but initially groundwater exceeding ARARs will be left onsite.

State Acceptance

FDEP has been involved with the **USEPA** in the entire remedial process. **FDEP** will have the opportunity to review and comment on this **FFS.**

Community Acceptance

Community acceptance for Alternative 2 will be established after the public comment period for the FFS.

3.2.3 Capping

The primary element in the capping alternative is containment — reducing risk to human health and the environment by eliminating the exposure pathway (dermal contact) and preventing contaminated leachate generation.

Short-Term Effectiveness

While constructing the cap(s), construction workers will be exposed to increased particulate emissions. However, worker risks can be minimized by implementing dust control technologies (e.g., water, foam sprays) and a site-specific H&S plan which specifies PPE, respiratory protection, etc. Adverse impacts to the surrounding environment are not anticipated during cap construction; engineering controls can be applied to manage storm water runoff and siltation, if necessary. A perimeter fence with warning signs will be installed onsite to limit access. Once design plans are approved, actual construction of the cap(s) is expected to take less than one year.

Long-Term Effectiveness and Permanence

The contaminated soil will be isolated, thus reducing and/or preventing leachate production due to infiltration. The caps would require proper observation and maintenance; caps are generally regarded as reliable containment control. Ongoing groundwater monitoring should effectively observe changes in groundwater concentrations. The lifetime of a cap is approximately 30 years. If wastes remains after cap deteriorates, the cap will need to be reconstructed or groundwater quality may be compromised.

Contaminated soil would remain in place onsite. If the cap fails in an area, the area would be exposed to infiltrating rainwater, and may contribute to leachate generation. Risks to human health and the environment onsite are expected to decrease with time, as constituents attenuate through natural biotic or abiotic degradation. However, the cap would limit water infiltration into the waste, which would slow the rate of natural degradation. Capped landfills can be expected to retain toxicity for more than 100 years.

Any controls which are currently in place onsite — including military security and limited access to the site — will remain. A perimeter fence with warning signs will be installed, further limiting access. These controls are considered reliable for protecting human health given the current and projected land use.

Reduction of Toxicity, Mobility, and Volume

Capping will eliminate human contact with soil and reduce leachate generation and infiltration into the groundwater. This alternative is a containment alternative. Intrinsic remediation processes (either biotic or abiotic degradation) will continue after the cap is installed, although at a slower rate. Aside from natural degradation action, this alternative is considered to be reversible, since the constituents will remain onsite; if a cap fails because of poor maintenance, constituents may be exposed. This alternative does not reduce toxicity or volume through treatment. Mobility is restricted by limiting leachate generation. This alternative does not satisfy the statutory preference for treatment as a principal element.

Implementability

The capping alternative is technically feasible and it can be readily applied at this site. Monitoring and maintenance actions will involve inspecting the cap periodically and repairing any damage or degradation. This alternative will not require any extraordinary services, materials, specialists, or innovative technologies. Installing the cap will involve clearing and grubbing the site, which will destroy a mature pine forest that is a significant habitat for many

animals. The capping alternative is administratively feasible and is part of the presumptive remedy for CERCLA municipal landfills.

cost

The cost breakdown associated with the complete capping alternative is detailed in Section 2. Direct capital costs associated with cap construction are $8,085,440; indirect costs for engineering services/report preparation and 30% for contingencies for the project are $2,642,631. Additional costs will be incurred by excavating and disposing of contaminated soil in the tar pit area, total cost $85,120. Annual maintenance costs are expected to be $140,400 per year. The total present value of Alternative 3 — complete cap, therefore, is $13,450,430 (assuming a ***5%*** discount rate over 30 years).

Compliance with **ARARs**

The capping alternative complies with the chemical-specific ARAR developed in the BRA and proposed as a PRG for protection of future child residents as no areas were identified above the $1x10^{-6}$ risk threshold.

This alternative also addresses the TBC criteria for protection of groundwater, as identified in the FDEP's ***Soil Cleanup Goals for Military Sites.*** The area is capped to reduce the quantity of leachate generated by infiltrating rainwater. The purpose of the caps is to isolate constituents exceeding residential risk and guidance concentrations in environmental media, not to manage solid or hazardous waste. Site grading activities must comply with federal, state, and local air emissions and storm water control regulations. Occupational Safety and Health Administration (OSHA) regulations will apply to any remedial activities on a site. This alternative does not trigger any location-specific ARARs.

Overall Protection of Human Health and the Environment

The capping alternative addresses the long-term effectiveness and permanence criterion by containing the contaminated soil, therefore controlling all exposure to the source. It minimizes further release of constituents to the groundwater by limiting infiltration. The contaminated soil will be left onsite indefinitely, attenuating through natural biotic or abiotic means (intrinsic remediation) although capping will slow this process; the caps will be monitored to ensure adequate protection. Short-term risks from dust and inhalation exposures during implementation will be minimal, and can be controlled using common engineering techniques and PPE. This alternative will comply with ARARs outlined above. The groundwater would remain the same, with the cap limiting further contamination to groundwater.

The capping alternative may adequately protect human heath and the environment while intrinsic remediation processes are under way. Cap construction and maintenance are easily implemented remedial actions, and institutional controls present onsite (site security and access control) are adequate to ensure minimal disturbance of onsite caps. A perimeter fence with warning signs will be installed at the site further limiting access.

State Acceptance

FDEP has been involved with the USEPA in the entire remedial process. FDEP will have the opportunity to review and comment on this FFS.

Community Acceptance

Community acceptance for the capping alternative will be established after the public comment period for the FFS.

3.2.4 Groundwater Extraction with Pumping and Treatment

Under this alternative contaminated groundwater is contained by well-base extraction to create hydraulic barriers. The extracted groundwater could be treated by air stripping or through constructed wetlands.

Short-Term Effectiveness

Constructed wetlands provide an onsite treatment that requires little maintenance or power after a landfill is closed. Adverse impacts to the surrounding environment are not anticipated during wetlands construction; engineering controls can be applied to manage storm water runoff and siltation, if necessary. Once design plans are approved and testing is complete, actual construction of the wetlands is expected to take less than 12 months, although start-up times can be as long as two years while plants mature.

Adverse impacts to the surrounding environment are not anticipated during air stripping construction. Air permitting needs to be completed before implementation. Actual construction associated with this alternative is expected to take less than 12 months.

Long-Term Effectiveness and Permanence

Ongoing groundwater monitoring should effectively observe changes in groundwater concentrations. Contaminated soil would remain in place onsite. Risks to human health and the environment onsite are expected to decrease with time, as constituents attenuate through natural biotic or abiotic degradation.

Constructed wetlands requires little maintenance or power after a landfill is closed. Treated water must be discharged to surface water or reinjected into the underlying aquifer. Plants provide a more rapid decrease in leachate volume through transpiration than is provide by lagoons without plants. Constructed wetlands have been applied in the past to landfill leachate

treatment and have successfully removed both inorganic and organic contaminants. **Risks** to human health and the environment onsite would diminish with time.

Potential exists for inorganic or biological fouling of the equipment with the air stripping tray aeration method. Air strippers must be taken out of service and packing materials acid-washed. Air stripping should effectively remove the volatile contaminants from the groundwater to concentrations below drinking water standards. Inorganic contaminants, however, would not be effectively removed by this technology; however, pretreatment should remove the most metals. **Risks** to human health and the environment onsite would diminish with time. Time to recover one volume of groundwater can be estimated as five years; however, due to retardation of contaminants in soil, the estimate for total cleanup of groundwater could exceed 30 years.

Any controls that are currently in place onsite — including military security and limited access to the site — will remain. A perimeter fence with warning signs will be installed, further limiting access. These controls are considered reliable for protecting human health given the current and projected land use.

Reduction of Toxicity, Mobility, and Volume

This alternative is a containment alternative. Constructed wetlands provide several characteristics that are beneficial for leachate treatment including, large vegetative bio-mass, large adsorptive surfaces on sediments and plant material, aerobic/anaerobic interfaces, and diverse, active microbial populations. The ability of vascular plants to absorb and concentrate heavy metals is well-documented. The process of collecting the leachate from the groundwater eliminates the contaminant migration. Aside from natural degradation action, this alternative is considered to be reversible, the inorganic contaminants will be entrained in wetland sediments and in wetlands bio mass. This alternative reduces toxicity, mobility, or volume through treatment, and satisfies the statutory preference for treatment as a principal element.

Air stripping is an established technology where volatile organics are partitioned from the groundwater by increasing the surface area of the contaminated water exposed to air. Tray aeration was chosen to be the type of method to implement at Site 1. The process of collecting the leachate from the groundwater eliminates contaminant migration. This technology transfers the organic contaminants from the groundwater to the air, where half-lives are much shorter. The inorganic contaminants would be separated in a sludge and disposed of offsite. This alternative reduces toxicity, mobility, or volume through treatment, and satisfies the statutory preference for treatment as a principle element.

Implementability

Extracting contaminated groundwater beneath the site is both technically and administratively feasible at Site 1. This alternative will not require any extraordinary services, materials, specialists, or innovative technologies. The groundwater extraction and treatment alternative is administratively feasible and is the presumptive remedy for CERCLA municipal landfills.

The constructed wetland alternative would require setting aside a large area of land to be converted to wetlands. Although this is an emerging technology, it is based on well-established processes and can be implemented, but it requires substantial testing and planning. This alternative could provide a valuable habitat for wetland animals. Wetlands have been successfully used to treat landfill leachate to remedial goals. Monitoring and maintenance actions will involve sampling and inspecting the wetlands periodically. This alternative will require some specialized services and specialists. This alternative is both technically and administratively feasible at Site 1.

The air stripping alternative would require calculating air emissions and completing all other requirements for air permitting. This alternative will not require any extraordinary services or materials. This alternative is both technically and administratively feasible at Site 1.

cost

Constructed wetlands provide an onsite treatment that requires little maintenance or power after a landfill is closed. Direct capital costs associated with constructed wetlands are **$866,810;** indirect costs for engineering services/report preparation and **30%** for contingencies for the project are **$477,042.** Annual maintenance costs are expected to be **$53,977** per year. The total present value of constructed wetlands is **$2,431,091** (assuming a **5%** discount rate over **30** years).

Direct capital costs associated with air stripping are **$149,520;** indirect costs for engineering services/report preparation and **30%** for contingencies for the project are **$261,856.** Annual maintenance costs are expected to be **$82,345** per year. The total present value of air stripping is **$2,018,023** (assuming a **5%** discount rate over **30** years).

Direct cost associated with groundwater extraction are **$412,570.** Indirect costs for engineer support/report preparation and **30%** contingencies for the project are **$340,770.** Annual maintenance costs are expected to be **$132,340** (including groundwater monitoring). The total present value of groundwater extraction is **$3,198,454** (assuming a **5%** discount rate over **30** years).

Compliance with **ARARs**

The groundwater extraction with treatment alternative complies with the chemical-specific ARAR developed in the BRA and proposed as a **PRG** for protection of future child residents as no areas were identified above the $1x10^{-6}$ risk threshold. The contaminated groundwater is captured by extraction wells. Site grading activities may require compliance with federal, state, and local air emissions and storm water control regulations. OSHA regulations will apply to **any** remedial activities onsite. This alternative does not trigger any location-specific ARARs.

Overall Protection of Human Health and the Environment

The groundwater extraction with treatment alternative addresses the long-term effectiveness and permanence criterion by containing the contaminated groundwater. The contaminated soil will be left onsite indefinitely, attenuating through natural biotic or abiotic means (intrinsic remediation) estimated at greater than 30 years. Short-term risks from dust and inhalation exposures during implementation will be minimal, and can be controlled using common engineering techniques and personal protective equipment. This alternative will comply with ARARs outlined above. This alternative protects human heath and the environment. Institutional controls present onsite (site security and access control) are adequate to ensure minimal site disturbance. A perimeter fence with warning signs will be installed, further limiting access.

State Acceptance

FDEP has been involved with the USEPA in the entire remedial process. FDEP will have the opportunity to review and comment on this FFS.

Community Acceptance

Community acceptance for Alternative 4 will be established after the public comment period for the FFS.

4.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section provides a comparative analysis of alternatives, examining potential advantages and disadvantages of each as per the nine criteria. All the alternatives evaluated in Chapter 4 are technically feasible, implementable, and have been developed and used at other sites. All alternatives except no action are generally protective of human health and the environment. All alternatives except no action and Alternative 2 share similar short-term risks. State and community acceptance will be determined in the same manner for each alternative. The key criteria that distinguish the alternatives focus on long-term effectiveness, reduction of mobility, cost, and compliance with ARARs.

4.1 Threshold Criteria

All alternatives considered for selection must comply with the threshold criteria, overall protection of human health and the environment, and compliance with ARARs.

4.1.1 Overall Protection of Human Health and the Environment

This criterion evaluates, overall, the degree of protectiveness afforded to human health and the environment. It assesses the overall adequacy of each alternative.

Protection of Human Health

As discussed in Section 1, risk and/or hazard associated with exposure to all environmental media did not exceed USEPA and FDEP risk and hazard thresholds for the trespassing child and the future site worker scenarios.

Alternative 1, no action, does not protect future child resident from risk. Exposure to shallow/intermediate groundwater presented an unacceptable risk and hazard via the ingestion and inhalation exposure pathways. There are no indications that the Site 1 area will be used for residential purposes. Although Site 1 groundwater is not currently being used as a potable water source or for any industrial uses, Alternative 1 does not protect future users of the groundwater.

The other alternatives protect future residents either through institutional controls or through containment of groundwater.

Protection of the Environment

The BRA concluded that the ecological risks at Site 1 were inconsequential for flora and fauna from contaminated soil. Based on a review of the variables that may affect availability of chemicals, and a critical assessment of the concentrations observed during the 1994 sampling activity, no appreciable ecological effects are expected from groundwater discharge to wetlands near Site 1. Alternatives 1 through 4 protect the environment to varying degrees. The clearing, grubbing, and excavation proposed in Alternative 3 will destroy a mature pine forest which is a significant habitat for many animals.

The "no action" alternative does not address soil in excess of FDEP leachability-based guidance concentrations. As discussed in Section 1, these constituents are present in groundwater. It is unclear from current site data whether current volumes of soil contaminated with leachable compounds will significantly impact the aquifer more than the current scenario. The "no action" alternative does not address the uncontained contaminated groundwater. Alternative 2, natural attenuation, seeks to quantify threats to the environment from the Site 1 area. If risks are deemed unacceptable, this alternative relies on Alternatives 3 and 4 as contingency remedies. Natural attenuation requires groundwater monitoring.

Alternatives 3 and 4 afford long-term protection of the environment by significantly reducing the quantity of rainfall infiltrating through contaminated soil or by containing the contaminated groundwater.

4.1.2 Compliance with ARARs

Alternative 1 does not comply with ARARs. Alternatives 2, 3, and 4 incur land disposal restrictions for tar pit disposal. Alternatives 4 meets statutory preference for treatment.

Alternatives 3 and 4 comply with state and federal MCLs. Compliance with action- and location-specific ARARs for Alternatives 3 and 4 is anticipated and easily attainable.

If State of Florida leachability goals are considered applicable to the site, Alternatives 3 and 4 will comply with chemical-specific TBCs. Alternative 2 seeks to quantify threats of groundwater. Alternative 3 reduces leachate generation at Site 1. Alternative 4 contains and treats contaminated groundwater.

Per the NCP, onsite remedial actions selected in the ROD must attain those ARARs that are identified at the time of the ROD signature or provide grounds for invoking a waiver under 300.430(f)(1)(ii)(C) (or CERCLA 121[d][4]).

4.2 Primary Balancing Criteria

Five primary balancing criteria typically highlight the major differences between alternatives. These criteria include: long-term effectiveness and permanence; reduction of toxicity, mobility, and volume through treatment; short-term effectiveness; implementability; and cost.

4.2.1 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence criterion assesses the results of a remedial action in terms of the risk remaining onsite, particularly in terms of the magnitude of remedial risk and the adequacy and reliability of controls.

Magnitude of Residual Risk

As stated in the BRA, no risk is posed to current and future site workers at Site 1. Alternative 1 has no long-term effectiveness, as no remedial actions are taken onsite. Alternative 2 long term effectiveness is based on natural processes and can only be estimated as more effective than Alternative 1 but less than Alternative 3 or Alternative 4. Alternative 3 isolates soil contaminants from rain and percolation, minimizing transport and contact with contaminated soil.

However, the average life for a cap is 20 to 30 years, depending upon the construction materials used. Groundwater containment in Alternative 3 is uncertain. Alternative 4 alleviates groundwater risks through a long-term recovery well system which captures/contains contaminants to treat, but contaminated media remains onsite.

Adequacy and Reliability of Controls

Controls inherent to Site 1 include fencing, limited access, security provided by military personnel, and base management plan institutional controls. If Site 1 remains a part of the NAS Pensacola installation, these controls will be adequate for minimizing trespasser risks in Alternative 2, and no further actions are required to protect human health under an industrial scenario. There are currently no plans to convert Site 1 into a residential area.

Alternative 3 provides slightly more reliable controls than the "no action" and natural attenuation alternatives if Site 1 becomes residential. The completed cap will minimize the threat to future child residents and help reduce leachate generation. However, the cap will require annual maintenance to ensure that contact risks are reduced and infiltration is minimized.

Alternative 4 provides more reliable controls than Alternatives 1, 2, and 3. The extraction and treatment of the contaminated groundwater will minimize the threat to future child residents and help reduce leachate generation, while the risk to contact with surface soil is within acceptable range.

4.2.2 Reduction of Toxicity, Mobility, and Volume through Treatment

Alternative 4 reduces mobility and volume of contaminants through treatment. Alternatives 2 through 4 restrict future land use on Site 1. Alternatives 3 reduces the mobility of constituents through containment.

Short-Term Effectiveness

No short-term effectiveness issues are associated with Alternatives 1 or 2, except for the ability to implement land and groundwater use restrictions. Alternatives 3 and 4 have short-term issues associated with implementation. In these alternatives, exposures to workers and the Site 1 environs can be controlled using engineering controls and correct personal protective equipment during grading, excavation or well installation. Duration of field activities for these alternatives is relatively short.

4.2.3 Implementability

All four alternatives are implementable at Site 1. Each alternative is technically and administratively feasible. Constructed wetlands would require a large area of land to be set aside and requires substantial testing and planning but this alternative will not require any extraordinary services or materials. Air permitting will need to be completed before implementation could take place for the air stripping treatment.

4.2.4 Cost

Capital (direct and indirect), O&M, and net present worth costs for all four alternatives are presented below.

No costs are associated with Alternative 1. Costs for Alternatives 4a and 4b are very similar, $5,216,477 to $5,629,545 million. Alternative 3 has the highest costs, $13,458,430 million. Alternative 2 has the lowest cost, $3,040,617 million.

4.3 Modifying Criteria

These criteria will be evaluated in detail following comment on the FFS report and the proposed plan, and will be addressed once a final decision is being made and the ROD is being proposed.

5.0 REFERENCES

Bagchi, Amalendu. **(1994).** ***Design, Construction and Monitoring*** *of* ***Landfills***, John Wiley & Sons Inc. New York, New York.

Carbonair Environmental Systems, Inc. ***Carbonair Stat Modeling Program (Version 2.4)***, Maple Grove, MN **1993.**

Comprehensive Environmental Response, Compensation, and Liability Act of **1990** (CERCLA). Public Law Number **99-499,** October **17, 1986.**

ECHOS, ***Environmental Restoration: Unit Cost Book*** ECHOS, Los Angeles, CA **1995.**

ECHOS. ***Environmental Restoration: Assemblies Cost Book*** ECHOS. Los Angeles, CA **1995.**

Ecology & Environment, Inc. **(1991).** ***Contamination Assessment/Remedial Activities Investigation, Sanitary Landfill (Site I)***, Naval Air Station Pensacola, Pensacola, Florida, Interim Data Report, Ecology & Environment, Inc.: Pensacola, Florida.

EnSafe/Allen & Hoshall. **(1996).** ***Final Remedial Investigation Report for Site I, Naval Air Station Pensacola, Pensacola Florida***. EnSafe/Allen & Hoshall: Memphis, Tennessee, January **5, 1996.**

Fetter, C.W. **(1988).** ***Applied Hydrogeology***. Merrill Publishing Company: Columbus, Ohio.

Florida Department of Environmental Protection. **(1988).** ***Water Quality Standards, Classification of Groundwater, Usage, Reclassijication,*** Chapter **62-3.803,** Florida Administrative Code.

Florida Department of Environmental Protection. **(1992).** *Surface Water Quality Standards,* Chapter **17-302,** Florida Administrative Code.

Florida Department of Environmental Protection. **(1993).** *Memorandum-Soil Cleanup Goals for Florida.* FDEP division of Waste Management. September **29, 1995.**

Florida Department of Environmental Protection. **(1994).** *Ground Water Guidance Concentrations.* Bureau of Drinking Water and Ground Water Resources, June **1994.**

Florida Department of Environmental Protection. **(1994).** *Memorandum: Soil Cleanup Goals for Military Sites.* Bureau of Waste Cleanup, April 5, **1995.**

Geraghty & Miller, Inc. **(1984).** *Verification Study, Assessment of Potential Ground Water Pollution at Naval Air Station, Pensacola, Florida.* Geraghty & Miller, Inc.: Tampa, Florida.

Geraghty & Miller, Inc. **(1986).** *Characterization Study, Assessment of Potential Ground Water Pollution at Naval Air Station, Pensacola, Florida.* Geraghty & Miller, Inc.: Tampa, Florida.

Guigver, N.J. and Franz, T. *Visual Modflow Version 1.49,* Waterloo Hydrogeologic Software, Inc. **1995.**

Industrial Economics, Inc. *Superfund Cashout Model Version 1.4,* Cambridge, Massachusetts, September **1992.**

McBean, E.A. and Rovers, F.A., Farquhar G.J. (1995). *Solid Waste Landfill Engineering and Design.* Prentice-Hall, Inc. Englewood Cliffs, New Jersey 1995.

Naval Energy and Environmental Support Activity. (1983). *Initial Assessment Study of Naval Air Station Pensacola, Pensacola, Florida,* NEESA 13-015, Naval Energy and Environmental Support Activity: Port Hueneme, California.

Reinhart, Debra R. and Al-Yousfi, A.B. (accepted Fall 1995). *The Impact of Leachate Recirculation on Municipal Solid Waste Landfill Operating Characteristics.* Waste Management and Research.

Superfund Amendment Reauthorization Act of 1986 (SARA). Public Law Number 99-499.

U.S. Environmental Protection Agency. (1986). *Interim Guidance on Superfund Selection of Remedy.* OSWER Directive 9355.9-19.

U.S. Environmental Protection Agency. (1987). *Remedial Action Costing Procedures Manual.* EPA/600/8-87/049, October 1987.

U.S. Environmental Protection Agency. (1988). *CERCLA Compliance with Other Laws Manual; Draft Guidance.* OSWER Directive 9234.1-01. EPA/540/6-89/006, August 1988.

U.S. Environmental Protection Agency. (1988). *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA; Interim Final.* OSWER Directive 9355.3-01. EPA/540/G-89/004, October 1988.

U.S. Environmental Protection Agency. (1990). ***National Oil and Hazardous Substances Pollution Contingency Plan; Final Rule.*** EPA/540/1-89/002. December 1989. Federal Register V55:46 pg. 8666-8865, March 8, 1990.

U.S. Environmental Protection Agency. (1990). ***Superfund Record of Decision: Munisport Landfill, Florida.*** EPA/ROD/R04-90/062 July 1990

U.S. Environmental Protection Agency. (1991). ***Conducting Remedial Investigations/Feasibility Studies for CERCLA Municipal Landfill Sites.*** OSWER Directive 9355.3-11. EPA/540/P-91/001, February 1991

U.S. Environmental Protection Agency. (1992). ***Landfill Containment and Cover Systems.*** USEPA/RREL/WMDDRD/MSWRMB. EPA/600/A-92/200 1992.

Weis, Samuel. (1974). ***Sanitary Landfill Technology.*** Noyes Data Corporation Park Ridge, New Jersey.

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6.0 FLORIDA PROFESSIONAL GEOLOGIST SEAL

I have read and approve of this Final Focused Feasibility Study Report, NAS Pensacola Site 1, and seal it in accordance with Chapter 492 of the Florida Statutes. In sealing this document, I certify the geological information contained in it is true to the best of my knowledge and the geological methods and procedures included herein are consistent with currently accepted geological practices.

Name:	Brian E. Caldwell
License Number:	#1330
State:	Florida
Expiration Date:	July 31, 1998

B. Caldwell

Brian E. Caldwell

11/8/96

November 8, 1996

7.0 FLORIDA PROFESSIONAL ENGINEER'S SEAL

I am registered to practice engineering by the Florida State Board of Professional Examiners (License number 41460). I certify, under penalty of law, that the Final Focused Feasibility Study for Naval Air Station Pensacola Site 1 (Operable Unit 1) was performed in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. To the best of my knowledge and belief, the information submitted is true, accurate, and complete, and the contents of this document are consistent with currently accepted engineering practices. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

November 8, 1996

Appendix A

Applicable or Relevant and Appropriate Requirements

Table A-1
Summary of Potential Chemical-Specific ARARs
NAS Pensacola Site 1

Requirements	Status	Requirement Synopsis	Application to the RI/FS
		Federal Requirements	
RCRA Maximum Concentration Limits 40 CFR 264 Subpart F	Applicable	Maximum Concentration Levels have been established for 14 toxic compounds under RCRA groundwater protection standards. A compliance monitoring program is included for RCRA facilities.	Applicable to Site 1 with current groundwater monitoring program; also applicable where identified hazardous wastes are treated, stored, or disposed onsite.
Safe Drinking Water Act MCLs 40 CFR 141.11 - 141.16	Applicable	MCLs have been set for toxic compounds as enforceable standards for public drinking water systems. SMCLs are unenforceable goals regulating the aesthetic quality of drinking water.	The Sand- and Gravel-Aquifer is a potential source of drinking water. Some contaminants in the plume below Site 1 are above MCLs and SMCLs.
Safe Drinking Water Act MCLGs 40 CFR 141.50-141.51	Relevant and Appropriate	MCLGs are unenforceable goals under the SDWA.	The Sand- and Gravel-Aquifer is a potential source of drinking water. Some contaminants is plume below Site 1 are above MCLGs.
Clean Water Act Federal Water Quality Criteria 51 Federal Register 43665	Relevant and Appropriate	Effluent limitations must meet BAT. Water Quality Criteria for ambient water quality are provided for toxic chemicals.	Discharges to Pensacola Bay or Bayou Grande associated with groundwater remediation or other activities would have AWQCs as potential goal.
Clean Air Act National Emission Standards for Hazardous Air Pollutants 40 CFR 61	Not Applicable	Establishes emissions standards, monitoring and testing requirements, and reporting requirements for 8 pollutants in air emission.	No NESHAPs have been identified for Site 1.
Clean Air Act National Ambient Air Qualitv Standards 40 CFR Part 50	Applicable	Establishes emissions standards to protect public health and welfare. These standards are national limitations on ambient air intended to protect health and welfare.	Escambia County is an attainment area for ozone for which VOCs are a precursor.

Table A-1
Summary of Potential Chemical-Specific ARARs
NAS Pensacola Site 1

Requirements	Status	Requirement Synopsis	Application to the RI/FS
		State Requirements	
Florida Air Pollution Rules Title 62 Chapter 62-2	Applicable	Establishes emission standards, emission rates, baseline areas, and source classifications for protection of health and welfare. Identifies new source requirements, test, and analysis methods.	Remedial actions may include technologies that have air emissions.
Florida Rules on Permits Title 62 Chapter 62-4	Applicable	Establishes requirements and procedures for all permitting required by FDEP, and identifies antidegradation requirements.	Requirements may be applicable to site depending upon remedial action and discharge options selected.
Florida Ambient Air Quality Standard Title 62 Chapter 62-2	Applicable	Establishes ambient air quality standards and ambient test methods.	Remedial actions may include technologies that have air emissions.
Florida Water Quality Standards Title 62 Chapter 62-3	Applicable	Establishes minimum water quality criteria for groundwater.	Remedial objectives require remediation of Sand- and Gravel-Aquifer.
Florida Surface Water Standards Title 62 Chapter 62-301 and 62-302	Applicable	Establishes water quality standards for all waters of the state.	Remedial objectives require protection of surficial water. Remedial actions may impact surficial water bodies.
Florida Drinking Water Standards Title 62 Chapter 62-550	Applicable	Establishes MCLs for drinking water. Establishes secondary requirements for drinking water.	Remedial objectives require restoration of Sand- and Gravel-Aquifer to drinking water standards.
Florida Guidance Document on Petroleum Contaminated Soils	To Be Considered	Establishes cleanup concentrations for soil contaminated bv petroleum spills/leaks.	Guidance provides cleanup concentrations for Florida soil.

Table A-2
Summary of Potential Location Specific ARARs
NAS Pensacola Operable Unit 10

Requirements	Status	Requirement Synopsis	Application to the RI/FS
		Federal Requirements	
RCRA Location Requirements 40 CFR 264.18©	Relevant and Appropriate	Sets forth minimum requirements for design, construction, and operation of a facility where treatment, storage, or disposal of hazardous waste will be within a 100-year floodplain.	Treatment, disposal, and storage of hazardous materials may take place during remediation of the site. Some wastes are within the 100-year floodplain.
National Historic Preservation Act of 1966 16 U.S.C. 470 et seq. 36 CFR Part BOO	Not ARAR	Requires that the action not affect or cause harm to registered historic places or historic landmarks.	No registered historic places or historic landmarks are onsite or nearby.
Endangered Species Act 16 U.S.C. 1531 et seq. 50 CFR Part 402	Applicable	Action must avoid jeopardizing the continued existence of listed endangered or threatened species or modification of their habitat.	Endangered species are present on Site 1.
Fish and Wildlife Coordination Act 16 U.S.C. 661 et seq.	Applicable	Requires actions to protect fish and wildlife from actions modifying streams or areas affecting streams.	Onsite remediation activities may include modifications to Bayou Grande adjacent to the site.
Clean Water Act Section 404 Pertaining to Wetlands 33 U.S.C. 1251 et seq.	Not Applicable	Prohibits discharge of dredged or fill materiel into navigable waters without a permit.	Remedial activities will not include discharge of dredge or fill material to Bayou Grande.
Executive Order 11990 Wetlands Protection Policy	Applicable	Sets forth policy for the protection of wetlands.	There are several wetlands on Site 1 that fit the definition under the Executive Order.
Executive Order 11988 Floodplain Management Policy	To Be Considered	Sets forth policy for the protection of floodplains.	The part of the site is located in a 100-year floodplain; however, Executive Order sets forth policy and is not enforceable.
Clean Air Act National Ambient Air Quality Standards 40 CFR Part 50	Applicable	Establishes emissions standards to protect public health and public welfare. These standards are national limitations on ambient air intended to protect health and welfare.	Escambia County is an attainment area for ozone for which VOCs are a precursor.

Table A-2
Summary of Potential Location Specific ARARs
NAS Pensacola Operable Unit 10

Requirements	Status	Requirement Synopsis	Application to the RI/FS
		State Requirements	
Florida Air Pollution Rules Title 62 Chapter 62-2	Applicable	Establishes emission standards, emission rates, baseline areas, and source classifications for protection of health and welfare. Identifies new source requirements, test and analysis methods.	Remedial actions may include technologies that have air emissions.
Florida Rules on Permits Title 62 Chapter 62-4	Applicable	Establishes requirements and procedures for all permitting required by the FDEP, and defines antidegradation requirements.	Requirements may be applicable to site depending upon remedial actions and discharge options selected.
Florida Ambient Air Quality Standards Title 62 Chapter 62-2	Applicable	Establishes ambient air quality standards and ambient test methods.	Remedial actions may include technologies that have air emissions.
Florida Industrial Wastewater Facilities Regulations Title 62 Chapter 62-660	Applicable	Establishes effluent limitations and minimum treatment requirements for industrial facilities; establishes water quality criteria.	Remedial actions may require treated effluent to be discharged as per state and federal regulations.
Florida Underground Injection Control Regulations Title 52 Chapter 62-28	Applicable	Establishes construction standards, permitting procedures, and operating requirements for underground injection wells.	Remedial actions may include underground injection as a disposal option for treated effluent.
Florida Water Quality Standards Title 62 Chapter 62-3	Applicable	Establishes minimum water quality criteria for groundwater.	Remedial objectives require remediation of Sand- and Gravel-Aquifer.
Florida Surface Water Standards Title 62 Chapter 62-301 and 62-302	Applicable	Establishes water quality standards for all waters of the state.	Remedial objectives require protection of surficial water. Remedial actions may impact surficial water bodies.
Florida Beach and Shore Preservation Act Chapter 161	Applicable	Establishes guidelines for work that may impact upon beaches and shorelines of the state.	Remediation actions may impact beaches or shorelines.

Table A-3
Summary of Potential Action Specific ARARs
NAS Pensacola Operable Unit 10

Requirements	Status	Requirement Synopsis	Application to the RI/FS
		Federal Requirements	
RCRA Identification of Hazardous Waste 40 CFR 261	Applicable	Criteria for identifying those solid wastes subject to regulation as hazardous waste under RCRA.	Suspected hazardous wastes at Site 1 should be identified as RCRA hazardous waste or non-hazardous waste prior to remedial activities.
RCRA Identification of Hazardous Waste 40 CFR 261.33(d)	Applicable	Defines a material as hazardous waste if it is a residue or contaminated soil, water, or other debris resulting from the cleanup of a spill into or on any land or water of any commercial chemical product or manufacturing chemical intermediate having the generic name listed in the section.	Soil and groundwater contamination at Site 1 are a result of contact with waste containing wastes. Spent solvents may also have been present in industrial waste.
RCRA Facility Standards	Applicable	Establishes minimum standards for the acceptable management of RCRA hazardous wastes. Includes preparedness and prevention measures, general facility standards, and contingency and emergency procedures.	Treatment, storage, andlor disposal of RCRA hazardous wastes may occur at Site 1 during remediation.
RCRA Manifest System, Record-keeping, and Reporting 40 CFR 264 Subpart E	Applicable	Establishes the rules and record-keeping requirements for offsite transportation of RCRA hazardous materials for treatment andlor disposal.	Offsite transportation of RCRA hazardous wastes for treatment andlor disposal may be included in the site remediation.
RCRA Groundwater Monitoring Requirements 40 CFR 264 Subpart F	Applicable	Establishes minimum requirements for groundwater monitoring and protection standards for RCRA facilities.	Onsite treatment, storage, andlor disposal of RCRA wastes may be included in the remediation of Site 1.
RCRA Closure and Postclosure Requirements 40 CFR 264 Subpart G	Applicable	Establishes minimum requirements for closure and postclosure care of a RCRA facility engaging in treatment, storage, andlor disposal of hazardous wastes. Closure requirements include in-place wastes and remediated areas.	At the conclusion of a remedial action involving the treatment, storage, disposal, removal of hazardous wastes, closure procedures and postclosure care would be required.
RCRA Storage Requirements 40 CFA 264 Subparts I, J, and L	Applicable	Established minimum requirements for of hazardous wastes storage.	RCRA hazardous waste may be stored onsite prior to offsite disposal or onsite treatment.
RCRA Landfill Requirements 40 CFR 264 Subpart M	Applicable	Establishes minimum requirements for the design and construction, operation and maintenance, monitoring and inspection, closure and post-closure care for a hazardous waste landfill.	Remedial actions may include RCRA hazardous waste to be landfilled onsite.

Table A-3
Summary of Potential Action Specific ARARs
NAS Pensacola Operable Unit 10

Requirements	Status	Requirement Synopsis	Application to the RI/FS
		Federal Requirements	
RCRA Treatment Requirements 40 CFR 264 Subparts O and X	Applicable	Establishes minimum requirements for the permit approval, operation, and standards for incineration and other treatment for hazardous wastes.	Remediation may include incineration and/or treatment of hazardous wastes.
RCRA Land Disposal Restrictions 40 CFR 268	Applicable	Certain classes of waste are restricted from land disposal without acceptable treatment.	Removal of soil from Site 1 for land disposal may trigger the regulation after its effective date for CERCLA wastes on 5/8/93.
Clean Air Act National Ambient Air Quality Standards 40 CFR Part 50	Applicable	Establishes emissions standards to protect public health and public welfare. These standards are national limitations on ambient air intended to protect health and welfare.	Escambia County is an attainment area for ozone for which VOCs are a precursor.
Clean Water Act Discharge Limitations NPDES Permit 40 CFR 122, 125, 129, 136 Pretreatment Standards 40 CFR 403.5	Applicable	Prohibits unpermitted discharge of any pollutant or combination of pollutants to waters of the U.S. from any point source. Standards and limitations are established for these discharges and discharges to publicly owned treatment works.	Remedial actions may include the discharge of treated groundwater, runoff, or other flows to a surface water or publicly owned treatment facility.
Clean Water Act Wetlands Regulations Part 404 40 CFR 230	Relevant and Appropriate	Controls the discharge of dredged or fill materials into waters of the U.S. such that the physical and biological integrity is maintained.	Remedial actions may occur along Bayou Grande.
Executive Order 11990 Wetlands Protection Policy	To Be Considered	Establishes guidelines for identification and protection of wetlands.	Several wetlands are present on Site 1.
Executive Order 11988 Floodplain Management Policy	To Be Considered	Establishes guidelines for activities conducted within a 100-year floodplain.	Site 1 is located within a 100-year floodplain.
Safe Drinking Water Act Underground Injection Control Program 40 CFR 144	Applicable	Regulates the use of five classes of underground injection wells for the purpose of disposal of hazardous substances.	Would be relevant and appropriate if injection well technology is used as a part of site remediation.
Department of Transportation Rules for the Transport of Hazardous Substances 49 CFR Parts 107 and 171-179	Applicable	Regulates the labelling, packaging, placarding, and transportation of solid and hazardous wastes offsite.	Remedial actions may include the offsite transport and disposal of solid and hazardous wastes.

Table A-3
Summary of Potential Action Specific ARARs
NAS Pensacola Operable Unit 10

Requirements	Status	Requirement Synopsis	Application to the RI/FS
		Federal Requirements	
Occupational Safety and Health Standards 29 CFR 1910.120 for Hazardous Waste Operations and Emergency Responses, Part 1926 for General Safety and Health Standards, and Reporting Requirements	Applicable	Sets limits on exposure to workers on hazardous site or emergency responses, sets forth minimum health and safety requirements such as personal protection and training, and reporting requirements.	All activities taking place at Site 1 including remediation, construction, and monitoring are subject to OSHA health and safety regulations.
		State Reauirements	
Florida Air Pollution Rules Title 62 Chapter 62-2	Applicable	Establishes emission standards. emission rates, baseline areas, and source classifications for protection of health and welfare. Identifies new source requirements, test and analysis methods.	Remedial actions may include technologies that have air emissions.
Florida Rules on Permits Title 62 Chapter 62-4	Applicable	Establishes requirements and procedures for all permitting required by the FDEP, and defines antidegradation requirements.	Requirements may be applicable to site depending upon remedial actions and discharge options selected.
Florida Ambient Air Quality Standards Title 62 Chapter 62-2	Applicable	Establishes ambient air quality standards and ambient test methods.	Remedial actions may include technologies which have air emissions.
Florida Stormwater Discharge Regulations Title 62 Chapter 62-25	Applicable	Establishes design and performance standards and permit requirements for stormwater discharge facilities.	Remedial actions may impact stormwater discharge patterns at Site 1.
Florida Underground Injection Control Regulations Title 62 Chapter 62-28	Applicable	Establishes construction standards, permitting procedures, and Operating requirements for underground injection wells.	Remedial actions may include underground injection as a disposal option for treated effluent.
Florida Water Quality Standards Title 62 Chapter 62-3	Applicable	Establishes minimum water quality criteria for groundwater.	Remedial objectives require remediation of the Sand and Gravel Aquifer.
Florida Surface Water Standards Title 62 Chapter 62-301 and 62-302	Applicable	Establishes water quality standards for all waters of the state.	Remedial objectives require protection of surficial water. Remedial actions may impact surficial water bodies.
Florida Drinking Water Standards Title 62 Chapter 62-550	Applicable	Establishes MCLs for drinking water. Establishes secondary requirements.	Remedial objectives require restoration of surficial aquifer to drinking water status.

Table A-3
Summary of Potential Action Specific ARARs
NAS Pensacola Operable Unit 10

Requirements	Status	Requirement Synopsis	Application to the RI/FS
		State Requirements	
Florida Resource Recovery and Management Regulations Title 62 Chapter 62-7	Applicable	Establishes guidelines for resource recovery programs as well as hazardous waste site disposal and monitoring criteria.	If hazardous wastes or other wastes are disposed of onsite, these regulations would become applicable.
Florida Hazardous Waste Rules Title 62 Chapter 62-730	Applicable	Establishes standards for generators and transporters of hazardous wastes, and owners and operators of hazardous waste facilities. Outlines permitting requirements.	Applicable if remedial actions generate and/or transport hazardous wastes.
Florida Hazardous Substance Release Notification Rules Title 62 Chapter 62-150	Applicable	Establishes notification requirements in the event of a hazardous substance release.	May be applicable if a hazardous substance is released in conjunction with remedial activities.
Florida Rules on Hazardous Waste Warning Signs	Applicable	Establishes standard warning messages and specifications for signs used at hazardous waste sites.	Remediation systems may require signage for public notification.
Florida Beach and Shore Preservation Act Chapter 161	Applicable	Establishes guidelines for work which may impact upon beaches or shorelines of the state.	Remediation actions may impact beaches or shorelines on Magazine Point.
Well Permits	To Be Considered	Establishes local criteria for design and installation of monitoring wells.	Installation of monitoring wells will be a necessary part of site remediation given any alternative.
Florida Solid Waste Management Facilities Rules Title 62 Chapter 62-701	To Be Considered	Establishes standards for the construction, ooeration. and closure of solid waste management facilities of the state.	Remediation may leave waste landfilled onsite.

Appendix B

Help Computer Model Output

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**                                                                          **
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.01    (14 OCTOBER 1994)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**                FOR USEPA RISK REDUCTION ENGINEERING LABORATORY           **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:      F:\MIKE\HELP3\NASPRAIN.D4
TEMPERATURE DATA FILE:        F:\MIKE\HELP3\NASPTEMP.D7
SOLAR RADIATION DATA FILE:    F:\MIKE\HELP3\NASPRAD.D13
EVAPOTRANSPIRATION DATA:      F:\MIKE\HELP3\NASPEVAP.D11
SOIL AND DESIGN DATA FILE:    F:\MIKE\HELP3\REVEXIST.D10
OUTPUT DATA FILE:             F:\MIKE\HELP3\EXISTING.OUT


TIME:  14:57     DATE:   2/20/1996


..............................................................................

     TITLE:  Pensacola Site1

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   1
          THICKNESS                    =     24.00    INCHES
          POROSITY                     =      0.4170  VOL/VOL
          FIELD CAPACITY               =      0.0450  VOL/VOL
          WILTING POINT                =      0.0180  VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.0803  VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  5.00
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

THICKNESS	=	96.00	INCHES
POROSITY	=	0.6710	VOL/VOL
FIELD CAPACITY	=	0.2920	VOL/VOL
WILTING POINT	=	0.0770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3099	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 1 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 5.% AND A SLOPE LENGTH OF 500. FEET.

SCS RUNOFF CURVE NUMBER	=	39.30	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	85.200	ACRES
EVAPORATIVE ZONE DEPTH	=	28.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.917	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12.692	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.740	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	31.680	INCHES
TOTAL INITIAL WATER	=	31.680	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM MOBILE ALABAMA

MAXIMUM LEAF AREA INDEX	=	4.50	
START OF GROWING SEASON (JULIAN DATE)	=	39	
END OF GROWING SEASON (JULIAN DATE)	=	351	
AVERAGE ANNUAL WIND SPEED	=	9.00	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	70.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR MOBILE ALABAMA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.59	4.91	6.48	5.35	5.46	5.07
7.74	6.75	6.56	2.62	3.67	5.44

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR MOBILE ALABAMA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
50.80	53.60	60.10	68.00	74.90	80.50
82.20	81.80	78.20	68.50	58.60	53.10

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR MOBILE ALABAMA

STATION LATITUDE = 30.41 DEGREES

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ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	57.07	17650380.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	38.155	11800566.000	66.86
PERC./LEAKAGE THROUGH LAYER 2	18.915947	5850248.000	33.15
CHANGE IN WATER STORAGE	-0.001	-437.114	0.00
SOIL WATER AT START OF YEAR	31.680	9797840.000	
SOIL WATER AT END OF YEAR	31.679	9797403.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	1.770	0.00

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ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	73.98	22880238.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	39.611	12250805.000	53.54
PERC./LEAKAGE THROUGH LAYER 2	33.074093	10229023.000	44.71
CHANGE IN WATER STORAGE	1.295	400408.594	1.75
SOIL WATER AT START OF YEAR	31.679	9797403.000	
SOIL WATER AT END OF YEAR	32.973	10197811.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	1.180	0.00

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ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	70.88	21921478.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	43.092	13327424.000	60.80
PERC./LEAKAGE THROUGH LAYER 2	30.745739	9508919.000	43.38
CHANGE IN WATER STORAGE	-2.958	-914864.375	-4.17
SOIL WATER AT START OF YEAR	32.973	10197811.000	
SOIL WATER AT END OF YEAR	30.015	9282947.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.000	0.00

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ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
PRECIPITATION	61.54	19032844.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	40.857	12636236.000	66.39
PERC./LEAKAGE THROUGH LAYER 2	21.552010	6665519.000	35.02
CHANGE IN WATER STORAGE	-0.870	-268917.000	-1.41
SOIL WATER AT START OF YEAR	30.015	9282947.000	
SOIL WATER AT END OF YEAR	29.146	9014030.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	6.489	0.00

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ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	72.47	22413228.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	41.192	12739699.000	56.84
PERC./LEAKAGE THROUGH LAYER 2	31.968069	9886956.000	44.11
CHANGE IN WATER STORAGE	-0.690	-213423.000	-0.95
SOIL WATER AT START OF YEAR	29.146	9014030.000	
SOIL WATER AT END OF YEAR	28.456	8800607.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-3.539	0.00

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ANNUAL TOTALS FOR YEAR 6

	INCHES	CU. FEET	PERCENT
PRECIPITATION	69.50	21494682.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	44.898	13885829.000	64.60
PERC./LEAKAGE THROUGH LAYER 2	23.538099	7279769.000	33.87
CHANGE IN WATER STORAGE	1.064	329079.406	1.53
SOIL WATER AT START OF YEAR	28.456	8800607.000	
SOIL WATER AT END OF YEAR	29.520	9129686.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	3.539	0.00

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ANNUAL TOTALS FOR YEAR 7

	INCHES	CU. FEET	PERCENT
PRECIPITATION	63.55	19654488.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	37.027	11451411.000	58.26
PERC./LEAKAGE THROUGH LAYER 2	28.107615	8693010.000	44.23
CHANGE IN WATER STORAGE	-1.584	-489930.187	-2.49
SOIL WATER AT START OF YEAR	29.520	9129686.000	
SOIL WATER AT END OF YEAR	27.935	8639756.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-3.539	0.00

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ANNUAL TOTALS FOR YEAR 8

	INCHES	CU. FEET	PERCENT
PRECIPITATION	60.94	18847274.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	40.124	12409361.000	65.84
PERC./LEAKAGE THROUGH LAYER 2	16.177885	5003431.500	26.55
CHANGE IN WATER STORAGE	4.638	1434481.120	7.61
SOIL WATER AT START OF YEAR	27.935	8639756.000	
SOIL WATER AT END OF YEAR	32.574	10074237.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.590	0.00

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ANNUAL TOTALS FOR YEAR 9

	INCHES	CU. FEET	PERCENT
PRECIPITATION	57.40	17752440.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	38.990	12058764.000	67.93
PERC./LEAKAGE THROUGH LAYER 2	19.442913	6013226.000	33.87
CHANGE IN WATER STORAGE	-1.033	-319552.562	-1.80
SOIL WATER AT START OF YEAR	32.574	10074237.000	
SOIL WATER AT END OF YEAR	31.540	9754685.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00

ANNUAL WATER BUDGET BALANCE	0.0000	1.770	0.00

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ANNUAL TOTALS FOR YEAR 10

	INCHES	CU. FEET	PERCENT
PRECIPITATION	66.29	20501904.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	42.594	13173395.000	64.25
PERC./LEAKAGE THROUGH LAYER 2	22.943161	7095769.000	34.61
CHANGE IN WATER STORAGE	0.753	232739.781	1.14
SOIL WATER AT START OF YEAR	31.540	9754685.000	
SOIL WATER AT END OF YEAR	32.293	9987425.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.590	0.00

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ANNUAL TOTALS FOR YEAR 11

	INCHES	CU. FEET	PERCENT
PRECIPITATION	68.39	21151382.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	37.382	11561418.000	54.66
PERC./LEAKAGE THROUGH LAYER 2	31.803455	9836045.000	46.50
CHANGE IN WATER STORAGE	-0.796	-246074.984	-1.16
SOIL WATER AT START OF YEAR	32.293	9987425.000	
SOIL WATER AT END OF YEAR	31.497	9741350.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00

SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-6.489	0.00

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ANNUAL TOTALS FOR YEAR 12

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.84	15105039.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	35.189	10882994.000	72.05
PERC./LEAKAGE THROUGH LAYER 2	18.796045	5813165.500	38.48
CHANGE IN WATER STORAGE	-5.145	-1591122.370	-10.53
SOIL WATER AT START OF YEAR	31.497	9741350.000	
SOIL WATER AT END OF YEAR	26.353	8150227.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	1.770	0.00

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ANNUAL TOTALS FOR YEAR 13

	INCHES	CU. FEET	PERCENT
PRECIPITATION	69.22	21408084.000	100.00
RUNOFF	0.000	0.000	*0.00*
EVAPOTRANSPIRATION	36.726	11358487.000	53.06
PERC./LEAKAGE THROUGH LAYER 2	28.475870	8806903.000	41.14
CHANGE IN WATER STORAGE	4.018	1242693.750	5.80
SOIL WATER AT START OF YEAR	26.353	8150227.000	
SOIL WATER AT END OF YEAR	30.371	9392921.000	

SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.590	0.00

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ANNUAL TOTALS FOR YEAR 14

	INCHES	CU. FEET	PERCENT
PRECIPITATION	55.31	17106050.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	29.805	9217923.000	53.89
PERC./LEAKAGE THROUGH LAYER 2	20.970263	6485598.500	37.91
CHANGE IN WATER STORAGE	4.535	1402536.370	8.20
SOIL WATER AT START OF YEAR	30.371	9392921.000	
SOIL WATER AT END OF YEAR	34.906	10795457.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-7.669	0.00

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ANNUAL TOTALS FOR YEAR 15

	INCHES	CU. FEET	PERCENT
PRECIPITATION	57.38	17746258.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	41.672	12888128.000	72.62
PERC./LEAKAGE THROUGH LAYER 2	22.785521	7047014.500	39.71
CHANGE IN WATER STORAGE	-7.077	-2188887.000	-12.33
SOIL WATER AT START OF YEAR	34.906	10795457.000	

SOIL WATER AT END OF YEAR	27.828	8606570.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	3.539	0.00

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ANNUAL TOTALS FOR YEAR 16

	INCHES	CU. FEET	PERCENT
PRECIPITATION	57.30	17721512.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	36.120	11171139.000	63.04
PERC./LEAKAGE THROUGH LAYER 2	12.980449	4014541.000	22.65
CHANGE IN WATER STORAGE	8.199	2535833.750	14.31
SOIL WATER AT START OF YEAR	27.828	8606570.000	
SOIL WATER AT END OF YEAR	36.027	11142404.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-2.655	0.00

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ANNUAL TOTALS FOR YEAR 17

	INCHES	CU. FEET	PERCENT
PRECIPITATION	80.96	25038988.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	45.271	14001100.000	55.92
PERC./LEAKAGE THROUGH LAYER 2	37.345875	11550182.000	46.13
CHANGE IN WATER STORAGE	-1.656	-512296.156	-2.05

SOIL WATER AT START OF YEAR	36.027	11142404.000	
SOIL WATER AT END OF YEAR	34.371	10630108.000	
WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	2.360	0.00

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ANNUAL TOTALS FOR YEAR 18

	INCHES	CU. FEET	PERCENT
PRECIPITATION	58.62	18129760.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	37.010	11446437.000	63.14
PERC./LEAKAGE THROUGH LAYER 2	20.185738	6242964.000	34.43
CHANGE IN WATER STORAGE	1.424	440357.031	2.43
SOIL WATER AT START OF YEAR	34.371	10630108.000	
SOIL WATER AT END OF YEAR	35.795	11070465.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	1.180	0.00

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ANNUAL TOTALS FOR YEAR 19

	INCHES	CU. FEET	PERCENT
PRECIPITATION	79.46	24575070.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	42.951	13283677.000	54.05
PERC./LEAKAGE THROUGH LAYER 2	42.037716	13001256.000	52.90

CHANGE IN WATER STORAGE	-5.529	-1709874.620	-6.96
SOIL WATER AT START OF YEAR	35.795	11070465.000	
SOIL WATER AT END OF YEAR	30.266	9360590.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	10.618	0.00

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ANNUAL TOTALS FOR YEAR 20

	INCHES	CU. FEET	PERCENT
PRECIPITATION	66.69	20625614.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	41.435	12814891.000	62.13
PERC./LEAKAGE THROUGH LAYER 2	26.885126	8314924.000	40.31
CHANGE IN WATER STORAGE	-1.630	-504203.344	-2.44
SOIL WATER AT START OF YEAR	30.266	9360590.000	
SOIL WATER AT END OF YEAR	28.636	8856387.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	2.360	0.00

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ANNUAL TOTALS FOR YEAR 21

	INCHES	CU. FEET	PERCENT
PRECIPITATION	62.16	19224596.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	43.446	13436861.000	69.89

PERC./LEAKAGE THROUGH LAYER 2	16.069820	4970009.500	25.85
CHANGE IN WATER STORAGE	2.644	817723.625	4.25
SOIL WATER AT START OF YEAR	28.636	8856387.000	
SOIL WATER AT END OF YEAR	31.280	9674111.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	2.360	0.00

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ANNUAL TOTALS FOR YEAR 22

	INCHES	CU. FEET	PERCENT
PRECIPITATION	72.03	22277146.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	44.040	13620597.000	61.14
PERC./LEAKAGE THROUGH LAYER 2	27.080481	8375342.500	37.60
CHANGE IN WATER STORAGE	0.909	281211.625	1.26
SOIL WATER AT START OF YEAR	31.280	9674111.000	
SOIL WATER AT END OF YEAR	32.189	9955322.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-4.719	0.00

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ANNUAL TOTALS FOR YEAR 23

	INCHES	CU. FEET	PERCENT
PRECIPITATION	77.32	23913220.000	100.00
RUNOFF	0.000	0.000	0.00

EVAPOTRANSPIRATION	43.532	13463405.000	56.30
PERC./LEAKAGE THROUGH LAYER 2	28.858982	8925390.000	37.32
CHANGE IN WATER STORAGE	4.929	1524431.000	6.37
SOIL WATER AT START OF YEAR	32.189	9955322.000	
SOIL WATER AT END OF YEAR	37.118	11479753.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-7.079	0.00

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ANNUAL TOTALS FOR YEAR 24

	INCHES	CU. FEET	PERCENT
PRECIPITATION	61.35	18974080.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	42.291	13079600.000	68.93
PERC./LEAKAGE THROUGH LAYER 2	28.229488	8730703.000	46.01
CHANGE IN WATER STORAGE	-9.171	-2836224.750	-14.95
SOIL WATER AT START OF YEAR	37.118	11479753.000	
SOIL WATER AT END OF YEAR	27.948	8643529.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	1.770	0.00

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ANNUAL TOTALS FOR YEAR 25

	INCHES	CU. FEET	PERCENT
PRECIPITATION	68.30	21123554.000	100.00

RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	41.728	12905384.000	61.09
PERC./LEAKAGE THROUGH LAYER 2	20.764864	6422074.000	30.40
CHANGE IN WATER STORAGE	5.807	1796092.250	8.50
SOIL WATER AT START OF YEAR	27.948	8643529.000	
SOIL WATER AT END OF YEAR	33.755	10439621.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	2.360	0.00

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ANNUAL TOTALS FOR YEAR 26

	INCHES	CU. FEET	PERCENT
PRECIPITATION	69.76	21575084.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	38.896	12029580.000	55.76
PERC./LEAKAGE THROUGH LAYER 2	34.837624	10774440.000	49.94
CHANGE IN WATER STORAGE	-3.974	-1228925.000	-5.70
SOIL WATER AT START OF YEAR	33.755	10439621.000	
SOIL WATER AT END OF YEAR	29.781	9210696.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-11.798	0.00

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ANNUAL TOTALS FOR YEAR 27

	INCHES	CU. FEET	PERCENT

PRECIPITATION	59.59	18429758.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	41.899	12958432.000	70.31
PERC./LEAKAGE THROUGH LAYER 2	14.895804	4606914.500	25.00
CHANGE IN WATER STORAGE	2.795	864416.937	4.69
SOIL WATER AT START OF YEAR	29.781	9210696.000	
SOIL WATER AT END OF YEAR	32.576	10075113.000	
SNOW WATER AT START OF YEAR	0.000	0.000	*0.00*
SNOW WATER AT END OF YEAR	0.000	0.000	*0.00*
ANNUAL WATER BUDGET BALANCE	0.0000	-6.194	*0.00*

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ANNUAL TOTALS FOR YEAR 28

	INCHES	CU. FEET	PERCENT
PRECIPITATION	63.40	19608094.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	37.388	11563350.000	58.97
PERC./LEAKAGE THROUGH LAYER 2	22.639362	7001811.000	35.71
CHANGE IN WATER STORAGE	3.372	1042934.560	5.32
SOIL WATER AT START OF YEAR	32.576	10075113.000	
SOIL WATER AT END OF YEAR	35.949	11118047.000	
SNOW WATER AT START OF YEAR	*0.000*	*0.000*	*0.00*
SNOW WATER AT END OF YEAR	*0.000*	0.000	0.00
ANNUAL WATER BUDGET BALANCE	*0.0000*	-1.180	0.00

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ANNUAL TOTALS FOR YEAR 29

	INCHES	CU. FEET	PERCENT
PRECIPITATION	61.57	19042118.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	39.337	12166131.000	63.89
PERC./LEAKAGE THROUGH LAYER 2	27.105576	8383103.500	44.02
CHANGE IN WATER STORAGE	-4.873	-1507114.000	-7.91
SOIL WATER AT START OF YEAR	35.949	11118047.000	
SOIL WATER AT END OF YEAR	31.076	9610933.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-3.539	0.00

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ANNUAL TOTALS FOR YEAR 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.73	15071021.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	31.034	9598066.000	63.69
PERC./LEAKAGE THROUGH LAYER 2	17.973112	5558652.000	36.88
CHANGE IN WATER STORAGE	-0.277	-85701.430	-0.57
SOIL WATER AT START OF YEAR	31.076	9610933.000	
SOIL WATER AT END OF YEAR	30.798	9525232.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	4.719	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.04	4.74	6.18	4.99	4.99	5.93
	7.66	6.67	7.26	2.49	3.16	6.56
STD. DEVIATIONS	2.02	2.37	3.07	3.08	3.26	2.70
	3.23	2.73	2.46	1.50	1.65	3.32
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	1.649	2.118	3.207	4.063	3.905	5.070
	5.680	4.717	2.550	2.734	2.342	1.755
STD. DEVIATIONS	0.187	0.401	0.774	1.099	1.726	1.445
	1.176	1.433	0.560	0.443	0.696	0.282
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	2.7215	2.4807	2.8418	3.1788	2.3774	1.3090
	1.1749	1.5185	1.7321	2.6528	1.5493	1.3693
STD. DEVIATIONS	2.0924	1.3638	1.5960	2.2602	1.7013	0.8560
	0.9172	1.3533	1.5321	1.3669	0.6428	0.6189

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	64.67	(8.125)	19999844.0	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	39.790	(3.7413)	12306035.00	61.531
PERCOLATION/LEAKAGE THROUGH FROM LAYER 2	24.90623	(7.04083)	7702898.000	38.51479
CHANGE IN WATER STORAGE	-0.029	(4.0098)	-9086.93	-0.045

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	5.47	1691739.620
RUNOFF	0.000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 2	1.285369	397533.62500
SNOW WATER	2.24	692452.2500

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.2457

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0182

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	2.2836	0.0952
2	28.5149	0.2970
SNOW WATER	0.000	

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**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.01    (14 OCTOBER 1994)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
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PRECIPITATION DATA FILE:      F:\MIKE\HELP3\NASPRAIN.D4
TEMPERATURE DATA FILE:        F:\MIKE\HELP3\NASPTEMP.D7
SOLAR RADIATION DATA FILE:    F:\MIKE\HELP3\NASPRAD.D13
EVAPOTRANSPIRATION DATA:      F:\MIKE\HELP3\NASPEVAP.D11
SOIL AND DESIGN DATA FILE:    F:\MIKE\HELP3\REVDES.D10
OUTPUT DATA FILE:             F:\MIKE\HELP3\claycap.OUT


TIME:  15:36      DATE:   2/20/1996


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     TITLE:  Site 1 Clay Cap

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
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                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   1
          THICKNESS                    =     18.00   INCHES
          POROSITY                     =      0.4170 VOL/VOL
          FIELD CAPACITY               =      0.0450 VOL/VOL
          WILTING POINT                =      0.0180 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.0681 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  5.00
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 1

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4170	VOL/VOL
FIELD CAPACITY	=	0.0450	VOL/VOL
WILTING POINT	=	0.0180	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3947	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.9999999780003-02	CM/SEC
SLOPE	=	5.00	PERCENT
DRAINAGE LENGTH	=	500.0	FEET

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 27

THICKNESS	=	24.00	INCHES
POROSITY	=	0.4000	VOL/VOL
FIELD CAPACITY	=	0.3660	VOL/VOL
WILTING POINT	=	0.2880	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.7799999930003-06	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

THICKNESS	=	96.00	INCHES
POROSITY	=	0.6710	VOL/VOL
FIELD CAPACITY	=	0.2920	VOL/VOL
WILTING POINT	=	0.0770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2807	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 1 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 5.% AND A SLOPE LENGTH OF 500. FEET.

SCS RUNOFF CURVE NUMBER	=	39.30	
FRACTION OF *AREA* ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	85.200	ACRES

EVAPORATIVE ZONE DEPTH	=	28.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	5.128	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	11.676	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.504	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	42.506	INCHES
TOTAL INITIAL WATER	=	42.506	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
MOBILE ALABAMA

MAXIMUM LEAF AREA INDEX	=	4.50	
START OF GROWING SEASON (JULIAN DATE)	=	39	
END OF GROWING SEASON (JULIAN DATE)	=	351	
AVERAGE ANNUAL WIND SPEED	=	9.00	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	70.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MOBILE ALABAMA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.59	4.91	6.48	5.35	5.46	5.07
7.74	6.75	6.56	2.62	3.67	5.44

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MOBILE ALABAMA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
50.80	53.60	60.10	68.00	74.90	80.50
82.20	81.80	78.20	68.50	58.60	53.10

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MOBILE ALABAMA

STATION LATITUDE = 30.41 DEGREES

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ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	57.07	17650380.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	39.075	12084866.000	68.47
DRAINAGE COLLECTED FROM LAYER 2	7.2878	2253931.000	12.77
PERC./LEAKAGE THROUGH LAYER 3	10.687090	3305260.250	18.73
AVG. HEAD ON TOP OF LAYER 3	5.0777		
PERC./LEAKAGE THROUGH LAYER 4	10.670642	3300173.250	18.70
CHANGE IN WATER STORAGE	0.037	11401.531	0.06
SOIL WATER AT START OF YEAR	42.506	13146118.000	
SOIL WATER AT END OF YEAR	42.543	13157520.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	7.374	0.00

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ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	73.98	22880238.000	100.00
RUNOFF	2.421	748797.437	3.27
EVAPOTRANSPIRATION	43.523	13460512.000	58.83
DRAINAGE COLLECTED FROM LAYER 2	13.6717	4228316.000	18.48
PERC./LEAKAGE THROUGH LAYER 3	12.656176	3914251.250	17.11
AVG. HEAD ON TOP OF LAYER 3	9.0526		
PERC./LEAKAGE THROUGH LAYER 4	13.155604	4068712.500	17.78
CHANGE IN WATER STORAGE	1.209	373902.750	1.63

SOIL WATER AT START OF YEAR	42.543	13157520.000	
SOIL WATER AT END OF YEAR	43.752	13531423.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-2.360	0.00

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ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	70.88	21921478.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	44.907	13888761.000	63.36
DRAINAGE COLLECTED FROM LAYER 2	14.9909	4636313.500	21.15
PERC./LEAKAGE THROUGH LAYER 3	13.701766	4237627.000	19.33
AVG. HEAD ON TOP OF LAYER 3	10.5566		
PERC./LEAKAGE THROUGH LAYER 4	13.098234	4050969.250	18.48
CHANGE IN WATER STORAGE	-2.116	-654562.812	-2.99
SOIL WATER AT START OF YEAR	43.752	13531423.000	
SOIL WATER AT END OF YEAR	41.635	12876860.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-2.360	0.00

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ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
PRECIPITATION	61.54	19032844.000	100.00

RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	42.285	13077750.000	68.71
@DRAINAGE COLLECTED FROM LAYER 2	8.8681	2742689.250	14.41
PERC./LEAKAGE THROUGH LAYER 3	11.575665	3580075.000	18.81
AVG. HEAD ON TOP OF LAYER 3	7.0390		
PERC./LEAKAGE THROUGH LAYER 4	11.970221	3702101.750	19.45
CHANGE IN WATER STORAGE	-1.583	-489694.844	-2.57
SOIL WATER AT START OF YEAR	41.635	12876860.000	
SOIL WATER AT END OF YEAR	40.052	12387165.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-2.065	0.00

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ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	72.47	22413228.000	100.00
RUNOFF	1.037	320728.469	1.43
EVAPOTRANSPIRATION	45.425	14048720.000	62.68
DRAINAGE COLLECTED FROM LAYER 2	13.5475	4189916.750	18.69
PERC./LEAKAGE THROUGH LAYER 3	13.352352	4129562.000	18.42
AVG. HEAD ON TOP OF LAYER 3	9.4823		
PERC./LEAKAGE THROUGH LAYER 4	13.093158	4049399.250	18.07
CHANGE IN WATER STORAGE	-0.632	-195532.016	-0.87
SOIL WATER AT START OF YEAR	40.052	12387165.000	
SOIL WATER AT END OF YEAR	39.420	12191633.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-3.539	0.00

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ANNUAL TOTALS FOR YEAR 6

	INCHES	CU. FEET	PERCENT
PRECIPITATION	69.50	21494682.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	47.751	14768293.000	68.71
DRAINAGE COLLECTED FROM LAYER 2	8.7384	2702562.750	12.57
PERC./LEAKAGE THROUGH LAYER 3	12.115446	3747016.500	17.43
AVG. HEAD ON TOP OF LAYER 3	6.0318		
PERC./LEAKAGE THROUGH LAYER 4	12.134654	3752957.250	17.46
CHANGE IN WATER STORAGE	0.876	270865.406	1.26
SOIL WATER AT START OF YEAR	39.420	12191633.000	
SOIL WATER AT END OF YEAR	40.296	12462498.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	2.949	0.00

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ANNUAL TOTALS FOR YEAR 7

	INCHES	CU. FEET	PERCENT
PRECIPITATION	63.55	19654488.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	40.229	12441865.000	63.30
DRAINAGE COLLECTED FROM LAYER 2	12.6779	3920979.500	19.95
PERC./LEAKAGE THROUGH LAYER 3	11.569468	3578158.750	18.21
AVG. HEAD ON TOP OF LAYER 3	8.4685		

PERC./LEAKAGE THROUGH LAYER 4	11.204712	3465348.250	17.63
CHANGE IN WATER STORAGE	-0.562	-173696.391	-0.88
SOIL WATER AT START OF YEAR	40.296	12462498.000	
SOIL WATER AT END OF YEAR	39.734	12288802.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-8.848	0.00

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ANNUAL TOTALS FOR YEAR 8

	INCHES	CU. FEET	PERCENT
PRECIPITATION	60.94	18847274.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	39.538	12228107.000	64.88
DRAINAGE COLLECTED FROM LAYER 2	6.8071	2105274.750	11.17
PERC./LEAKAGE THROUGH LAYER 3	10.434794	3227231.250	17.12
AVG. HEAD ON TOP OF LAYER 3	5.1061		
PERC./LEAKAGE THROUGH LAYER 4	10.920219	3377361.750	17.92
CHANGE IN WATER STORAGE	3.675	1136537.120	6.03
SOIL WATER AT START OF YEAR	39.734	12288802.000	
SOIL WATER AT END OF YEAR	43.409	13425339.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-6.194	0.00

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ANNUAL TOTALS FOR YEAR 9

	INCHES	CU. FEET	PERCENT
PRECIPITATION	57.40	17752440.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	39.909	12342896.000	69.53
DRAINAGE COLLECTED FROM LAYER 2	7.8837	2438238.750	13.73
PERC./LEAKAGE THROUGH LAYER 3	10.696645	3308215.500	18.64
AVG. HEAD ON TOP OF LAYER 3	5.7311		
PERC./LEAKAGE THROUGH LAYER 4	11.082632	3427592.000	19.31
CHANGE IN WATER STORAGE	-1.475	-456285.406	-2.57
SOIL WATER AT START OF YEAR	43.409	13425339.000	
SOIL WATER AT END OF YEAR	41.934	12969054.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-2.065	0.00

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ANNUAL TOTALS FOR YEAR 10

	INCHES	CU. FEET	PERCENT
PRECIPITATION	66.29	20501904.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	44.906	13888217.000	67.74
DRAINAGE COLLECTED FROM LAYER 2	8.9371	2764034.000	13.48
PERC./LEAKAGE THROUGH LAYER 3	12.187765	3769383.000	18.39
AVG. HEAD ON TOP OF LAYER 3	6.1770		
PERC./LEAKAGE THROUGH LAYER 4	11.516872	3561892.000	17.37
CHANGE IN WATER STORAGE	0.930	287754.187	1.40
SOIL WATER AT START OF YEAR	41.934	12969054.000	
SOIL WATER AT END OF YEAR	42.864	13256808.000	

SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	5.604	0.00

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ANNUAL TOTALS FOR YEAR 11

	INCHES	CU. FEET	PERCENT
PRECIPITATION	68.39	21151382.000	100.00
RUNOFF	0.290	89686.437	0.42
EVAPOTRANSPIRATION	41.973	12981276.000	61.37
DRAINAGE COLLECTED FROM LAYER 2	13.7732	4259710.000	20.14
PERC./LEAKAGE THROUGH LAYER 3	12.246509	3787551.000	17.91
AVG. HEAD ON TOP OF LAYER 3	9.4727		
PERC./LEAKAGE THROUGH LAYER 4	12.010797	3714651.000	17.56
CHANGE IN WATER STORAGE	0.343	106062.320	0.50
SOIL WATER AT START OF YEAR	42.864	13256808.000	
SOIL WATER AT END OF YEAR	43.207	13362870.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-3.834	0.00

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ANNUAL TOTALS FOR YEAR 12

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.84	15105039.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	36.582	11313974.000	74.90

DRAINAGE COLLECTED FROM LAYER 2	7.2485	2241789.000	14.84
PERC./LEAKAGE THROUGH LAYER 3	10.429440	3225575.250	21.35
AVG. HEAD ON TOP OF LAYER 3	5.3455		
PERC./LEAKAGE THROUGH LAYER 4	11.064643	3422028.500	22.65
CHANGE IN WATER STORAGE	-6.055	-1872752.250	-12.40
SOIL WATER AT START OF YEAR	43.207	13362870.000	
SOIL WATER AT END OF YEAR	37.152	11490118.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.295	0.00

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ANNUAL TOTALS FOR YEAR 13

	INCHES	CU. FEET	PERCENT
PRECIPITATION	69.22	21408084.000	100.00
RUNOFF	0.228	70399.430	0.33
EVAPOTRANSPIRATION	39.899	12339746.000	57.64
DRAINAGE COLLECTED FROM LAYER 2	13.1351	4062382.000	18.98
PERC./LEAKAGE THROUGH LAYER 3	11.610013	3590698.250	16.77
AVG. HEAD ON TOP OF LAYER 3	7.9776		
PERC./LEAKAGE THROUGH LAYER 4	11.120657	3439352.250	16.07
CHANGE IN WATER STORAGE	4.838	1496197.370	6.99
SOIL WATER AT START OF YEAR	37.152	11490118.000	
SOIL WATER AT END OF YEAR	41.989	12986315.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	6.489	0.00

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ANNUAL TOTALS FOR YEAR 14

	INCHES	CU. FEET	PERCENT
PRECIPITATION	55.31	17106050.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	33.289	10295385.000	60.19
DRAINAGE COLLECTED FROM LAYER 2	8.6734	2682476.000	15.68
PERC./LEAKAGE THROUGH LAYER 3	9.817127	3036201.750	17.75
AVG. HEAD ON TOP OF LAYER 3	6.1123		
PERC./LEAKAGE THROUGH LAYER 4	10.452493	3232705.000	18.90
CHANGE IN WATER STORAGE	2.895	895490.937	5.23
SOIL WATER AT START OF YEAR	41.989	12986315.000	
SOIL WATER AT END OF YEAR	44.885	13881806.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-6.489	0.00

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ANNUAL TOTALS FOR YEAR 15

	INCHES	CU. FEET	PERCENT
PRECIPITATION	57.38	17746258.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	44.002	13608838.000	76.69
DRAINAGE COLLECTED FROM LAYER 2	8.5534	2645364.750	14.91
PERC./LEAKAGE THROUGH LAYER 3	10.977560	3395095.750	19.13
AVG. HEAD ON TOP OF LAYER 3	6.6481		
PERC./LEAKAGE THROUGH LAYER 4	10.936723	3382465.750	19.06
CHANGE IN WATER STORAGE	-6.112	-1890413.750	-10.65

SOIL WATER AT START OF YEAR	44.885	13881806.000	
SOIL WATER AT END OF YEAR	38.772	11991392.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	3.834	0.00

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ANNUAL TOTALS FOR YEAR 16

	INCHES	CU. FEET	PERCENT
PRECIPITATION	57.30	17721512.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	35.369	10938920.000	61.73
DRAINAGE COLLECTED FROM LAYER 2	5.5287	1709905.370	9.65
PERC./LEAKAGE THROUGH LAYER 3	9.940536	3074369.000	17.35
AVG. HEAD ON TOP OF LAYER 3	3.2759		
PERC./LEAKAGE THROUGH LAYER 4	9.639272	2981195.250	16.82
CHANGE IN WATER STORAGE	6.763	2091493.250	11.80
SOIL WATER AT START OF YEAR	38.772	11991392.000	
SOIL WATER AT END OF YEAR	45.535	14082886.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-2.655	0.00

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ANNUAL TOTALS FOR YEAR 17

	INCHES	CU. FEET	PERCENT
PRECIPITATION	80.96	25038988.000	100.00

RUNOFF	3.899	1205712.500	4.82
EVAPOTRANSPIRATION	50.361	15575485.000	62.20
DRAINAGE COLLECTED FROM LAYER 2	13.9529	4315292.500	17.23
PERC./LEAKAGE THROUGH LAYER 3	13.657185	4223839.500	16.87
AVG. HEAD ON TOP OF LAYER 3	9.8574		
PERC./LEAKAGE THROUGH LAYER 4	13.491549	4172612.250	16.66
CHANGE IN WATER STORAGE	-0.744	-230108.250	-0.92
SOIL WATER AT START OF YEAR	45.535	14082886.000	
SOIL WATER AT END OF YEAR	44.791	13852777.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-6.489	0.00

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ANNUAL TOTALS FOR YEAR 18

	INCHES	CU. FEET	PERCENT
PRECIPITATION	58.62	18129760.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	38.773	11991503.000	66.14
DRAINAGE COLLECTED FROM LAYER 2	7.5078	2321977.750	12.81
PERC./LEAKAGE THROUGH LAYER 3	11.037715	3413700.250	18.83
AVG. HEAD ON TOP OF LAYER 3	5.4205		
PERC./LEAKAGE THROUGH LAYER 4	11.754194	3635290.000	20.05
CHANGE IN WATER STORAGE	0.585	180991.047	1.00
SOIL WATER AT START OF YEAR	44.791	13852777.000	
SOIL WATER AT END OF YEAR	45.376	14033768.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00

ANNUAL WATER BUDGET BALANCE	0.0000	-2.949	0.00

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ANNUAL TOTALS FOR YEAR 19

	INCHES	CU. FEET	PERCENT
PRECIPITATION	79.46	24575070.000	100.00
RUNOFF	0.097	29949.125	0.12
EVAPOTRANSPIRATION	46.731	14452744.000	58.81
DRAINAGE COLLECTED FROM LAYER 2	21.3204	6593881.500	26.83
PERC./LEAKAGE THROUGH LAYER 3	15.060874	4657966.500	18.95
AVG. HEAD ON TOP OF LAYER 3	13.3758		
PERC./LEAKAGE THROUGH LAYER 4	13.915734	4303802.500	17.51
CHANGE IN WATER STORAGE	-2.604	-805313.375	-3.28
SOIL WATER AT START OF YEAR	45.376	14033768.000	
SOIL WATER AT END OF YEAR	42.772	13228455.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	6.194	0.00

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ANNUAL TOTALS FOR YEAR 20

	INCHES	CU. FEET	PERCENT
PRECIPITATION	66.69	20625614.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	44.436	13742979.000	66.63
DRAINAGE COLLECTED FROM LAYER 2	13.1704	4073293.000	19.75
PERC./LEAKAGE THROUGH LAYER 3	11.170131	3454653.250	16.75

AVG. HEAD ON TOP OF LAYER 3	7.8197		
PERC./LEAKAGE THROUGH LAYER 4	12.740590	3940358.500	19.10
CHANGE IN WATER STORAGE	-3.657	-1131013.250	-5.48
SOIL WATER AT START OF YEAR	42.772	13228455.000	
SOIL WATER AT END OF YEAR	39.115	12097442.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-4.129	0.00

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ANNUAL TOTALS FOR YEAR 21

	INCHES	CU. FEET	PERCENT
PRECIPITATION	62.16	19224596.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	42.120	13026628.000	67.76
DRAINAGE COLLECTED FROM LAYER 2	6.6667	2061856.250	10.73
PERC./LEAKAGE THROUGH LAYER 3	10.879298	3364705.750	17.50
AVG. HEAD ON TOP OF LAYER 3	4.5580		
PERC./LEAKAGE THROUGH LAYER 4	9.786204	3026638.000	15.74
CHANGE IN WATER STORAGE	3.587	1109470.250	5.77
SOIL WATER AT START OF YEAR	39.115	12097442.000	
SOIL WATER AT END OF YEAR	42.703	13206912.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	3.244	0.00

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ANNUAL TOTALS FOR YEAR 22

	INCHES	CU. FEET	PERCENT
PRECIPITATION	72.03	22277146.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	46.860	14492560.000	65.06
DRAINAGE COLLECTED FROM LAYER 2	11.0253	3409848.000	15.31
PERC./LEAKAGE THROUGH LAYER 3	13.103769	4052681.250	18.19
AVG. HEAD ON TOP OF LAYER 3	8.4619		
PERC./LEAKAGE THROUGH LAYER 4	12.934234	4000248.000	17.96
CHANGE IN WATER STORAGE	1.211	374492.656	1.68
SOIL WATER AT START OF YEAR	42.703	13206912.000	
SOIL WATER AT END OF YEAR	43.914	13581405.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-2.655	0.00

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ANNUAL TOTALS FOR YEAR 23

	INCHES	CU. FEET	PERCENT
PRECIPITATION	77.32	23913220.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	47.108	14569481.000	60.93
DRAINAGE COLLECTED FROM LAYER 2	13.5210	4181731.750	17.49
PERC./LEAKAGE THROUGH LAYER 3	13.200027	4082451.250	17.07
AVG. HEAD ON TOP OF LAYER 3	8.7910		
PERC./LEAKAGE THROUGH LAYER 4	13.153010	4067910.250	17.01
CHANGE IN WATER STORAGE	3.538	1094092.750	4.58
SOIL WATER AT START OF YEAR	43.914	13581405.000	
SOIL WATER AT END OF YEAR	47.451	14675497.000	

SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	3.244	0.00

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ANNUAL TOTALS FOR YEAR 24

	INCHES	CU. FEET	PERCENT
PRECIPITATION	61.35	18974080.000	100.00
RUNOFF	0.127	39132.074	0.21
EVAPOTRANSPIRATION	44.043	13621516.000	71.79
DRAINAGE COLLECTED FROM LAYER 2	12.8102	3961875.750	20.88
PERC./LEAKAGE THROUGH LAYER 3	12.174512	3765284.250	19.84
AVG. HEAD ON TOP OF LAYER 3	7.4517		
PERC./LEAKAGE THROUGH LAYER 4	13.454398	4161122.250	21.93
CHANGE IN WATER STORAGE	-9.084	-2809559.500	-14.81
SOIL WATER AT START OF YEAR	47.451	14675497.000	
SOIL WATER AT END OF YEAR	38.367	11865938.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-6.489	0.00

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ANNUAL TOTALS FOR YEAR 25

	INCHES	CU. FEET	PERCENT
PRECIPITATION	68.30	21123554.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	42.172	13042845.000	61.75

DRAINAGE COLLECTED FROM LAYER 2	8.7207	2697101.750	12.77
PERC./LEAKAGE THROUGH LAYER 3	11.847818	3664245.750	17.35
AVG. HEAD ON TOP OF LAYER 3	6.2060		
PERC./LEAKAGE THROUGH LAYER 4	10.464141	3236307.500	15.32
CHANGE IN WATER STORAGE	6.943	2147290.500	10.17
SOIL WATER AT START OF YEAR	38.367	11865938.000	
SOIL WATER AT END OF YEAR	45.310	14013228.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	8.554	0.00

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ANNUAL TOTALS FOR YEAR 26

	INCHES	CU. FEET	PERCENT
PRECIPITATION	69.76	21575084.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	45.979	14220135.000	65.91
DRAINAGE COLLECTED FROM LAYER 2	14.4736	4476323.000	20.75
PERC./LEAKAGE THROUGH LAYER 3	13.855228	4285089.500	19.86
AVG. HEAD ON TOP OF LAYER 3	10.3766		
PERC./LEAKAGE THROUGH LAYER 4	14.418600	4459327.000	20.67
CHANGE IN WATER STORAGE	-5.111	-1580688.250	-7.33
SOIL WATER AT START OF YEAR	45.310	14013228.000	
SOIL WATER AT END OF YEAR	40.199	12432540.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-12.978	0.00

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ANNUAL TOTALS FOR YEAR 27

	INCHES	CU. FEET	PERCENT
PRECIPITATION	59.59	18429758.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	41.588	12862068.000	69.79
DRAINAGE COLLECTED FROM LAYER 2	5.4860	1696697.870	9.21
PERC./LEAKAGE THROUGH LAYER 3	9.616735	2974225.250	16.14
AVG. HEAD ON TOP OF LAYER 3	3.2597		
PERC./LEAKAGE THROUGH LAYER 4	9.865159	3051056.750	16.56
CHANGE IN WATER STORAGE	2.651	819933.375	4.45
SOIL WATER AT START OF YEAR	40.199	12432540.000	
SOIL WATER AT END OF YEAR	42.850	13252473.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.590	0.00

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ANNUAL TOTALS FOR YEAR 28

	INCHES	CU. FEET	PERCENT
PRECIPITATION	63.40	19608094.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	39.635	12258237.000	62.52
DRAINAGE COLLECTED FROM LAYER 2	9.5262	2946231.750	15.03
PERC./LEAKAGE THROUGH LAYER 3	11.668982	3608935.750	18.41
AVG. HEAD ON TOP OF LAYER 3	6.7194		
PERC./LEAKAGE THROUGH LAYER 4	11.695321	3617082.000	18.45

CHANGE IN WATER STORAGE	2.543	786547.562	4.01
SOIL WATER AT START OF YEAR	42.850	13252473.000	
SOIL WATER AT END OF YEAR	45.393	14039021.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-3.834	0.00

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ANNUAL TOTALS FOR YEAR 29

	INCHES	CU. FEET	PERCENT
PRECIPITATION	61.57	19042118.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	42.131	13030217.000	68.43
DRAINAGE COLLECTED FROM LAYER 2	10.7247	3316900.250	17.42
PERC./LEAKAGE THROUGH LAYER 3	12.233047	3783387.750	19.87
AVG. HEAD ON TOP OF LAYER 3	8.5617		
PERC./LEAKAGE THROUGH LAYER 4	11.531834	3566519.250	18.73
CHANGE IN WATER STORAGE	-2.818	-871521.062	-4.58
SOIL WATER AT START OF YEAR	45.393	14039021.000	
SOIL WATER AT END OF YEAR	42.575	13167500.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	1.770	0.00

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ANNUAL TOTALS FOR YEAR 30

	INCHES	CU. FEET	PERCENT

PRECIPITATION	48.73	15071021.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	31.794	9833115.000	65.25
DRAINAGE COLLECTED FROM LAYER 2	7.7390	2393480.000	15.88
PERC./LEAKAGE THROUGH LAYER 3	9.883031	3056584.250	20.28
AVG. HEAD ON TOP OF LAYER 3	5.5077		
PERC./LEAKAGE THROUGH LAYER 4	10.476146	3240020.250	21.50
CHANGE IN WATER STORAGE	-1.279	-395602.687	-2.62
SOIL WATER AT START OF YEAR	42.575	13167500.000	
SOIL WATER AT END OF YEAR	41.296	12771897.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	8.554	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.04	4.74	6.18	4.99	4.99	5.93
	7.66	6.67	7.26	2.49	3.16	6.56
STD. DEVIATIONS	2.02	2.37	3.07	3.08	3.26	2.70
	3.23	2.73	2.46	1.50	1.65	3.32
RUNOFF						
TOTALS	0.004	0.000	0.022	0.156	0.081	0.000
	0.000	0.000	0.008	0.000	0.000	0.000
STD. DEVIATIONS	0.023	0.000	0.072	0.684	0.442	0.000
	0.000	0.000	0.042	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	1.608	2.102	3.188	5.104	4.742	5.319
	5.627	4.693	2.517	2.785	2.651	1.743

STD. DEVIATIONS	0.163	0.394	0.751	0.753	1.951	1.477
	1.195	1.469	0.528	0.474	0.401	0.277

LATERAL DRAINAGE COLLECTED FROM LAYER 2

TOTALS	1.2472	1.2686	1.4227	1.2546	0.6770	0.3192
	0.4008	0.5210	0.9570	1.1286	0.6147	0.7540
STD. DEVIATIONS	0.9891	0,6881	0.8519	0.7596	0.7627	0.3339
	0.4677	0.5402	0.7033	0.6273	0.2758	0.4852

PERCOLATION/LEAKAGE THROUGH LAYER 3

TOTALS	1.1569	1.1066	1.2182	1.1373	0.9156	0.6647
	0.6941	0.8179	0.9804	1.1642	0.9486	0.9752
STD. DEVIATIONS	0.2626	0.1598	0.2191	0.1701	0.2773	0.3380
	0.3510	0.3643	0.2777	0.1467	0.1143	0.2339

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.9659	0.9306	1.1061	1.1300	1.1664	1.0492
	0.9611	0.8714	0,8191	0.7923	0.9678	1.0318
STD. DEVIATIONS	0.1767	0.1497	0.1837	0.1588	0.1584	0.1576
	0.1762	0.1762	0.2113	0.2709	0.1921	0.1218

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 3

AVERAGES	10.0418	11.7505	11.9375	10.2914	5.0101	2.3436
	2.9710	4.2078	7.9102	9.9718	4.7757	5.9573
STD. DEVIATIONS	6.1282	5.1613	5.1643	5.1279	5.3246	2.8068
	3.7226	4.8073	5.0157	4.2816	3.1551	4.2537

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	64.67	(8.125)	19999844.0	100.00
RUNOFF	0.270	(0.8328)	83480.18	0.417
EVAPOTRANSPIRATION	42.080	(4.2831)	13014253.00	65.072
LATERAL DRAINAGE COLLECTED FROM LAYER 2	10.56558	(3.57408)	3267678.750	16.33852

PERCOLATION/LEAKAGE THROUGH FROM LAYER 3	11.77955	(1.36687)	3643133.250	18.21581
AVERAGE HEAD ACROSS TOP OF LAYER 3	7.264	(2.293)		
PERCOLATION/LEAKAGE THROUGH FROM LAYER 4	11.79175	(1.29939)	3646906.500	18.23467
CHANGE IN WATER STORAGE	-0.040	(3.7413)	-12474.04	-0.062

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	5.47	1691739.620
RUNOFF	3.346	1034943.3100
DRAINAGE COLLECTED FROM LAYER 2	0.22847	70661.10940
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.059521	18408.37500
AVERAGE HEAD ACROSS LAYER 3	29.841	
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.059574	18424.69920
SNOW WATER	2.24	692452.2500

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4170

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0104

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	1.5176	0.0843
2	3.5999	0.3000
3	9.6000	0.4000
4	26.5786	0.2769
SNOW WATER	0.000	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.01    (14 OCTOBER 1994)              **
**                   DEVELOPED BY ENVIRONMENTAL LABORATORY                  **
**                     USAE WATERWAYS EXPERIMENT STATION                    **
**                FOR USEPA RISK REDUCTION ENGINEERING LABORATORY           **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:     C:\HELP3\HELP3\NASPRAIN.D4
TEMPERATURE DATA FILE:       C:\HELP3\HELP3\NASPTEMP.D7
SOLAR RADIATION DATA FILE:   C:\HELP3\HELP3\NASPRAD.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\HELP3\NASPEVAP.D11
SOIL AND DESIGN DATA FILE:   C:\HELP3\HELP3\MEMBRANE.D10
OUTPUT DATA FILE:            C:\HELP3\HELP3\liner20.OUT


TIME:  12:11     DATE:   4/ 9/1996


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     TITLE:  Site 1 Clay Cap with 20 Mil Liner

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   1
          THICKNESS                  =     18.00   INCHES
          POROSITY                   =      0.4170 VOL/VOL
          FIELD CAPACITY             =      0.0450 VOL/VOL
          WILTING POINT              =      0.0180 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.1473 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.9999999780003-02 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  5.00
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 1

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4170	VOL/VOL
FIELD CAPACITY	=	0.0450	VOL/VOL
WILTING POINT	=	0.0180	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4170	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.999999978000E-02	CM/SEC
SLOPE	=	5.00	PERCENT
DRAINAGE LENGTH	=	500.0	FEET

LAYER 3

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 37

THICKNESS	=	0.01	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999999000E-10	CM/SEC
FML PINHOLE DENSITY	=	2.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	4.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 4

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 27

THICKNESS	=	24.00	INCHES
POROSITY	=	0.4000	VOL/VOL
FIELD CAPACITY	=	0.3660	VOL/VOL
WILTING POINT	=	0.2880	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.779999993000E-06	CM/SEC

LAYER 5

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

THICKNESS	=	96.00	INCHES
POROSITY	=	0.6710	VOL/VOL
FIELD CAPACITY	=	0.2920	VOL/VOL
WILTING POINT	=	0.0770	VOL/VOL

INITIAL SOIL WATER CONTENT = 0.2305 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000005000E-02 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 1 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 5.% AND A SLOPE LENGTH OF 500. FEET.

SCS RUNOFF CURVE NUMBER	=	39.30	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	85.200	ACRES
EVAPORATIVE ZONE DEPTH	=	28.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	6.821	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	11.676	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.504	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	39.382	INCHES
TOTAL INITIAL WATER	=	39.382	INCHES
TOTAL SUBSURFACE INFLOW	=	*0.00*	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM MOBILE ALABAMA

MAXIMUM LEAF AREA INDEX	=	4.50
START OF GROWING SEASON (JULIAN DATE)	=	39
END OF GROWING SEASON (JULIAN DATE)	=	351
AVERAGE ANNUAL WIND SPEED	=	9.00 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR MOBILE ALABAMA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.59	4.91	6.48	5.35	5.46	5.07
7.74	6.75	6.56	2.62	3.67	5.44

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING

COEFFICIENTS FOR MOBILE ALABAMA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
50.80	53.60	60.10	68.00	74.90	80.50
82.20	81.80	78.20	68.50	58.60	53.10

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR MOBILE ALABAMA

STATION LATITUDE = 30.41 DEGREES

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ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	57.07	17650380.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	43.443	13435859.000	76.12
DRAINAGE COLLECTED FROM LAYER 2	13.2882	4109711.000	23.28
PERC./LEAKAGE THROUGH LAYER 4	0.283047	87539.586	0.50
AVG. HEAD ON TOP OF LAYER 4	9.7960		
PERC./LEAKAGE THROUGH LAYER 5	1.842002	569686.937	3.23
CHANGE IN WATER STORAGE	-1.503	-464879.031	-2.63
SOIL WATER AT START OF YEAR	39.382	12179981.000	
SOIL WATER AT END OF YEAR	37.879	11715102.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	1.180	0.00

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ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	73.98	22880238.000	100.00
RUNOFF	4.308	1332456.500	5.82
EVAPOTRANSPIRATION	46.381	14344627.000	62.69
DRAINAGE COLLECTED FROM LAYER 2	21.4443	6632207.500	28.99
PERC./LEAKAGE THROUGH LAYER 4	0.358802	110968.766	0.48
AVG. HEAD ON TOP OF LAYER 4	12.4657		
PERC./LEAKAGE THROUGH LAYER 5	1.156991	357829.375	1.56
CHANGE IN WATER STORAGE	0.689	213112.125	0.93
SOIL WATER AT START OF YEAR	37.879	11715102.000	
SOIL WATER AT END OF YEAR	38.568	11928214.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	5.309	0.00

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ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	70.88	21921478.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	47.146	14580998.000	66.51
DRAINAGE COLLECTED FROM LAYER 2	24.7615	7658126.000	34.93
PERC./LEAKAGE THROUGH LAYER 4	0.432523	133769.016	0.61
AVG. HEAD ON TOP OF LAYER 4	14.9993		
PERC./LEAKAGE THROUGH LAYER 5	0.863815	267157.156	1.22
CHANGE IN WATER STORAGE	-1.891	-584792.125	-2.67
SOIL WATER AT START OF YEAR	38.568	11928214.000	
SOIL WATER AT END OF YEAR	36.677	11343422.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00

SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-10.434	0.00

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ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
PRECIPITATION	61.54	19032844.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	45.247	13993697.000	73.52
DRAINAGE COLLECTED FROM LAYER 2	18.0187	5572765.500	29.28
PERC./LEAKAGE THROUGH LAYER 4	0.328383	101560.922	0.53
AVG. HEAD ON TOP OF LAYER 4	11.3997		
PERC./LEAKAGE THROUGH LAYER 5	0.728201	225215.094	1.18
CHANGE IN WATER STORAGE	-2.454	-758827.125	-3.99
SOIL WATER AT START OF YEAR	36.677	11343422.000	
SOIL WATER AT END OF YEAR	34.224	10584595.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-6.526	0.00

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ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	72.47	22413228.000	100.00
RUNOFF	2.789	862617.437	3.85
EVAPOTRANSPIRATION	47.456	14676849.000	65.48
DRAINAGE COLLECTED FROM LAYER 2	21.6544	6697176.500	29.88

PERC./LEAKAGE THROUGH LAYER 4	0.399613	123590.641	0.55
AVG. HEAD ON TOP OF LAYER 4	13.9275		
PERC./LEAKAGE THROUGH LAYER 5	0.617255	190902.234	0.85
CHANGE IN WATER STORAGE	-0.046	-14310.904	-0.06
SOIL WATER AT START OF YEAR	34.224	10584595.000	
SOIL WATER AT END OF YEAR	34.178	10570284.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-5.917	0.00

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ANNUAL TOTALS FOR YEAR 6

	INCHES	CU. FEET	PERCENT
PRECIPITATION	69.50	21494682.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	50.081	15488735.000	72.06
DRAINAGE COLLECTED FROM LAYER 2	18.1456	5612001.500	26.11
PERC./LEAKAGE THROUGH LAYER 4	0.397606	122969.977	0.57
AVG. HEAD ON TOP OF LAYER 4	13.7873		
PERC./LEAKAGE THROUGH LAYER 5	0.559444	173022.469	0.80
CHANGE IN WATER STORAGE	0.714	220923.547	1.03
SOIL WATER AT START OF YEAR	34.178	10570284.000	
SOIL WATER AT END OF YEAR	34.892	10791208.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-2.102	0.00

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ANNUAL TOTALS FOR YEAR 7

	INCHES	CU. FEET	PERCENT
PRECIPITATION	63.55	19654488.000	100.00
RUNOFF	1.026	317347.219	1.61
EVAPOTRANSPIRATION	42.000	12989444.000	66.09
DRAINAGE COLLECTED FROM LAYER 2	21.8181	6747799.500	34.33
PERC./LEAKAGE THROUGH LAYER 4	0.358095	110750.328	0.56
AVG. HEAD ON TOP OF LAYER 4	12.4855		
PERC./LEAKAGE THROUGH LAYER 5	0.514633	159163.672	0.81
CHANGE IN WATER STORAGE	-1.808	-559266.125	-2.85
SOIL WATER AT START OF YEAR	34.892	10791208.000	
SOIL WATER AT END OF YEAR	33.084	10231942.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.830	0.00

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ANNUAL TOTALS FOR YEAR 8

	INCHES	CU. FEET	PERCENT
PRECIPITATION	60.94	18847274.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	43.332	13401425.000	71.11
DRAINAGE COLLECTED FROM LAYER 2	13.0300	4029875.250	21.38
PERC./LEAKAGE THROUGH LAYER 4	0.264996	81956.812	0.43
AVG. HEAD ON TOP OF LAYER 4	9.2155		
PERC./LEAKAGE THROUGH LAYER 5	0.475656	147108.984	0.78
CHANGE IN WATER STORAGE	4.103	1268861.620	6.73

SOIL WATER AT START OF YEAR	33.084	10231942.000	
SOIL WATER AT END OF YEAR	37.186	11500803.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	3.106	0.00

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ANNUAL TOTALS FOR YEAR 9

	INCHES	CU. FEET	PERCENT
PRECIPITATION	57.40	17752440.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	42.587	13171060.000	74.19
DRAINAGE COLLECTED FROM LAYER 2	15.5738	4816610.500	27.13
PERC./LEAKAGE THROUGH LAYER 4	0.294671	91134.703	0.51
AVG. HEAD ON TOP OF LAYER 4	10.2584		
PERC./LEAKAGE THROUGH LAYER 5	0.435822	134789.187	0.76
CHANGE IN WATER STORAGE	-1.196	-370021.219	-2.08
SOIL WATER AT START OF YEAR	37.186	11500803.000	
SOIL WATER AT END OF YEAR	35.990	11130782.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.839	0.00

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ANNUAL TOTALS FOR YEAR 10

	INCHES	CU. FEET	PERCENT
PRECIPITATION	66.29	20501904.000	100.00

RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	48.628	15039461.000	73.36
DRAINAGE COLLECTED FROM LAYER 2	17.2660	5339963.000	26.05
PERC./LEAKAGE THROUGH LAYER 4	0.380284	117612.812	0.57
AVG. HEAD ON TOP OF LAYER 4	13.1617		
PERC./LEAKAGE THROUGH LAYER 5	0.409627	126687.867	0.62
CHANGE IN WATER STORAGE	-0.014	-4221.304	-0.02
SOIL WATER AT START OF YEAR	35.990	11130782.000	
SOIL WATER AT END OF YEAR	35.976	11126561.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	12.010	0.00

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ANNUAL TOTALS FOR YEAR 11

	INCHES	CU. FEET	PERCENT
PRECIPITATION	68.39	21151382.000	100.00
RUNOFF	2.280	705261.375	3.33
EVAPOTRANSPIRATION	43.144	13343493.000	63.09
DRAINAGE COLLECTED FROM LAYER 2	22.3797	6921508.000	32.72
PERC./LEAKAGE THROUGH LAYER 4	0.391768	121164.430	0.57
AVG. HEAD ON TOP OF LAYER 4	13.5962		
PERC./LEAKAGE THROUGH LAYER 5	0.402586	124510.312	0.59
CHANGE IN WATER STORAGE	0.183	56614.785	0.27
SOIL WATER AT START OF YEAR	35.976	11126561.000	
SOIL WATER AT END OF YEAR	36.159	11183175.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-5.300	0.00

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ANNUAL TOTALS FOR YEAR 12

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.84	15105039.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	40.468	12515926.000	82.86
DRAINAGE COLLECTED FROM LAYER 2	13.2522	4098593.750	27.13
PERC./LEAKAGE THROUGH LAYER 4	0.300588	92964.531	0.62
AVG. HEAD ON TOP OF LAYER 4	10.3927		
PERC./LEAKAGE THROUGH LAYER 5	0.368672	114021.492	0.75
CHANGE IN WATER STORAGE	-5.249	-1623507.750	-10.75
SOIL WATER AT START OF YEAR	36.159	11183175.000	
SOIL WATER AT END OF YEAR	30.910	9559668.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	5.328	0.00

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ANNUAL TOTALS FOR YEAR 13

	INCHES	CU. FEET	PERCENT
PRECIPITATION	69.22	21408084.000	100.00
RUNOFF	2.072	640865.562	2.99
EVAPOTRANSPIRATION	42.792	13234544.000	61.82
DRAINAGE COLLECTED FROM LAYER 2	19.7129	6096738.000	28.48
PERC./LEAKAGE THROUGH LAYER 4	0.342949	106065.914	0.50
AVG. HEAD ON TOP OF LAYER 4	11.9452		

PERC./LEAKAGE THROUGH LAYER 5	0.394199	121916.398	0.57
CHANGE IN WATER STORAGE	4.249	1314012.370	6.14
SOIL WATER AT START OF YEAR	30.910	9559668.000	
SOIL WATER AT END OF YEAR	35.159	10873680.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	8.111	0.00

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ANNUAL TOTALS FOR YEAR 14

	INCHES	CU. FEET	PERCENT
PRECIPITATION	55.31	17106050.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	37.123	11481212.000	67.12
DRAINAGE COLLECTED FROM LAYER 2	15.7526	4871901.500	28.48
PERC./LEAKAGE THROUGH LAYER 4	0.294109	90960.719	0.53
AVG. HEAD ON TOP OF LAYER 4	10.2307		
PERC./LEAKAGE THROUGH LAYER 5	0.344722	106614.109	0.62
CHANGE IN WATER STORAGE	2.090	646327.875	3.78
SOIL WATER AT START OF YEAR	35.159	10873680.000	
SOIL WATER AT END OF YEAR	37.248	11520008.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-5.834	0.00

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ANNUAL TOTALS FOR YEAR 15

	INCHES	CU. FEET	PERCENT
~PRECIPITATION	57.38	17746258.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	46.612	14415827.000	81.23
DRAINAGE COLLECTED FROM LAYER 2	15.4007	4763078.000	26.84
PERC./LEAKAGE THROUGH LAYER 4	0.309759	95801.164	0.54
AVG. HEAD ON TOP OF LAYER 4	10.7677		
PERC./LEAKAGE THROUGH LAYER 5	0.351829	108812.266	0.61
CHANGE IN WATER STORAGE	-4.984	-1541457.750	-8.69
SOIL WATER AT START OF YEAR	37.248	11520008.000	
SOIL WATER AT END OF YEAR	32.264	9978550.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.433	0.00

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ANNUAL TOTALS FOR YEAR 16

	INCHES	CU. FEET	PERCENT
PRECIPITATION	57.30	17721512.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	39.086	12088405.000	68.21
DRAINAGE COLLECTED FROM LAYER 2	11.7908	3646621.000	20.58
PERC./LEAKAGE THROUGH LAYER 4	0.232526	71914.625	0.41
AVG. HEAD ON TOP OF LAYER 4	8.0120		
PERC./LEAKAGE THROUGH LAYER 5	0.361237	111722.086	0.63
CHANGE IN WATER STORAGE	6.062	1874765.000	10.58
SOIL WATER AT START OF YEAR	32.264	9978550.000	
SOIL WATER AT END OF YEAR	38.326	11853315.000	

SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-2.350	0.00

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ANNUAL TOTALS FOR YEAR 17

	INCHES	CU. FEET	PERCENT
PRECIPITATION	80.96	25038988.000	100.00
RUNOFF	6.431	1988979.120	7.94
EVAPOTRANSPIRATION	51.415	15901354.000	63.51
DRAINAGE COLLECTED FROM LAYER 2	23.3769	7229908.500	28.87
PERC./LEAKAGE THROUGH LAYER 4	0.436375	134960.328	0.54
AVG. HEAD ON TOP OF LAYER 4	15.1350		
PERC./LEAKAGE THROUGH LAYER 5	0.315055	97439.031	0.39
CHANGE IN WATER STORAGE	-0.578	-178688.094	-0.71
SOIL WATER AT START OF YEAR	38.326	11853315.000	
SOIL WATER AT END OF YEAR	37.748	11674627.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-4.544	0.00

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ANNUAL TOTALS FOR YEAR 18

	INCHES	CU. FEET	PERCENT
PRECIPITATION	58.62	18129760.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	43.075	13321908.000	73.48

DRAINAGE COLLECTED FROM LAYER 2	14.8045	4578671.000	25.26
PERC./LEAKAGE THROUGH LAYER 4	0.255645	79064.727	0.44
AVG. HEAD ON TOP OF LAYER 4	8.8797		
PERC./LEAKAGE THROUGH LAYER 5	0.307518	95107.836	0.52
CHANGE IN WATER STORAGE	0.434	134075.359	0.74
SOIL WATER AT START OF YEAR	37.748	11674627.000	
SOIL WATER AT END OF YEAR	38.182	11808702.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-3.733	0.00

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ANNUAL TOTALS FOR YEAR 19

	INCHES	CU. FEET	PERCENT
PRECIPITATION	79.46	24575070.000	100.00
RUNOFF	1.347	416580.875	1.70
EVAPOTRANSPIRATION	47.953	14830579.000	60.35
DRAINAGE COLLECTED FROM LAYER 2	32.8251	10152002.000	41.31
PERC./LEAKAGE THROUGH LAYER 4	0.516621	159778.609	0.65
AVG. HEAD ON TOP OF LAYER 4	17.9826		
PERC./LEAKAGE THROUGH LAYER 5	0.312346	96601.078	0.39
CHANGE IN WATER STORAGE	-2.977	-920699.625	-3.75
SOIL WATER AT START OF YEAR	38.182	11808702.000	
SOIL WATER AT END OF YEAR	35.205	10888003.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	6.120	0.00

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ANNUAL TOTALS FOR YEAR 20

	INCHES	CU. FEET	PERCENT
PRECIPITATION	66.69	20625614.000	100.00
RUNOFF	0.902	279045.437	1.35
EVAPOTRANSPIRATION	46.782	14468479.000	70.15
DRAINAGE COLLECTED FROM LAYER 2	21.2501	6572142.000	31.86
PERC./LEAKAGE THROUGH LAYER 4	0.340730	105379.750	0.51
AVG. HEAD ON TOP OF LAYER 4	11.8518		
PERC./LEAKAGE THROUGH LAYER 5	0.316042	97744.094	0.47
CHANGE IN WATER STORAGE	-2.560	-791797.687	-3.84
SOIL WATER AT START OF YEAR	35.205	10888003.000	
SOIL WATER AT END OF YEAR	32.645	10096205.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	1.364	0.00

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ANNUAL TOTALS FOR YEAR 21

	INCHES	CU. FEET	PERCENT
PRECIPITATION	62.16	19224596.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	46.129	14266633.000	74.21
DRAINAGE COLLECTED FROM LAYER 2	12.3608	3822911.500	19.89
PERC./LEAKAGE THROUGH LAYER 4	0.270040	83516.875	0.43
AVG. HEAD ON TOP OF LAYER 4	9.3740		
PERC./LEAKAGE THROUGH LAYER 5	0.392071	121258.102	0.63
CHANGE IN WATER STORAGE	3.278	1013790.120	5.27

SOIL WATER AT START OF YEAR	32.645	10096205.000	
SOIL WATER AT END OF YEAR	35.923	11109995.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	2.922	0.00

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ANNUAL TOTALS FOR YEAR 22

	INCHES	CU. FEET	PERCENT
PRECIPITATION	72.03	22277146.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	48.114	14880443.000	66.80
DRAINAGE COLLECTED FROM LAYER 2	22.4920	6956248.000	31.23
PERC./LEAKAGE THROUGH LAYER 4	0.454591	140594.187	0.63
AVG. HEAD ON TOP OF LAYER 4	15.7640		
PERC./LEAKAGE THROUGH LAYER 5	0.341382	105581.258	0.47
CHANGE IN WATER STORAGE	1.083	334872.781	1.50
SOIL WATER AT START OF YEAR	35.923	11109995.000	
SOIL WATER AT END OF YEAR	37.005	11444868.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	1.484	0.00

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ANNUAL TOTALS FOR YEAR 23

	INCHES	CU. FEET	PERCENT
PRECIPITATION	77.32	23913220.000	100.00

RUNOFF	1.204	372461.625	1.56
EVAPOTRANSPIRATION	48.096	14874868.000	62.20
DRAINAGE COLLECTED FROM LAYER 2	25.0079	7734340.500	32.34
PERC./LEAKAGE THROUGH LAYER 4	0.431027	133306.250	0.56
AVG. HEAD ON TOP OF LAYER 4	14.9741		
PERC./LEAKAGE THROUGH LAYER 5	0.349401	108061.281	0.45
CHANGE IN WATER STORAGE	2.663	823484.562	3.44
SOIL WATER AT START OF YEAR	37.005	11444868.000	
SOIL WATER AT END OF YEAR	39.668	12268353.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	2.562	0.00

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ANNUAL TOTALS FOR YEAR 24

	INCHES	CU. FEET	PERCENT
PRECIPITATION	61.35	18974080.000	100.00
RUNOFF	1.994	616562.312	3.25
EVAPOTRANSPIRATION	47.399	14659380.000	77.26
DRAINAGE COLLECTED FROM LAYER 2	19.2791	5962558.000	31.42
PERC./LEAKAGE THROUGH LAYER 4	0.326192	100883.344	0.53
AVG. HEAD ON TOP OF LAYER 4	11.2762		
PERC./LEAKAGE THROUGH LAYER 5	0.381761	118069.625	0.62
CHANGE IN WATER STORAGE	-7.703	-2382483.500	-12.56
SOIL WATER AT START OF YEAR	39.668	12268353.000	
SOIL WATER AT END OF YEAR	31.965	9885869.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00

ANNUAL WATER BUDGET BALANCE	0.0000	-6.507	0.00

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ANNUAL TOTALS FOR YEAR 25

	INCHES	CU. FEET	PERCENT
PRECIPITATION	68.30	21123554.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	46.020	14232816.000	67.38
DRAINAGE COLLECTED FROM LAYER 2	16.1988	5009907.500	23.72
PERC./LEAKAGE THROUGH LAYER 4	0.333458	103130.453	0.49
AVG. HEAD ON TOP OF LAYER 4	11.5762		
PERC./LEAKAGE THROUGH LAYER 5	0.396878	122744.773	0.58
CHANGE IN WATER STORAGE	5.685	1758083.370	8.32
SOIL WATER AT START OF YEAR	31.965	9885869.000	
SOIL WATER AT END OF YEAR	37.649	11643952.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	1.613	0.00

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ANNUAL TOTALS FOR YEAR 26

	INCHES	CU. FEET	PERCENT
PRECIPITATION	69.76	21575084.000	100.00
RUNOFF	*0.000*	*0.000*	*0.00*
EVAPOTRANSPIRATION	48.320	14944345.000	69.27
@DRAINAGE COLLECTED FROM LAYER 2	24.7308	7648645.000	35.45
PERC./LEAKAGE THROUGH LAYER 4	0.433234	133988.937	0.62

AVG. HEAD ON TOP OF LAYER 4	15.0617		
PERC./LEAKAGE THROUGH LAYER 5	0.319425	98790.586	0.46
CHANGE IN WATER STORAGE	-3.611	-1116690.620	-5.18
SOIL WATER AT START OF YEAR	37.649	11643952.000	
SOIL WATER AT END OF YEAR	34.038	10527262.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-6.415	0.00

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ANNUAL TOTALS FOR YEAR 27

	INCHES	CU. FEET	PERCENT
PRECIPITATION	59.59	18429758.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	44.733	13834922.000	75.07
DRAINAGE COLLECTED FROM LAYER 2	11.5820	3582045.750	19.44
PERC./LEAKAGE THROUGH LAYER 4	0.263515	81498.945	0.44
AVG. HEAD ON TOP OF LAYER 4	9.1388		
PERC./LEAKAGE THROUGH LAYER 5	0.407201	125937.641	0.68
CHANGE IN WATER STORAGE	2.867	806847.812	4.81
SOIL WATER AT START OF YEAR	34.038	10527262.000	
SOIL WATER AT END OF YEAR	36.906	11414110.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	3.927	0.00

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ANNUAL TOTALS FOR YEAR 28

	INCHES	CU. FEET	PERCENT
PRECIPITATION	63.40	19608094.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	42.025	12997241.000	66.29
DRAINAGE COLLECTED FROM LAYER 2	18.7371	5794926.500	29.55
PERC./LEAKAGE THROUGH LAYER 4	0.334464	103441.687	0.53
AVG. HEAD ON TOP OF LAYER 4	11.5516		
PERC./LEAKAGE THROUGH LAYER 5	0.367449	113643.266	0.58
CHANGE IN WATER STORAGE	2.271	702279.625	3.58
SOIL WATER AT START OF YEAR	36.906	11414110.000	
SOIL WATER AT END OF YEAR	39.177	12116389.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	3.954	0.00

ANNUAL TOTALS FOR YEAR 29

	INCHES	CU. FEET	PERCENT
PRECIPITATION	61.57	19042118.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	44.329	13710048.000	72.00
DRAINAGE COLLECTED FROM LAYER 2	20.5359	6351247.000	33.35
PERC./LEAKAGE THROUGH LAYER 4	0.377896	116874.125	0.61
AVG. HEAD ON TOP OF LAYER 4	13.1131		
PERC./LEAKAGE THROUGH LAYER 5	0.360695	111554.297	0.59
CHANGE IN WATER STORAGE	-3.656	-1130732.500	-5.94
SOIL WATER AT START OF YEAR	39.177	12116389.000	
SOIL WATER AT END OF YEAR	35.521	10985657.000	

SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.562	0.00

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ANNUAL TOTALS FOR YEAR 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.73	15071021.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	34.300	10608139.000	70.39
DRAINAGE COLLECTED FROM LAYER 2	14.2728	4414219.500	29.29
PERC./LEAKAGE THROUGH LAYER 4	0.285132	88184.414	0.59
AVG. HEAD ON TOP OF LAYER 4	9.9396		
PERC./LEAKAGE THROUGH LAYER 5	0.359060	111048.734	0.74
CHANGE IN WATER STORAGE	-0.202	-62383.980	-0.41
SOIL WATER AT START OF YEAR	35.521	10985657.000	
SOIL WATER AT END OF YEAR	35.319	10923273.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-2.369	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						

TOTALS	4.04	4.74	6.18	4.99	4.99	5.93
	7.66	6.67	7.26	2.49	3.16	6.56
STD. DEVIATIONS	2.02	2.37	3.07	3.08	3.26	2.70
	3.23	2.73	2.46	1.50	1.65	3.32

RUNOFF

TOTALS	0.066	0.031	0.230	0.217	0.136	0.000
	0.000	0.000	0.075	0.034	0.000	0.021
STD. DEVIATIONS	0.364	0.165	0.715	0.785	0.745	0.000
	0.000	0.000	0.372	0.187	0.000	0.116

EVAPOTRANSPIRATION

TOTALS	1.572	2.108	3.255	5.565	5.677	5.786
	5.916	4.934	2.489	2.871	2.839	1.796
STD. DEVIATIONS	0.139	0.372	0.689	0.391	1.544	1.474
	1.155	1.471	0.530	0.510	0.283	0.182

LATERAL DRAINAGE COLLECTED FROM LAYER 2

TOTALS	2.3213	2.3750	2.4937	2.0006	1.1502	0.6457
	0.7611	0.9394	1.5615	1.7469	1.0700	1.6261
STD. DEVIATIONS	1.2940	1.0667	1.0722	0.9408	0.9321	0.3751
	0.6560	0.7887	1.0658	0.8995	0.3748	0.8129

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0408	0.0403	0.0438	0.0363	0.0210	0.0129
	0.0142	0.0181	0.0286	0.0359	0.0248	0.0310
STD. DEVIATIONS	0.0125	0.0082	0.0087	0.0100	0.0147	0.0097
	0.0123	0.0142	0.0131	0.0097	0.0083	0.0110

PERCOLATION/LEAKAGE THROUGH LAYER 5

TOTALS	0.0452	0.0403	0.0455	0.0459	0.0447	0.0373
	0.0371	0.0395	0.0380	0.0403	0.0406	0.0374
STD. DEVIATIONS	0.0363	0.0310	0.0314	0.0281	0.0286	0.0297
	0.0294	0.0254	0.0233	0.0219	0.0198	0.0208

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 4

AVERAGES	16.5368	18.2177	17.9137	15.3099	8.5527	5.3943
	5.7584	7.3390	12.0438	14.6720	10.4260	12.6596
STD. DEVIATIONS	5.0516	3.7504	3.5671	4.2363	6.0340	4.0936
	5.0344	5.8080	5.5766	3.9677	3.5131	4.5156

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	64.67	(8.125)	19999844.0	100.00
RUNOFF	0.812	(1.5146)	251072.58	1.255
EVAPOTRANSPIRATION	44.807	(3.7963)	13857758.00	69.289
LATERAL DRAINAGE COLLECTED FROM LAYER 2	18.69144	(4.92124)	5780814.500	28.90430
PERCOLATION/LEAKAGE THROUGH FROM LAYER 4	0.34762	(0.06924)	107510.930	0.53756
AVERAGE HEAD ACROSS TOP OF LAYER 4	12.069	(2.410)		
PERCOLATION/LEAKAGE THROUGH FROM LAYER 5	0.49177	(0.31465)	152091.375	0.76046
CHANGE IN WATER STORAGE	-0.135	(3.2792)	-41890.29	-0.209

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	5.47	1691739.620
RUNOFF	3.376	1044179.6900
DRAINAGE COLLECTED FROM LAYER 2	0.23054	71300.45310
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.002362	730.65063
AVERAGE HEAD ACROSS LAYER 4	30.000	
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.007010	2168.01514
SNOW WATER	2.24	692452.2500

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4170

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0114

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	2.9123	0.1618
2	5.0039	0.4170
3	0.0000	0.0000
4	9.6000	0.4000
5	17.8026	0.1854
SNOW WATER	0.000	

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Appendix C

Groundwater Modeling

1.0 MODELING OBJECTIVE

The groundwater flow model for Naval Air Station Site 1, Pensacola, Florida (Figure 1), will be used to help predict the movement of groundwater and contaminants under ambient and pumping conditions.

2.0 CONCEPTUAL MODEL

Included in Remedial Investigation.

2.1 Aquifer Characteristics

Included in Remedial Investigation.

2.2 Groundwater Flow System

Included in Remedial Investigation.

2.3 Hydraulic Properties

Included in Remedial Investigation.

2.4 Sources and Sinks

The source of groundwater within this model is rain. The groundwater sink in this model is Bayou Grande.

3.0 COMPUTER CODE

The computer code used was VisualMODFLOW, version 1.49-VB by Waterloo Hydrogeologic, Inc. 1995. VisualMODFLOW is a three dimensional finite-difference groundwater flow model. The solution arrays are computed by a combination of iterative techniques and direct solution techniques on a system of linear algebraic equations.

VisualMODFLOW was used for calibration, calculating budgetary data, and creating output suitable for import into the contouring and 3-D surface mapping software package Surfer, v5.03, 1995 Golden Software, Inc.

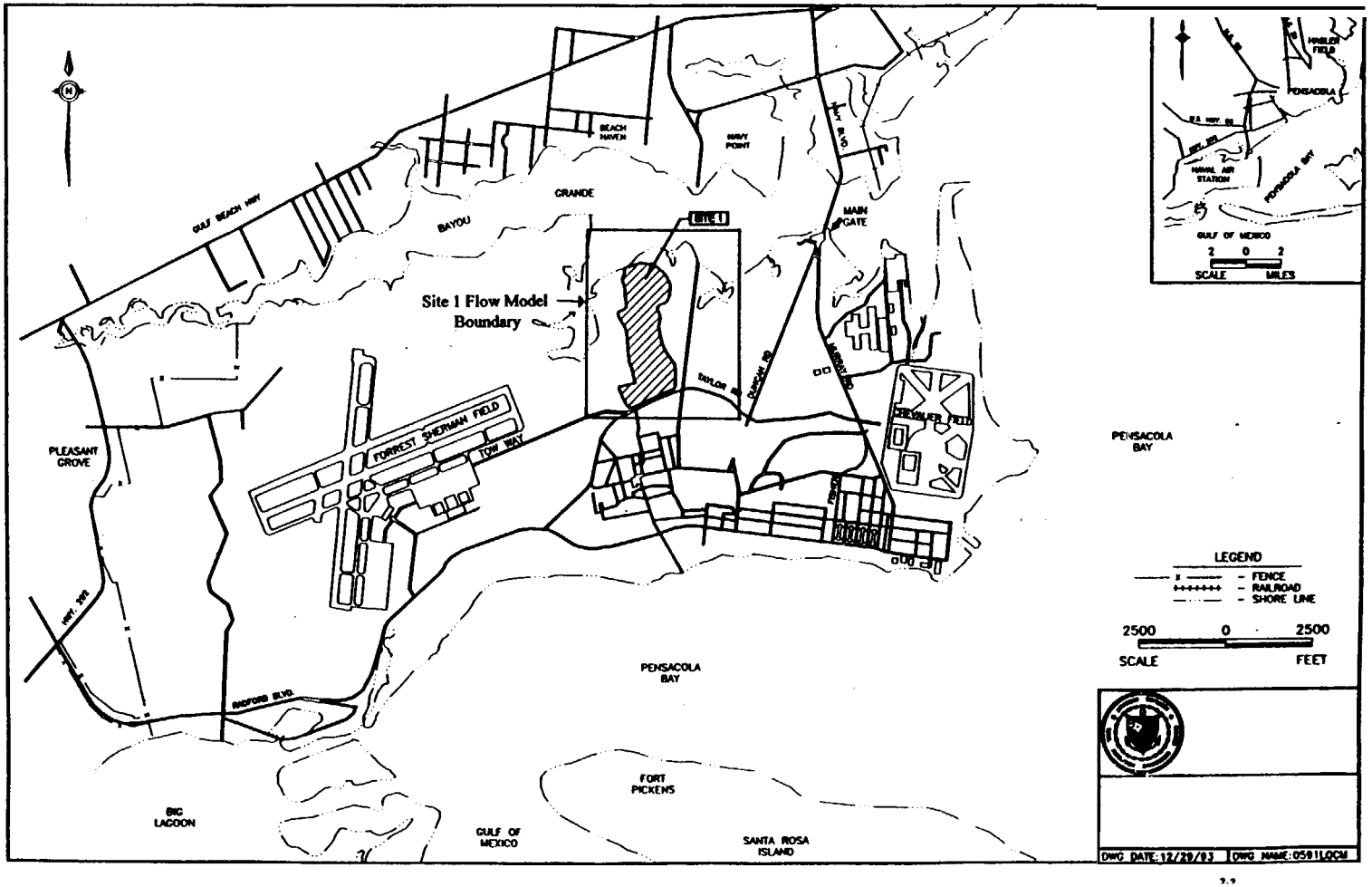

Figure 1. Map of Naval Air Sation, West Florida showing the location of Site 1

MODPATH is a particle tracking post-processing package for computing 3D path lines using output from steady-state simulations obtained from the MODFLOW portion of the VisualMODFLOW package. Particles are placed at points of interest within a completed flow model and Modpath computes advective transport pathlines into the future (forward tracking), or into the past (backward tracking). This type of information is commonly used to delineate zones of contribution for pumping wells.

4.0 GROUNDWATER FLOW MODEL CONSTRUCTION

4.1 Model Grid

The model consists of 34 columns and 33 rows (Figure 2). The grid spacing between columns is 150 ft for a total east-west dimension of 5,100 ft. The grid spacing between rows is also 150 ft for a total north-south dimension of 7,050 ft. The areal extent represented by the grid is 35,955,000 square feet (or 1.29 square miles).

The grid is split vertically into three layers to represent a difference in hydraulic conductivity with depth. The top layer, layer 1, is 30 ft thick. The middle layer, layer 2, is 15 ft thick. The bottom layer, layer 3, is 8 ft thick. The total thickness of the model is 53 ft. The three layers are hydrostratigraphic units and have no stratigraphic counter parts in the classic sense. Layers 1 and 2 belong to a higher hydraulic conductivity layer and will be referred to as the shallow interval of the surficial aquifer. Layer 3 has a lower hydraulic conductivity relative to layers 1 and 2 and will be know as the intermediate interval of the surficial aquifer. The deep interval is represent by a no-flow boundary at the base of the model. Each cell within the grided volume is assigned the status of specified head cell, inactive cell, or active cells (Figure 3 a, b, c). Inactive cells are not included in any model calculations. Specified head cells never change their assigned head value. Active head cells *can* vary in response to modeled hydraulic stresses. Layer 1 is modeled as unconfined. Layers 2 and 3 are modeled as confined/unconfined where transmissivities and storativities (not applicable to this model) can vary. Initial heads in the model are set constant by layer at 5.32 ft. The aquifer materials are considered homogeneous within layers and isotropic throughout. Porosity throughout the model is .3.

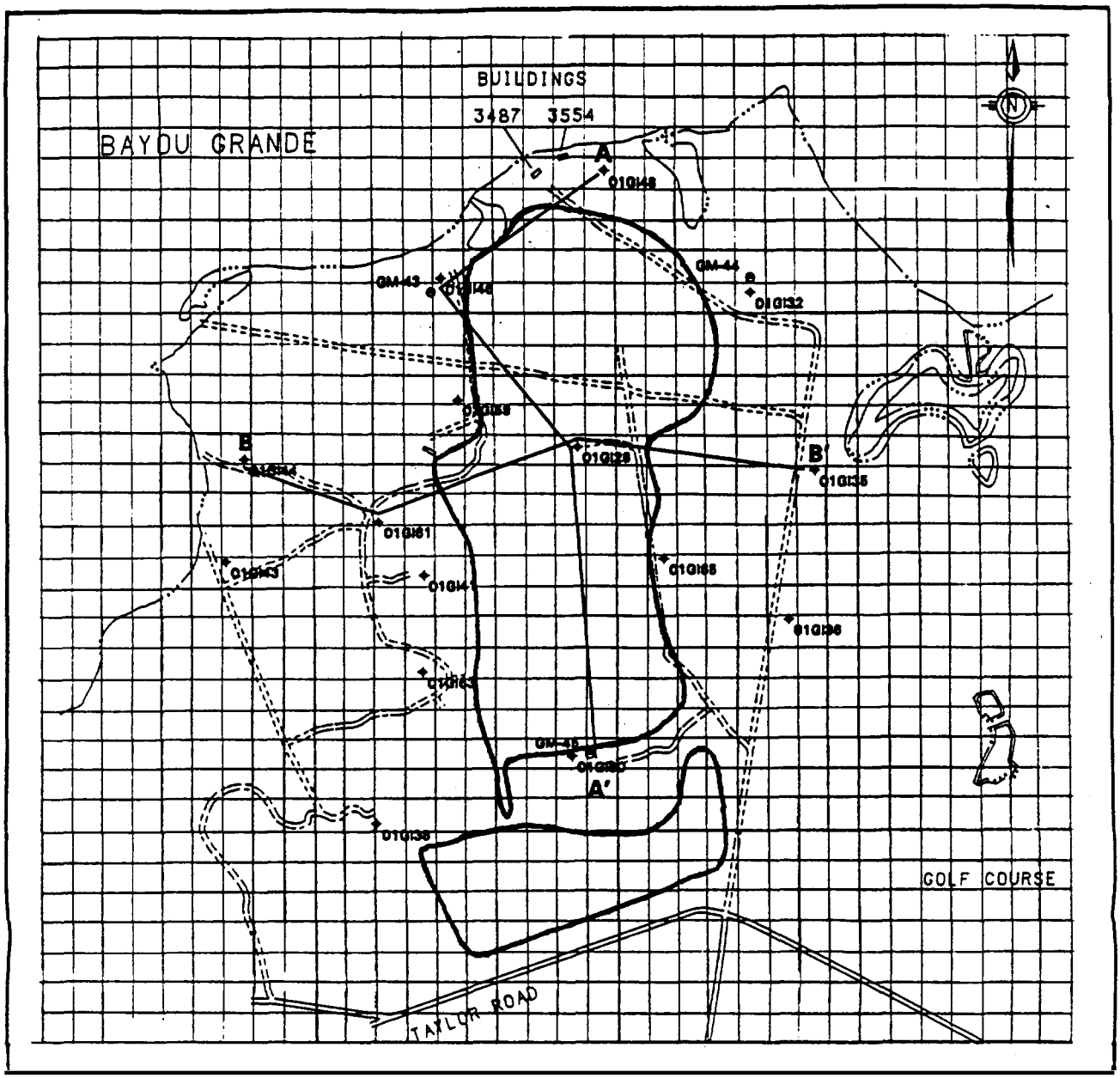

Figure 2. Map of Site 1 and the area around it showing the model grid design.

Figure 3a. Map showing the **cell status** of **layer** 1

-1 = **specified head cells**
0 = **inactive cells**
1 = **active cells**

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0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0-1-1-1-1-1-1-1 1 1-1 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0-1-1 1 1 1-1-1 1 1 1 1-1 0 0 0 0 0 0 0 0
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Figure 3b. Map showing the cell status of layer **2.**

-1 = specified **head** cells
0 = inactive cells
1 = active **cells**

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 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0
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Figure 3c Map showing the cell status of layer 3

-1 = specified head cells
0 = inactive cells
1 = active cells

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Layers 2 and 3 are horizontal and remain at a constant thickness throughout the model domain. The upper boundary of layer 1 was generated from elevation data at each monitoring well on Site 1 and from assigning an elevation of zero at each grid cell along the shoreline. These data were processed through Surfer and the resulting grid file was imported into VisualMODFLOW (Figure 4). The variogram model used in the Kriging process was linear with no drift and no nugget effect. The Kriging search parameter was set to consider all data points within the model boundaries. The hydraulic head is allowed to exceed the ground surface elevation in VisualMODFLOW.

4.2 Boundary Conditions

The boundary conditions along the northern shoreline consists of specified head in layer 1 and no flow boundaries in layers 2 and 3. The specified head boundaries in layer 1 are set at 0.0 ft representing mean sea level (msl). This represents where the fresh water discharges into Bayou Grande. The no flow boundaries in layers 2 and 3 represents the freshwater/saltwater interface. The representation of a mixing zone is not necessary in this model due to its large areal extent compared to its thickness. The freshwater/saltwater interface is vertical within the model and coincident with the edge of the land.

The eastern, western, and southern boundaries are all specified heads. The nodal values were derived from Kriging with Surfer the potentiometric surface elevations from the surficial and intermediate wells, respectively. The Kriging grid was created with the same dimensions as the flow model grid and used the same Kriging model as used for the topographic surface. The mesh centered Kriged grid values were converted to block centered by averaging the four mesh centered values and assigning them to their central cell. This procedure was done for all eastern, western and southern boundary specified head cells. Due to the lack of vertical gradient expressed in the initial model output, the specified head values from layer 1 and 2 *are* ultimately used in layer 3. This redefinition of the lower boundary conditions did not change the horizontal or vertical head distribution of calculated head output in any way. This modification also made the calibration and sensitivity testing process more efficient.

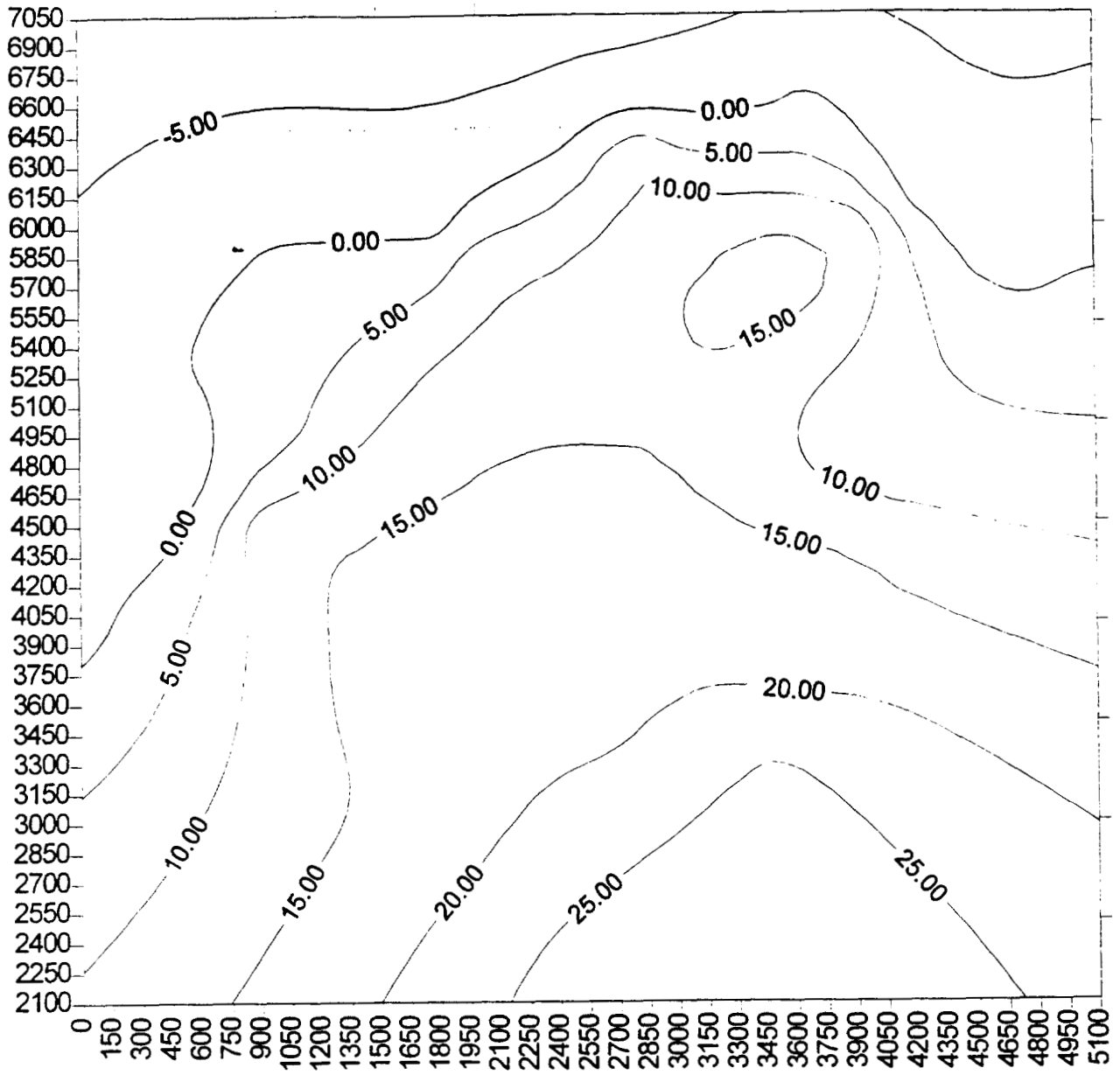


Figure 4. Kriged topographic surface at Site 1. Shaded region represent bathymetric contours that are out of the active active model region. Countour interval = 5.0 ft.

The lower boundary is a no-flow boundary representing a lower conductivity layer that underlies the entire surficial aquifer. The top layer of the model is unbounded.

Layers 2 acts as a lower limit to the inland water bodies represented as specified head nodes in layer 1.

4.4 Recharge/Evapotranspiration

The average yearly rainfall at Site 1 is 60 in/yr (Fernald and Patten, 1984). A recharge value of 30 in/yr is applied to the entire modeled domain. Evapotranspiration data are limited to a yearly average value: 30 in/yr (Fernald and Patten, 1984). Sixty in/yr of rain minus 30 in/yr evapotranspiration leaves a net recharge of 30 in/yr.

4.5 Hydraulic Parameters

Hydraulic parameters consist of 10 specific capacities tests in the shallow interval of the surficial aquifer and 15 specific capacity tests in the intermediate interval of the surficial aquifer. Specific capacity tests were done after well development in the shallow interval of the surficial aquifer and during well development in the intermediate interval of the surficial aquifer. The specific capacity test data were then converted to hydraulic conductivities. Due to the differences in the stage of well development of the wells in the shallow and intermediate intervals, the geometric mean of the hydraulic conductivities will be used in the preliminary model. The geometric mean for hydraulic conductivity of the shallow interval is 47.9 ft/day. This value is assigned uniformly to layers 1 and 2. The geometric mean for hydraulic conductivity for the intermediate interval is 24.2 ft/day. This value is assigned uniformly to layer 3.

4.6 Other Assumptions

Other modeling assumptions are necessary to allow a simple model to represent the natural state of the system. 1) Steady-state conditions exist within the aquifer. There are no head changes over time. All stresses, if any, have reached equilibrium within the aquifer. 2) One fluid: fresh water only. Brackish water and sea water have higher specific weights and higher dynamic

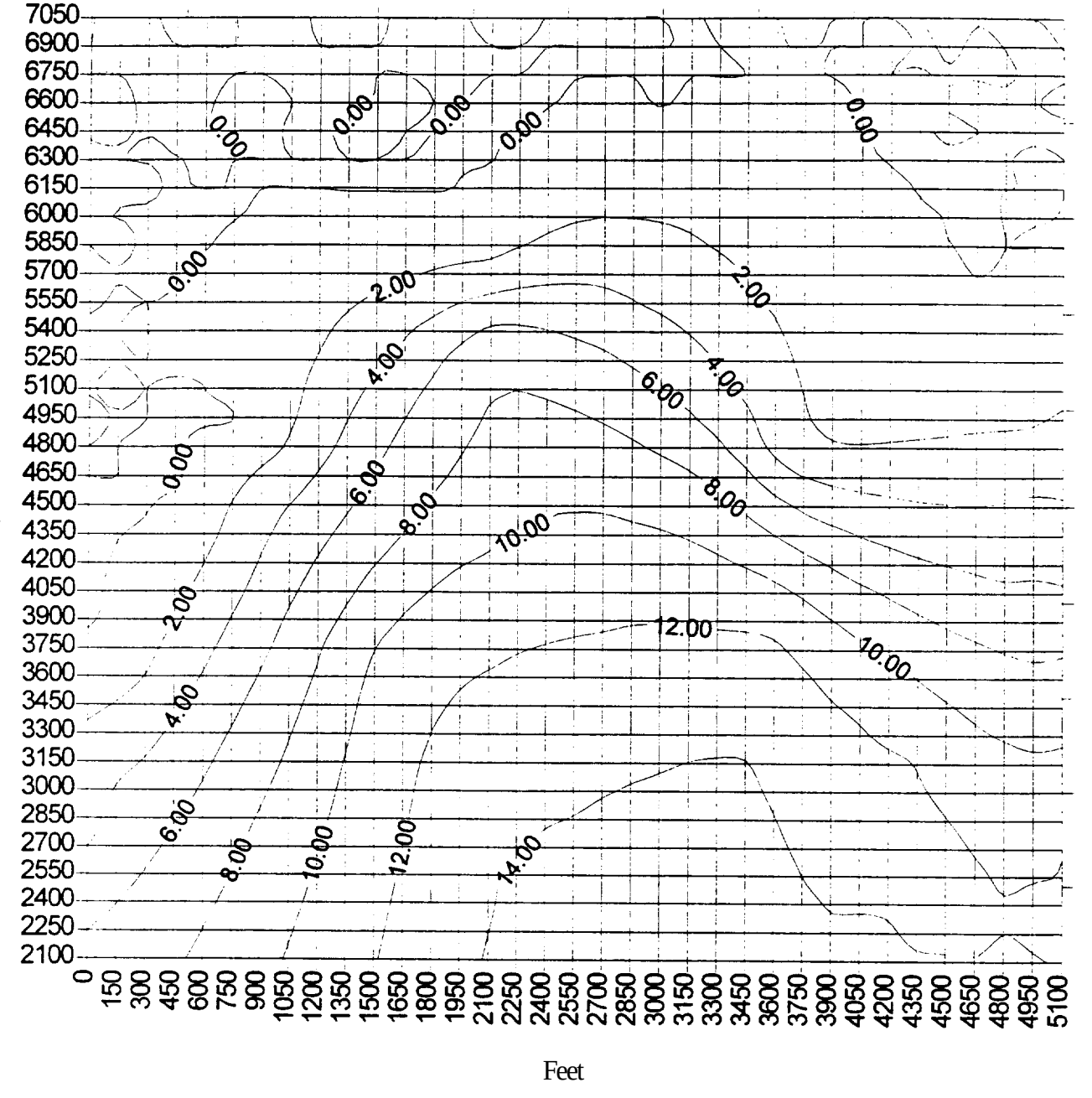
viscosities than fresh water. The driving force of a fluid is the force exerted by gravity on that fluid. Brackish water and sea water have a higher specific weight than fresh water. Thus, the hydraulic conductivity of a medium is directly proportional to the specific weight of the fluid passing through that medium. Dynamic viscosity is the measure of the resistance of a fluid to shear stress that is necessary for fluids to flow (Fetter, 1988). The dynamic viscosity in sea water is greater than fresh water because of increased potential for electrical interactions between aqueous ions and water molecules. With a more dilute solution, as in the case of fresh water, there are fewer ion-water interactions and less resistance to flow. The addition of an organic contaminant phase with its own viscosity and non-polar partitioning tendencies will further complicate the assumption of one fluid phase.

4.7 Calibration Target

The calibration targets were generated by Kriging the potentiometric surface measurements from 33 wells and staff gauges in the shallow interval at low tide on August 12, 1993 (Figure 5). This is the calibration target for the shallow interval (layers 1 and 2). The potentiometric surface on August 12, 1993, at low tide was also measured at 16 wells in the intermediate layer (Figure 6). This is the calibration target for the intermediate interval (layer 3). When the model is run, the calculated potentiometric surface in layer 3 is identical to that found in layer 1 and 2. Thus, one calculated potentiometric surface is compared to two observed throughout calibration and sensitivity analyses. No seasonal water table fluctuation data are available. Rainfall is the principal form of recharge to Site 1 and is the only form of recharge to the model. Rainfall averages 60 in/yr with a minimum of 3.2 inches in November. Static water levels at a particular time represent a potentiometric surface between the seasonal high and low but probably do not represent an average potentiometric surface. Seasonal changes in the amount of recharge probably cause significant variation in the water table elevation.

No percentage will be stated for an acceptable/unacceptable deviation of the calculated potentiometric surface from the observed potentiometric surface due to the large number of uncertainties concerning temporal changes in the water table. Initial calibration will be done to achieve a calculated potentiometric surface as close as possible to the observed low tide potentiometric surface of August 1993 using minimal assumptions.

Observed Potentiometric Surface: Shallow Interval



Feet

Figure 5. Shallow observed potentiometric surface Site 1. Contour interval = 2.0 ft.

Observed Potentiometric Surface: Intermediate Interval

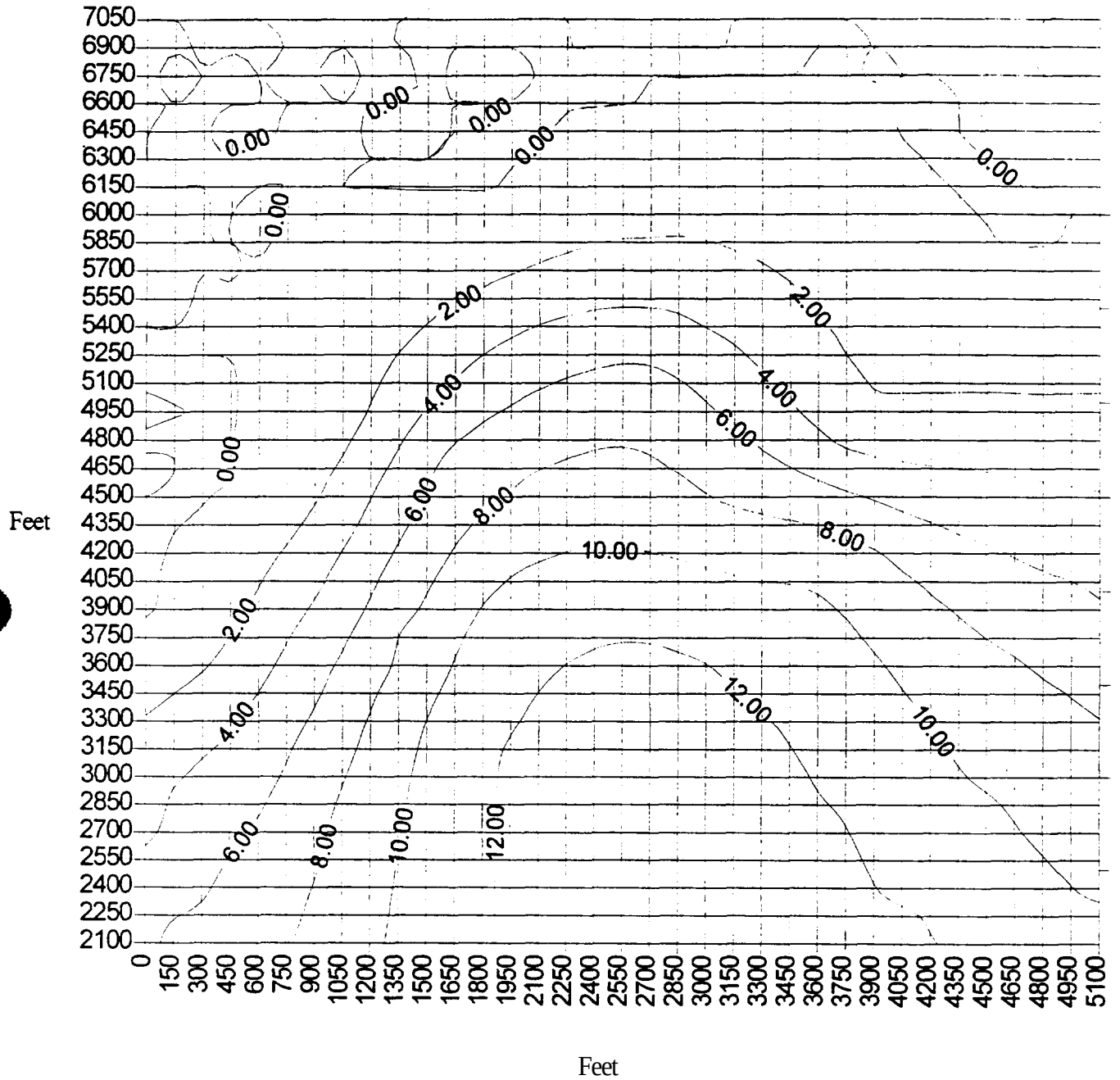


Figure 6. Intermediate **observed** potentiometric **surface** Site 1. Contour interval = 2.0 ft.

4.8 Convergence Criteria

The convergence criterion used in this flow model is 0.01 ft, that is, the difference between the head computed during model execution at each node compared to the head computed in the previous iteration will need to be less than .01 ft for every node in the model array. When this criterion is satisfied, the present iteration is accepted as the numeric solution.

5.0 CALIBRATION

Calibration points within the model are located where monitoring wells are located or staff gauge measurements were taken in the field (Figures 7 and 8) . The head measured at those points and their approximate depths are then entered into VisualMODFLOW. Each time VisualMODFLOW is run, the calculated heads at the specified calibration points are statistically analyzed by comparison to the input observed head values at each monitoring point.

The calculated head output is identical for all three layers independent of parameter variation between layers. The calibrated potentiometric surface for layers 1, 2, and 3 is found in Figure 9.

5.1 Residual Analysis

A qualitative comparison of the observed and calculated potentiometric surfaces can be seen in Figures 10 and 11 for the shallow and intermediate intervals. The solid equipotential lines represent the calculated potentiometric surface elevations and the dash equipotential lines represent the observed potentiometric surface elevations.

The major discrepancies between the observed and the calculated potentiometric surface for the shallow interval appears at 1) the region northwest of Golf Course Pond, Figure 11, and 2) the area due west of Golf Course Pond between 4 and 10 ft, Figure 11. The calculated potentiometric surface is too high in the region north-west of Golf Course Pond. The calculated potentiometric surface is too low in the region due west of Golf Course Pond. With these two regions adjacent to each other the lack of head in one may be linked to the excess head in the other. The potentiometric surface along the northern shore is also slightly higher than the observed potentiometric surface.

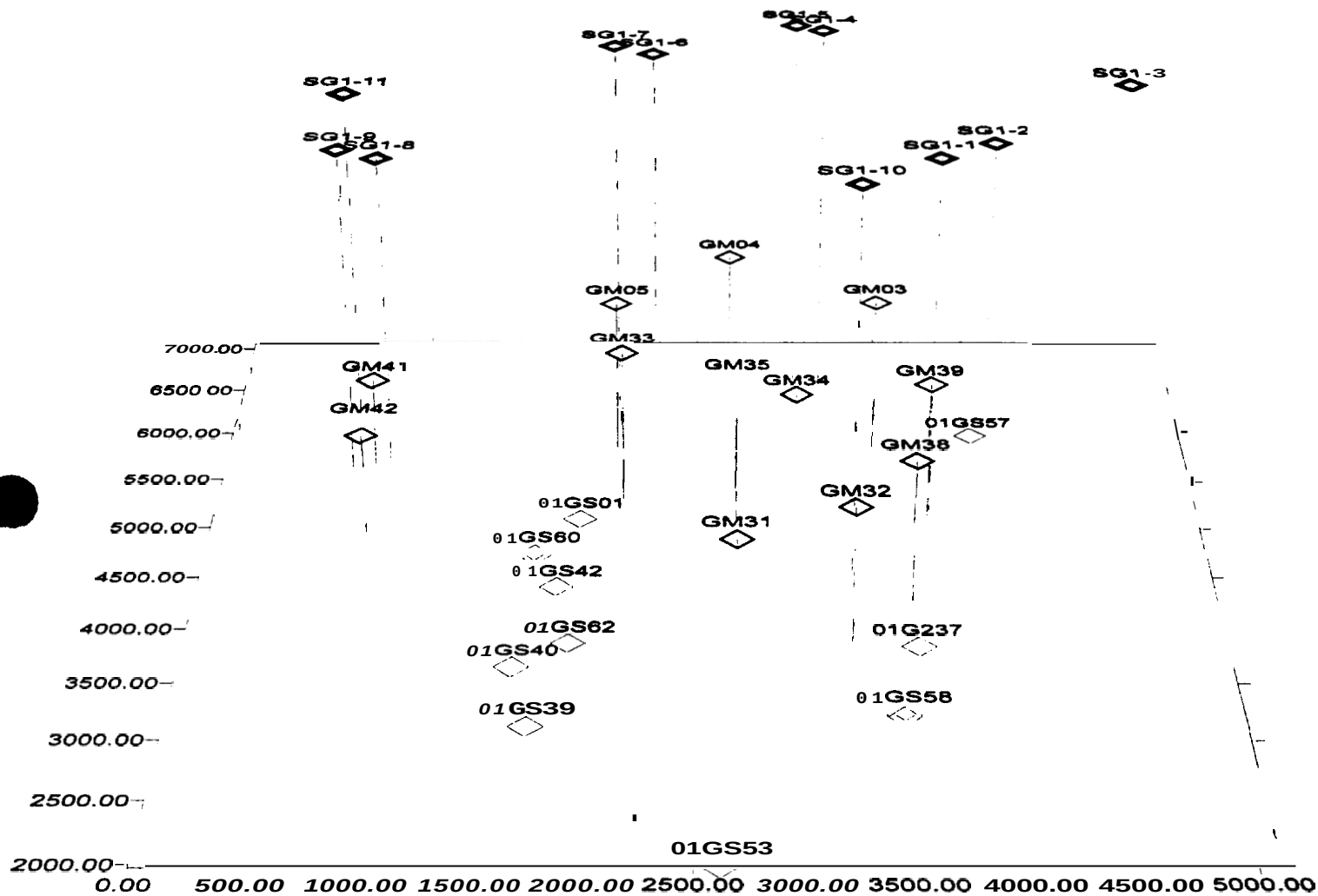


Figure 7. **Shallow** interval wells within the **model grid.** Data points with ***GS*** and GM prefixes *are* **monitoring wells.** Data points with ***SG* prefixes *are stream*** gauges.

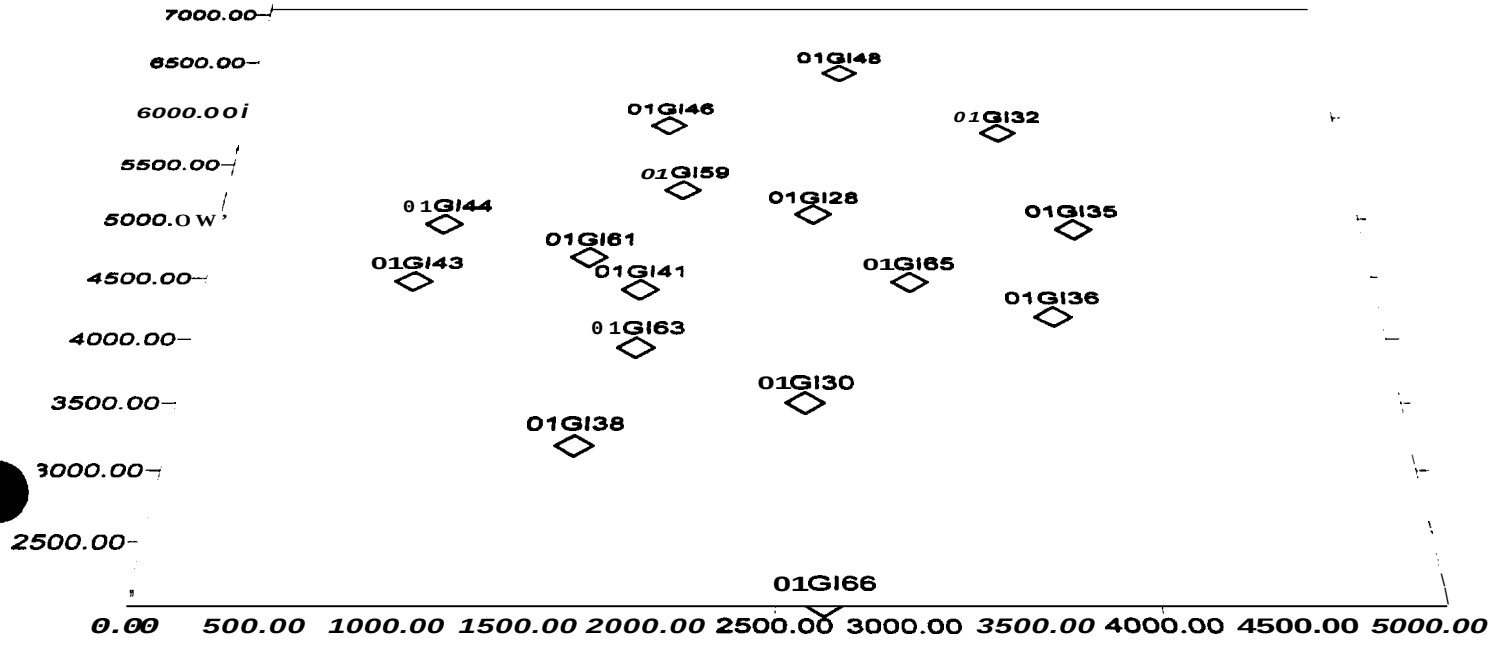


Figure 8. Intermediate interval wells within model grid

calculated Potentiometric Surface: **Shallow and** I n t e d a t e Interval.

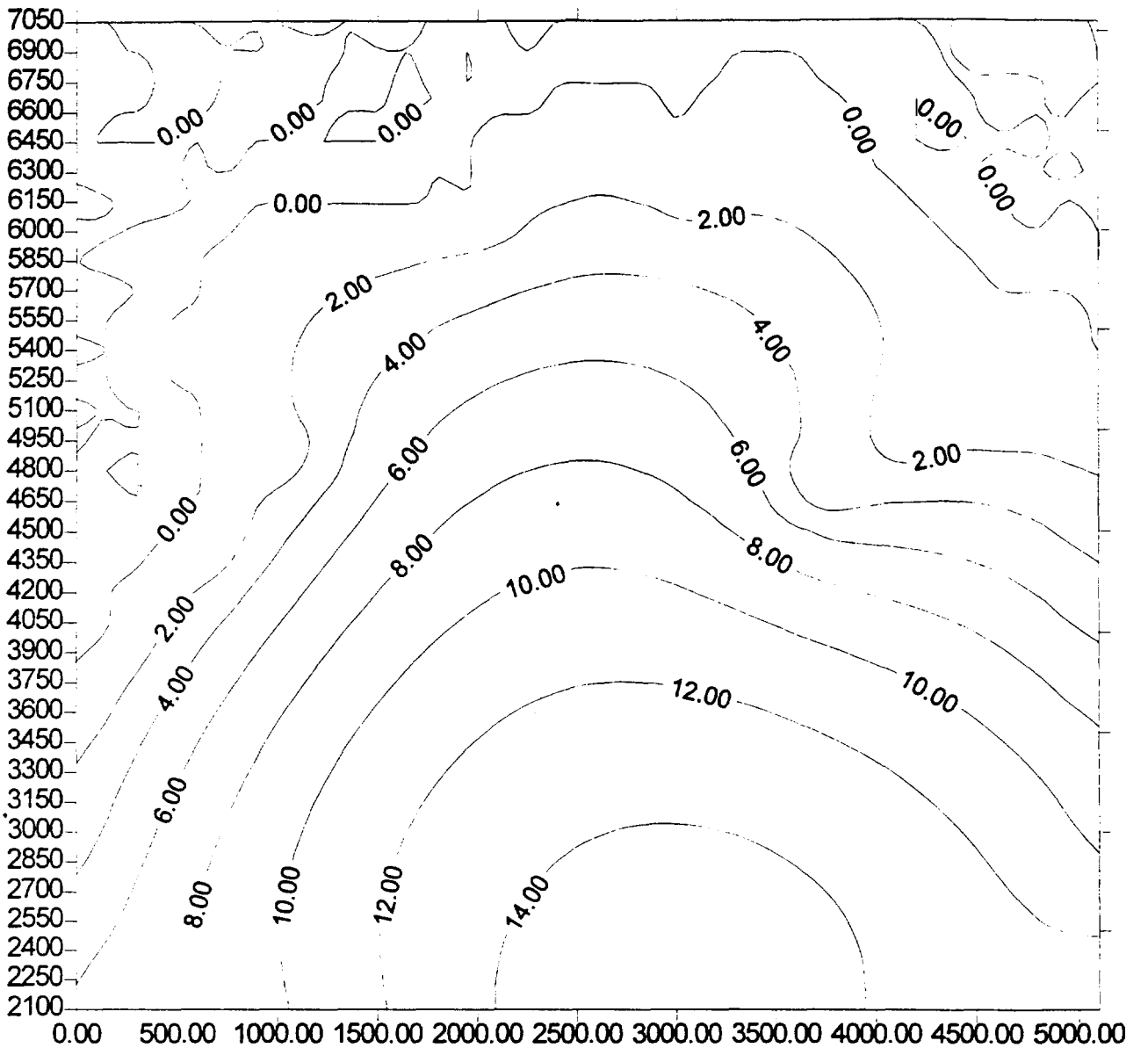


Figure **9.** Calculated potentiometric surface. **Due** to the large **similarity between** the calculated **surfaces** for all **layers** the Layer 1 potentiometric **surfaces** will be the **surface** compared to the observed **head** during **calibration** and sensitivity testing.

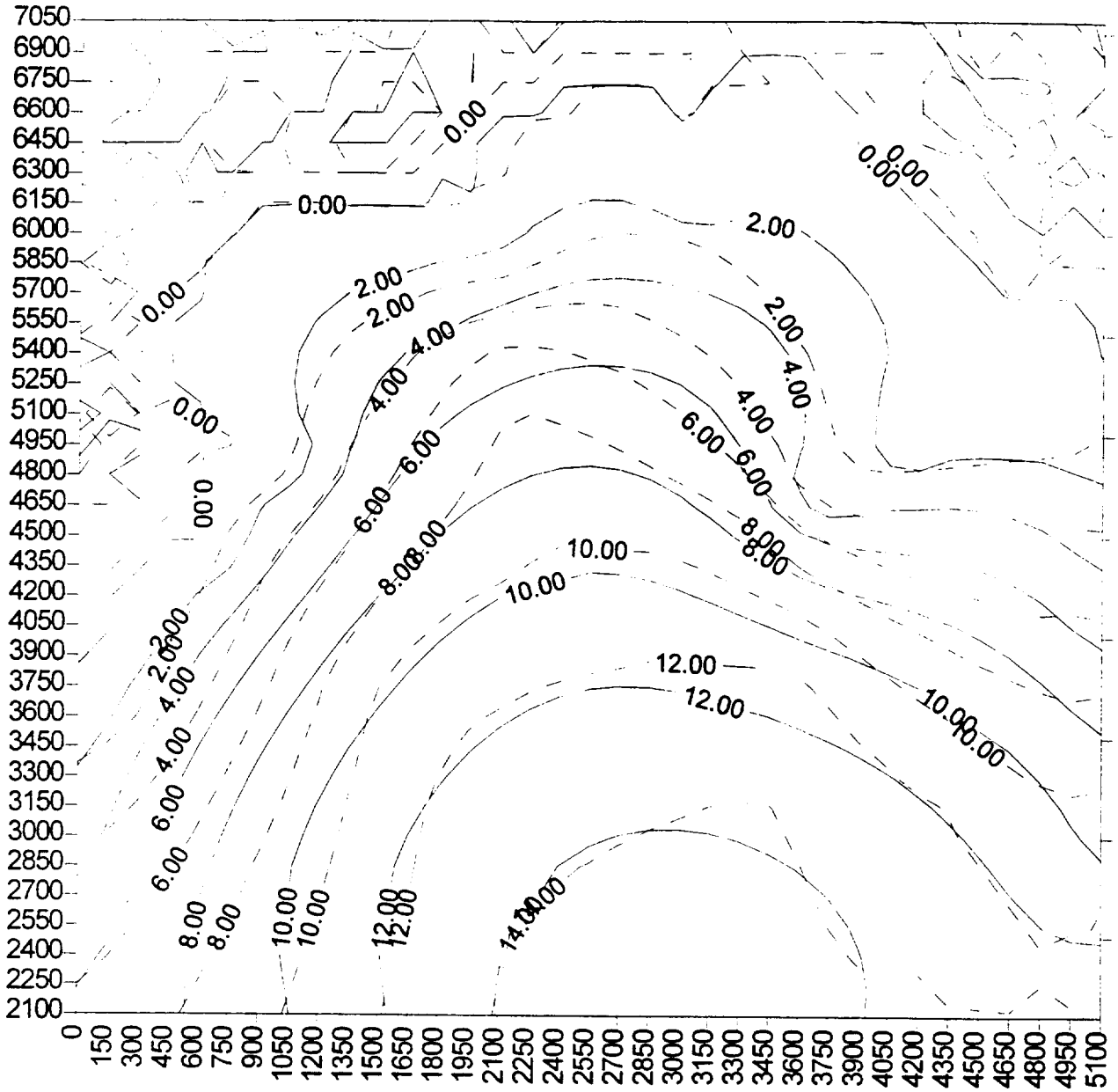


Figure 10. Equipotential plot of the calculated potentiometric surface (solid line) *Superimposed* upon the observed shallow potentiometric surface (dashed lines). Contour interval = 2.0 ft.

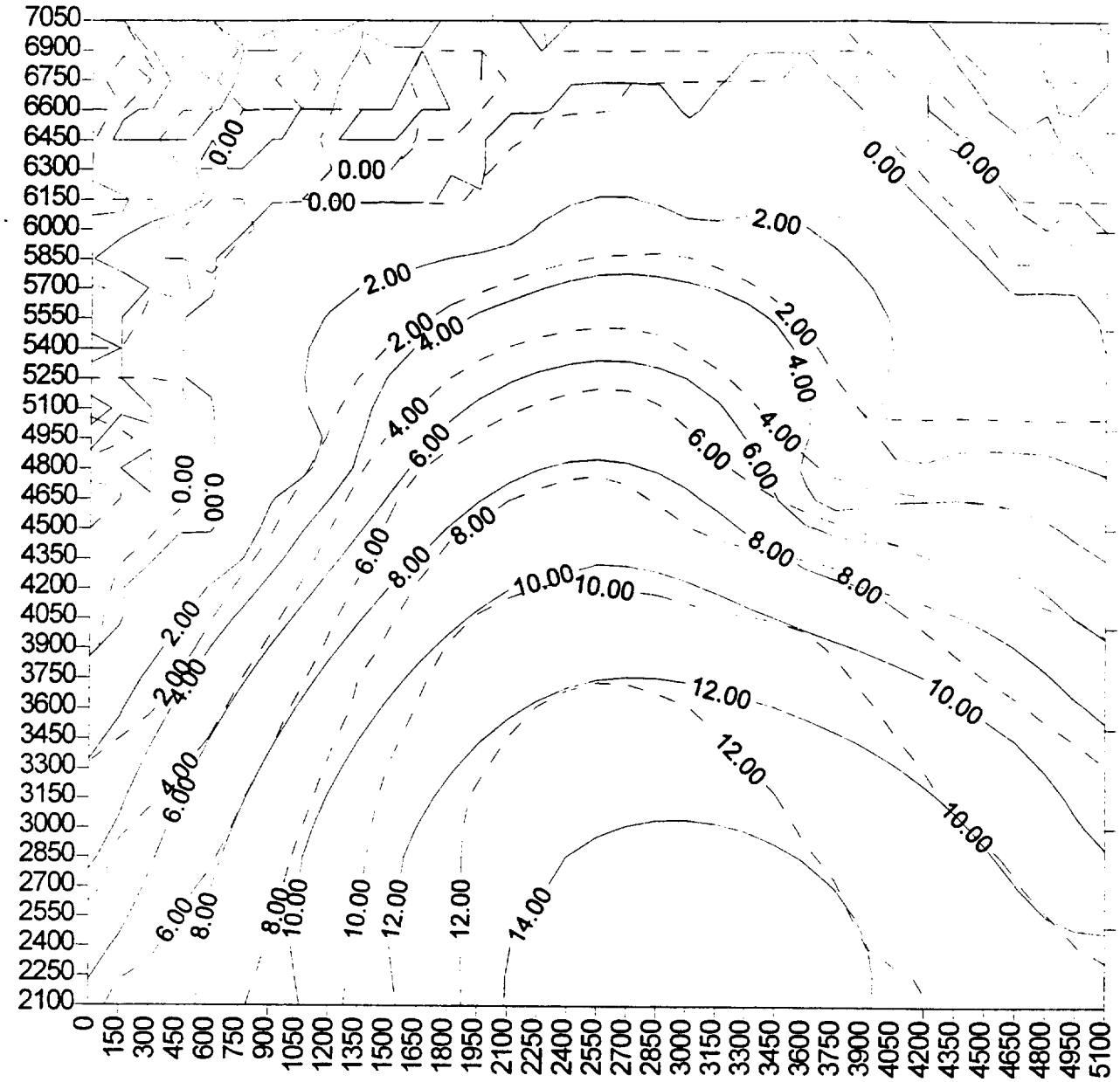


Figure 11. Equipotential plot of the calculated **potentiometric surface** (solid lines) superimposed upon the **observed** intermediate potentiometric **surface (dashed lines).** Contour interval = **2.0 ft.**

The major discrepancy between the observed and the calculated potentiometric surface for the intermediate interval appears around the edges of the model domain. The center of the model appears to have the least amount of error.

The difference between the calculated potentiometric surface and the Kriged observed potentiometric surface is the residual error (Figure 12 and 13). Residuals that are positive mean that the calculated potentiometric surface elevation falls below the observed potentiometric surface elevation. Likewise, a negative residual means that the calculated potentiometric d a c e elevation exceeds that of the observed. The observed and calculated heads can be found in Table 1. The residual surface was computed with Surfer by subtracting the observed potentiometric surface grid from the calculated potentiometric surface grid.

The major residual extremes within the shallow interval are associated with bullseyes which are in turn associated with specific wells or clusters of wells (Figure 12). The residuals also show differences of more than a 1 ft in elevation of the observed and calculated potentiometric surfaces in the region northwest of Golf Course Pond and the region slightly to the west of it. Two additional regions also are identified as having a residual in excess of 1 foot (Figure 12).

Residual extrema within the intermediate interval are found in three large regions (Figure 13). The calculated potentiometric surface is too high by approximately 1.0 ft or more in both the northern and southern portions of the model domain. The central region has residuals close to zero.

5.2 Residual Statistics

The difference between the observed heads and the computed heads can be seen in Figure 14. The difference between the observed heads and the computed heads can be expressed as mean error, mean absolute error, and the standard deviation (root mean square error). The mean error is the average difference between the measured heads and the calculated heads. The mean error

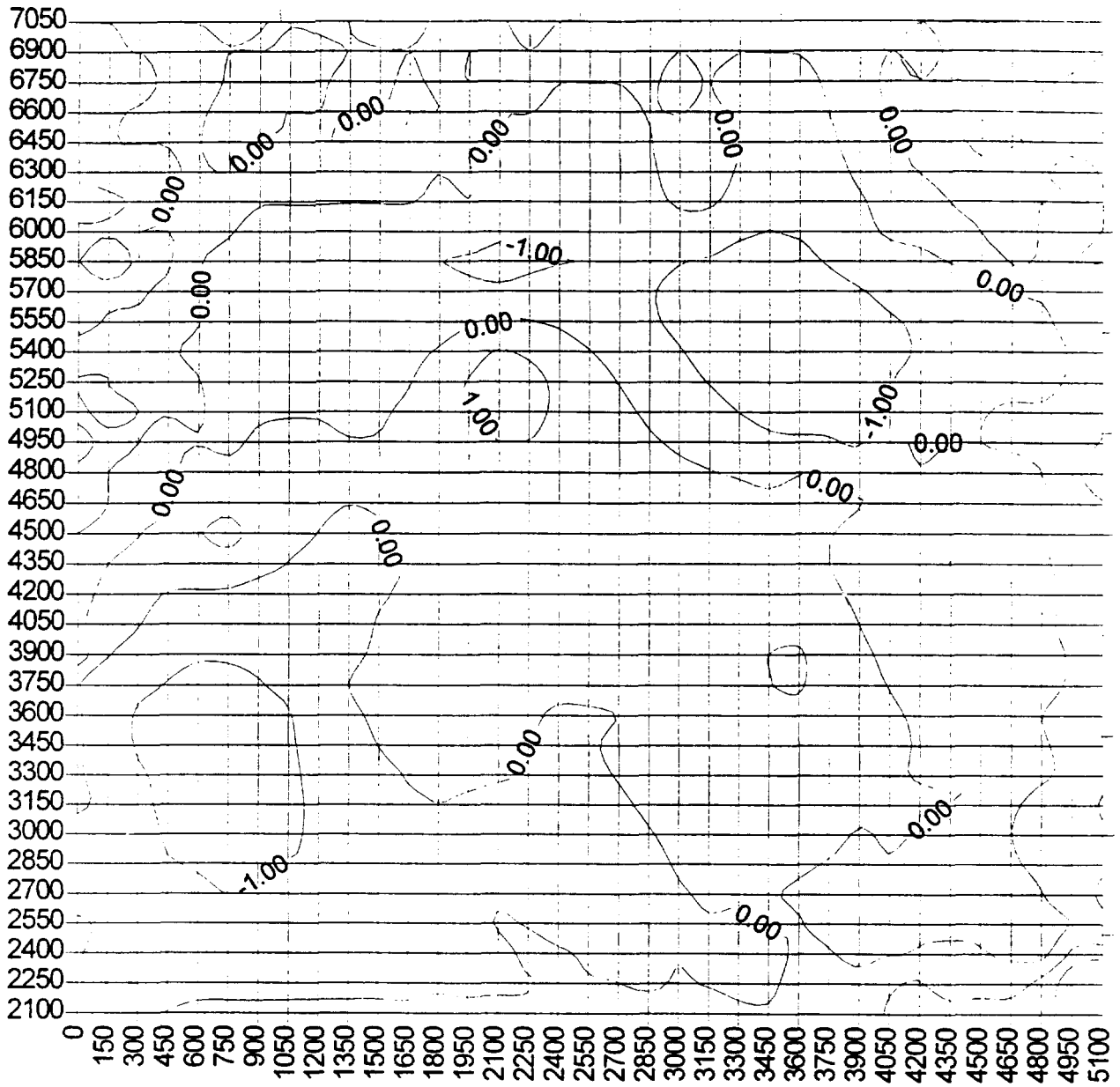


Figure 12. **Shallow** potentiometric residual surface. Residual = **Observed - Calculated**
Contour interval = 2.0 ft.

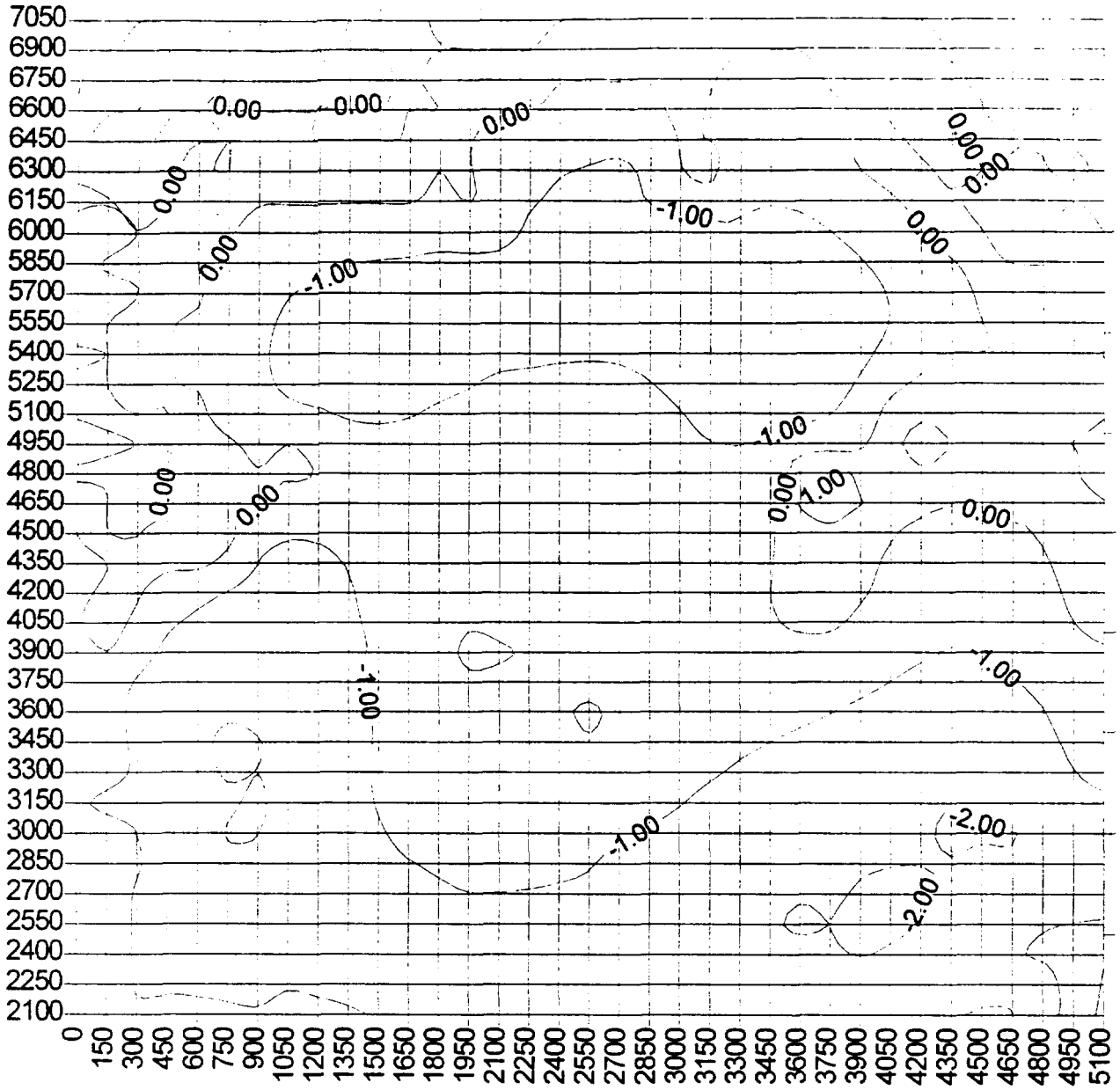


Figure 13. Intermediate **potentiometric** residual **surface.** Residual = Observed - **Calculated.** Contour interval = 2.0 ft.

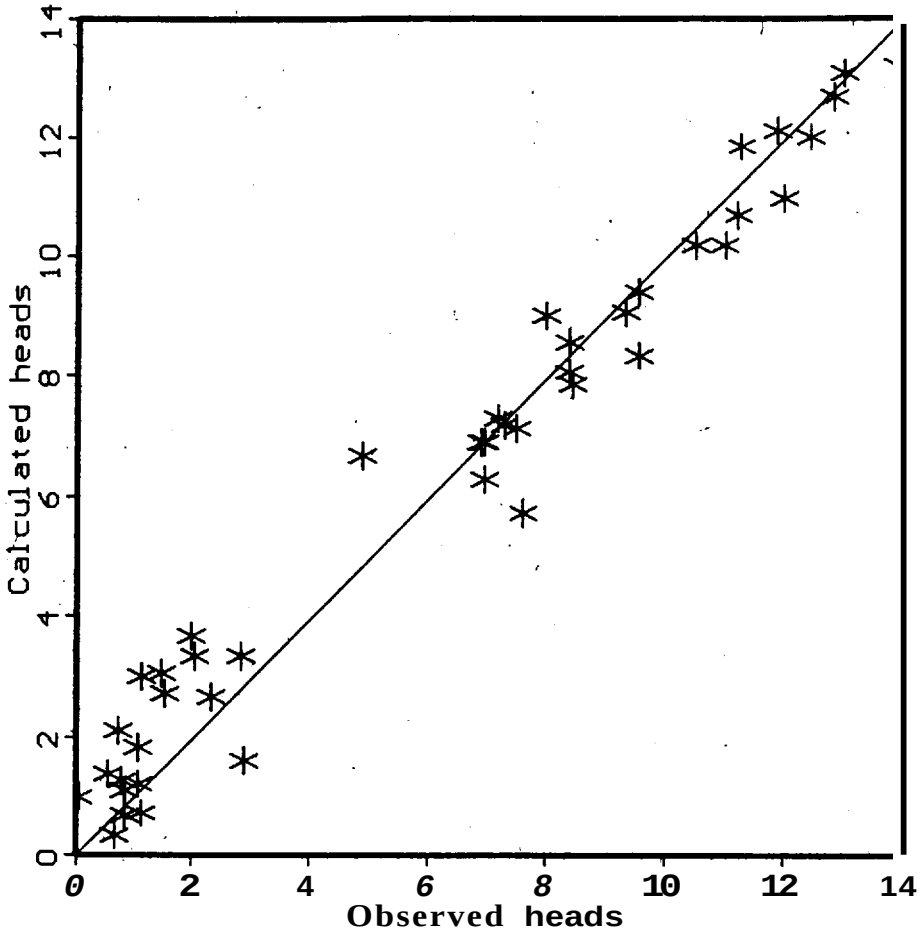


Figure 14. Observed head (ft) versus calculated head (ft) for shallow and intermediate wells.

is not the best measure of error because it tends to minimize or cancel errors when calculated values both exceed and fall below the observed values. Mean error values will be presented in calibration and sensitivity plots but will not be discussed. The mean absolute error is the average difference between the absolute value of the measured heads subtracted from the calculated heads. This is a better measure of error because it filters out error cancellations that occurs when computing just the mean error. When all calculated errors exceed or all calculated errors fall below the observed values the mean error and the absolute mean error will be equal. The best measure of error is the standard deviation. The standard deviation describes statistically how close the computed heads are to the observed heads.

The mean absolute error for the calibrated model surface is 0.6777806 ft. That is, the average difference between the observed head and the calculated head at the 43 monitoring points distributed throughout the model is 0.68 ft. This error is less than 5% of the total relief of the potentiometric surface at Site 1. Taking into account the uncertainties involved with stating a precise calibration goal, this value is deemed adequate. The standard deviation for the first part of the calibration is 0.8640254 ft. This means that 68.26% of all the calculated heads in the model are within +/- 0.86 ft of the observed heads. Ninety-five percent of all calculated heads are within 1.7 ft. (or two standard deviations) of the observed head measurements. This error is less than 12% of the total relief of the potentiometric surface on Site 1. Taking into account the uncertainties involved with stating a precise calibration goal, this value is deemed adequate.

The mass balance of water entering the model and leaving the model is -.39%. This value is well within the acceptable mass balance range for a numerical solution.

6.0 SENSITIVITY ANALYSIS

The sensitivity analyses were done by varying one parameter of the calibrated model while holding all other parameters constant. The mean error, mean absolute error, and standard deviation (root mean square error) are graphed versus the variation of that parameter, i.e., yearly rainfall from 15 in/yr to 45 in/yr, for each parameter, i.e., recharge, conductivity, etc. Equipotential head plots of the end members of each parameters variation were superimposed

on the analytical shallow and intermediate head solutions to illustrate where in the model domain a specific parameter variation has the greatest impact.

6.1 Recharge Sensitivity

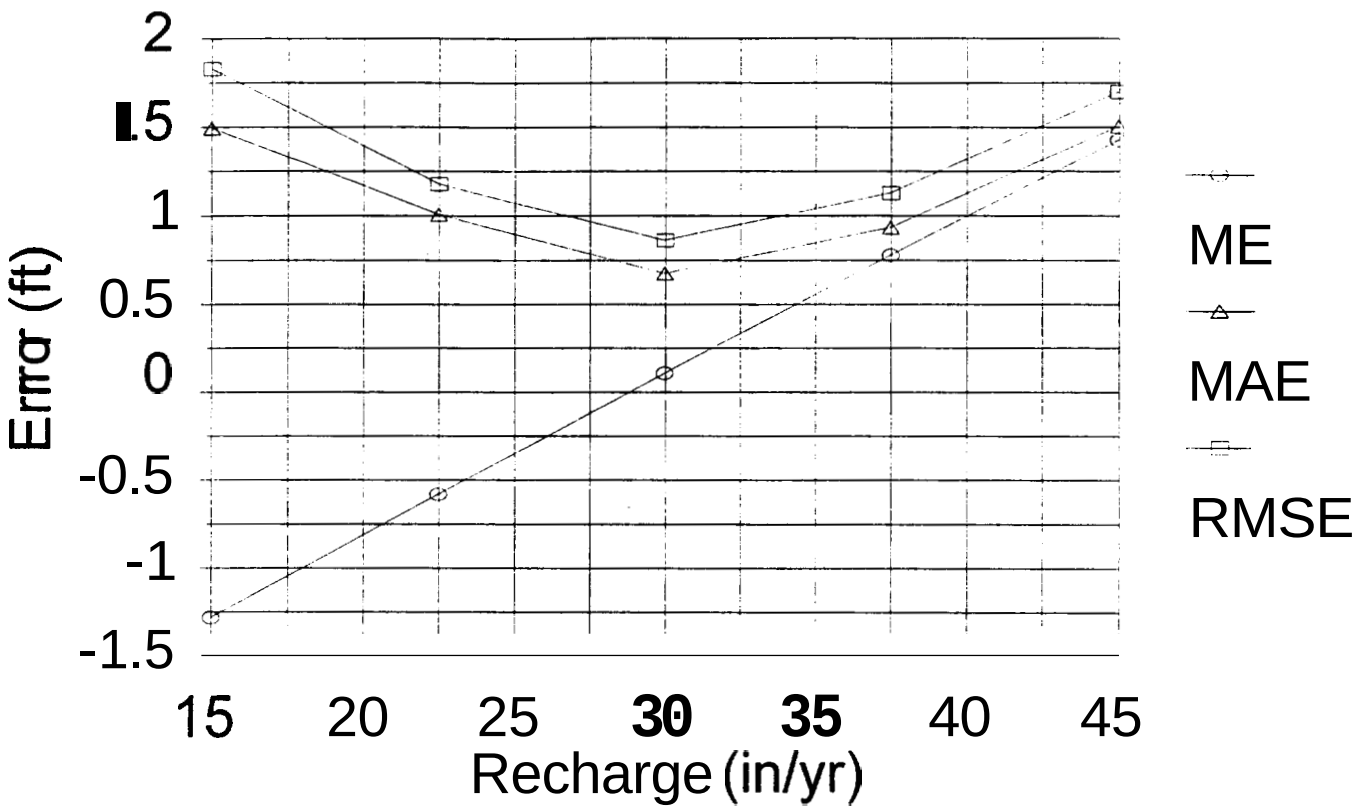
Recharge sensitivity was examined by varying the recharge over the entire model in 7.5 in/yr increments starting at 15 in/yr and ending at 45 in/yr (Figure 15). The mean absolute error and the standard deviation are minimized at 30 in/yr. With recharge set at 30 in/yr, the entire suite of model parameters is set identically to those of the calibrated model and have identical error values.

A recharge value of 15 in/yr produces a mean absolute error and a standard deviation of 1,497 ft. and 1.832 ft., respectively. The equipotential plot (Figure 16a) shows that the shallow calculated potentiometric surface is too high in the southern and central region of Site 1. Along the shoreline a recharge rate of 15 in/yr produces a potentiometric surface in good agreement with the observed potentiometric surface. This may be an indication that the aquifer along the shoreline is unable to use all the recharge provided. In reality some of the recharge becomes runoff when the ground becomes saturated in lower lying areas. The equipotential plot of the intermediate calculated potentiometric (Figure 16b) surface is also in good agreement along the shoreline and along the west side of the model domain but appears to deviate by up to 2.0 ft in the center and east side of the model.

A recharge value of 45 in/yr produces a mean absolute error and a standard deviation of 1.51 ft. and 1.70 ft. respectively. The equipotential plot (Figure 17a), shows that the shallow sensitivity potentiometric surface is approximately 2.0 ft too high over most of the model domain. Errors are less near the shore. This is probably due to the specified head cells used to represent the shoreline. The equipotential plot for the intermediate potentiometric surface (Figure 17b), also shows an approximately 2.0 ft exceedance of the calculated over the observed potentiometric surface.

Recharge Sensitivity

Figure 15



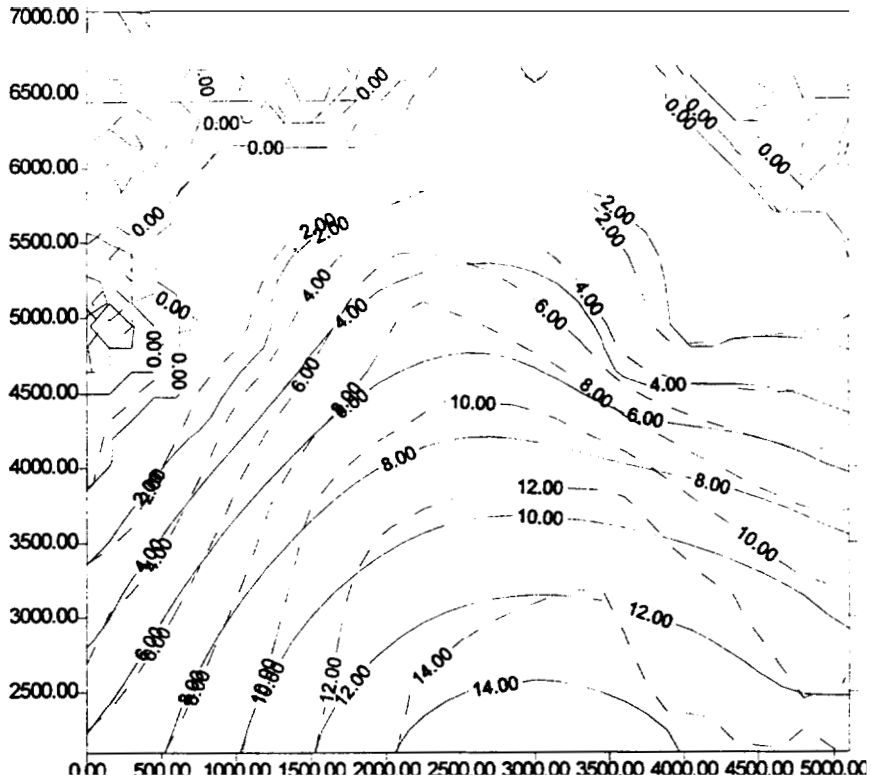


Figure 16 a. Calculated **shallow potentiometric** surface when **recharge is** 15 in/yr. **Contour interval is 2.0** ft. Dashed lines are *observed* **potentiometric** *contours*. **Solid lines are calculated potentiometric** countours.

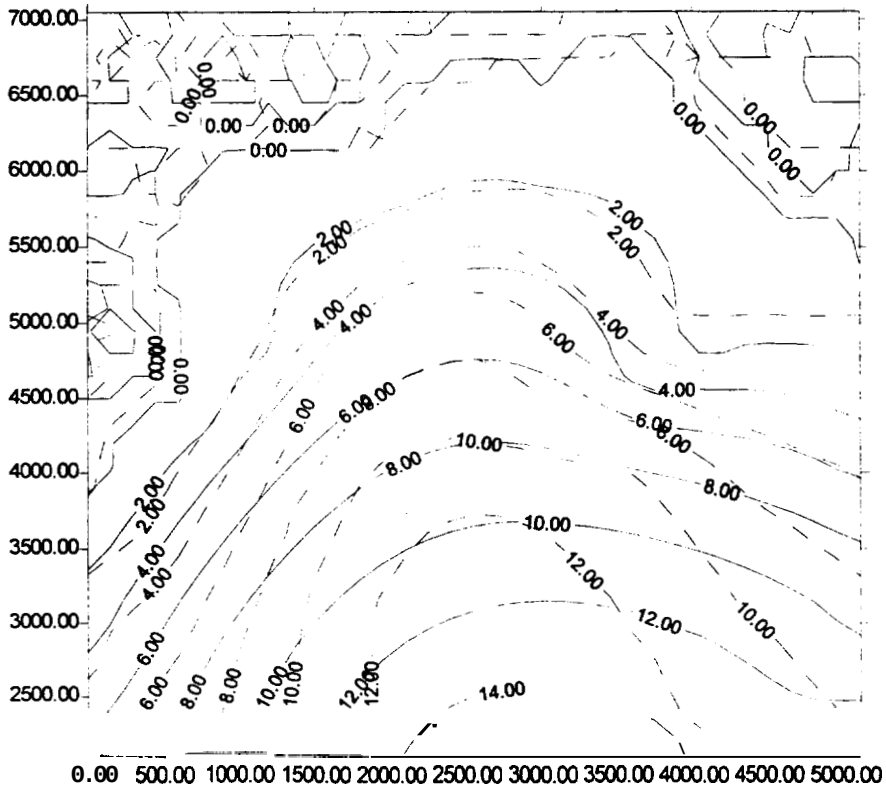


Figure **16 b. Calculated intermediate potentiometric surface** when **recharge is** 15 in/yr. **Contour interval is 2.0** ft **Dashed lines** are observed **potentiometric countours. Solid lines** are **calculated potentiometric countours.**

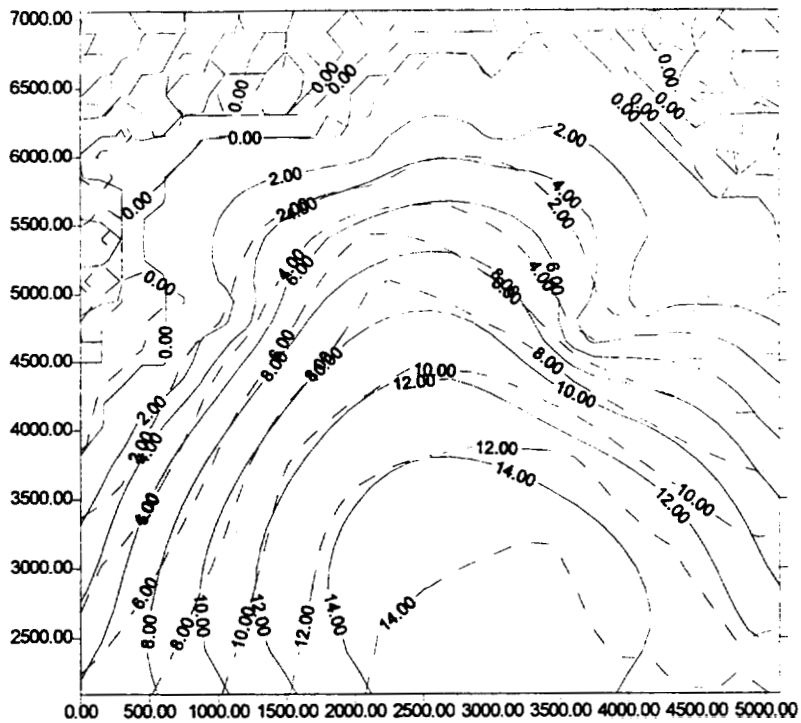


Figure 17 a Calculated shallow potentiometric surface when recharge is 45 in/yr. Countour interval is 2.0 ft. Dashed lines are observed potentiometric contours. Solid lines are calculated potentiometric contours.

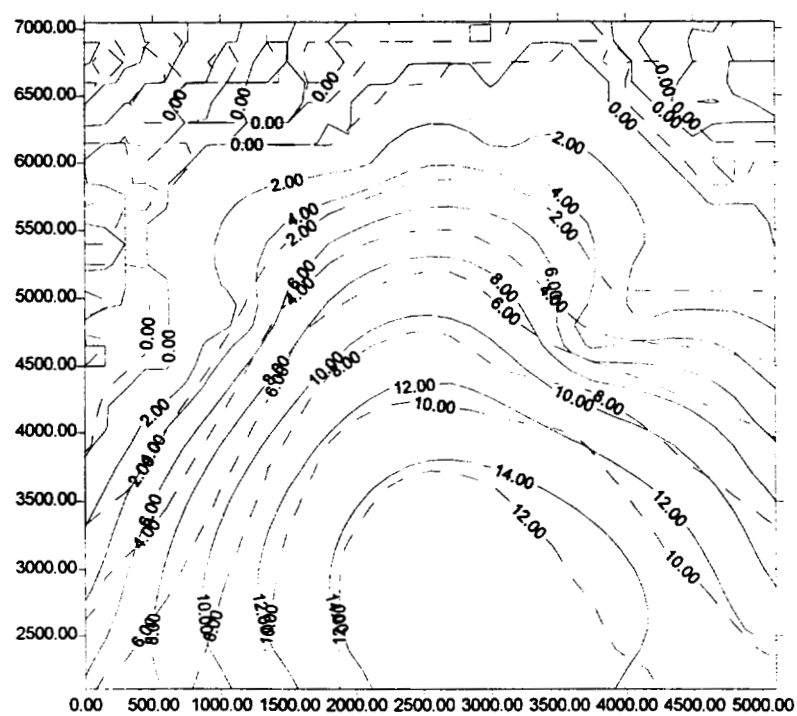


Figure 17 b. Calculated intermediate potentiometric surface when recharge is 45 in/yr. Countour interval is 2.0 ft. Dashed lines are observed potentiometric contours. Solid lines are calculated potentiometric contours.

The model displays a significant sensisitivity to recharge variations. The southern portion of the model is most sensitive to recharge variations. This is probably due to the specified head boundary conditions forcing the recharge in the center of the model to conform to its fixed values.

6.2 Layer Thickness Sensitivity.

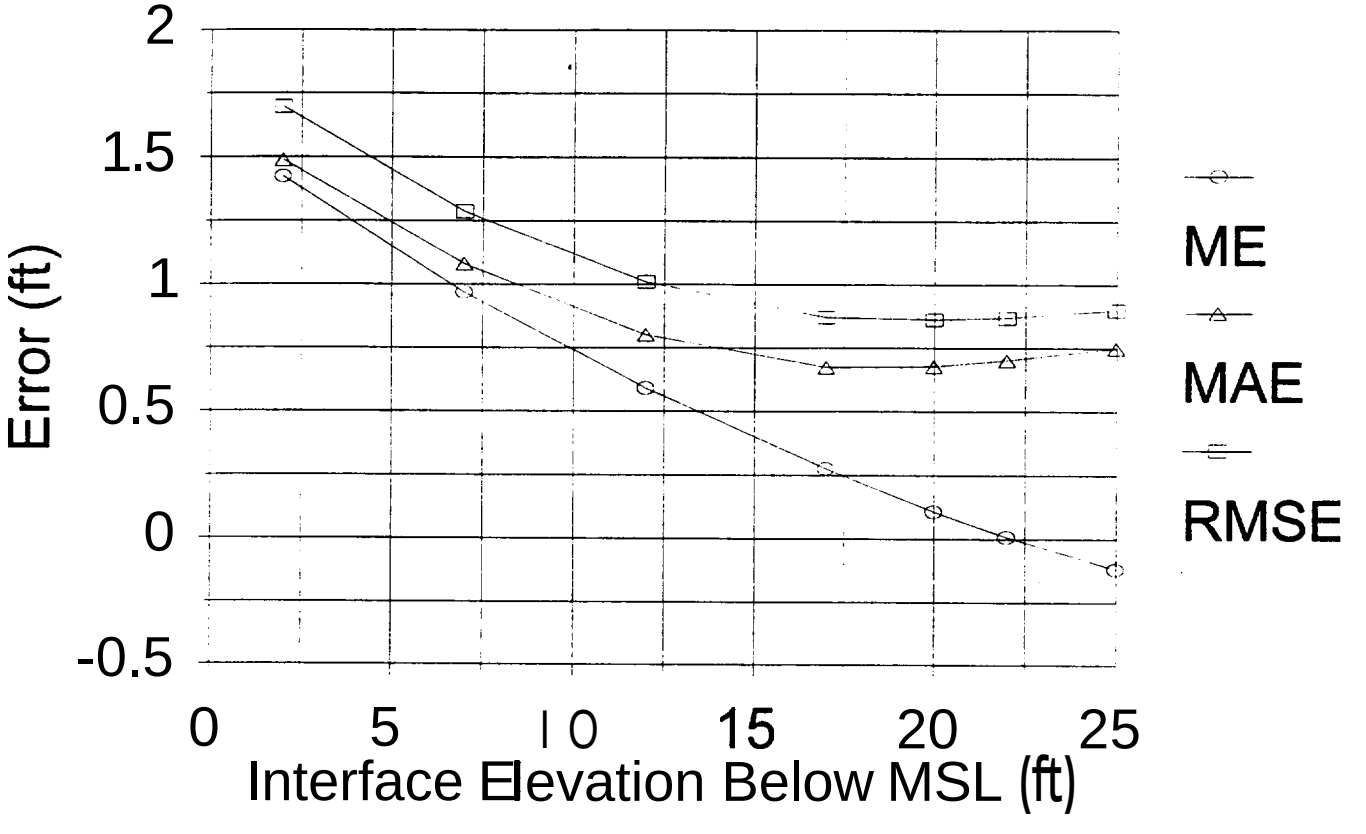
Layer thickness sensitivity was examined by varying the thickness of layer three by moving the top of layer 3 from -2 ft below msl to eliminating layer 3 from the model completely (Figure 18). The transition from layer 1-2 to layer 3 denotes a drop in hydraulic conductivity. The total thickness of the model does not change, merely the proportions that represents the respective layers. Due to the similarities of layers 1 and 2, the sensitivity analysis can be done by vary the properties of only layers 2 and 3. The mean absolute error and the standard deviation are minimized with a thickness of 20 ft for layer 2. With layer 2 set to 20 ft thick the entire suite of model parameters is set identically to those of the calibrated model and have identical error values.

When layer 3 is 23 ft thick produces a mean absolute error and a standard deviation of 1.489 ft. and 1.699 ft., respectively. The equipotential plot (Figure 19a), shows that the shallow calculated potentiometric surface is generally 2.0 ft too high over the entire model domain except again by the shore line. The southern and eastern regions of the sensitivity potentiometric surface show the largest deviation from the observed potentiometric surface. The equipotential plot for the intermediate calculated potentiometric surface (Figure 19b) shows the same deviations as the shallow layer except in the southern region where the error is slightly larger.

Eliminating layer 3 from the model produces a mean absolute error and a standard deviation of 0.7511 ft. and 0.9022 ft., respectively. The equipotential plot (Figure 20a) shows that the shallow calculated potentiometric surface is very similar to the calculated calibration potentiometric surface. This lack of sensitivity is also expressed in the associated errors which are very close to those of the calibration. Slight errors can be see in the central portion of the model domain between the 6.0 to 12.0 ft contours. The equipotential plot for the intermediate calculated potentiometric surface (Figure 20b) shows the exact inverse error distribution of the

L1-L2/L3 Boundry Elev. Sensitivity

Figure 18



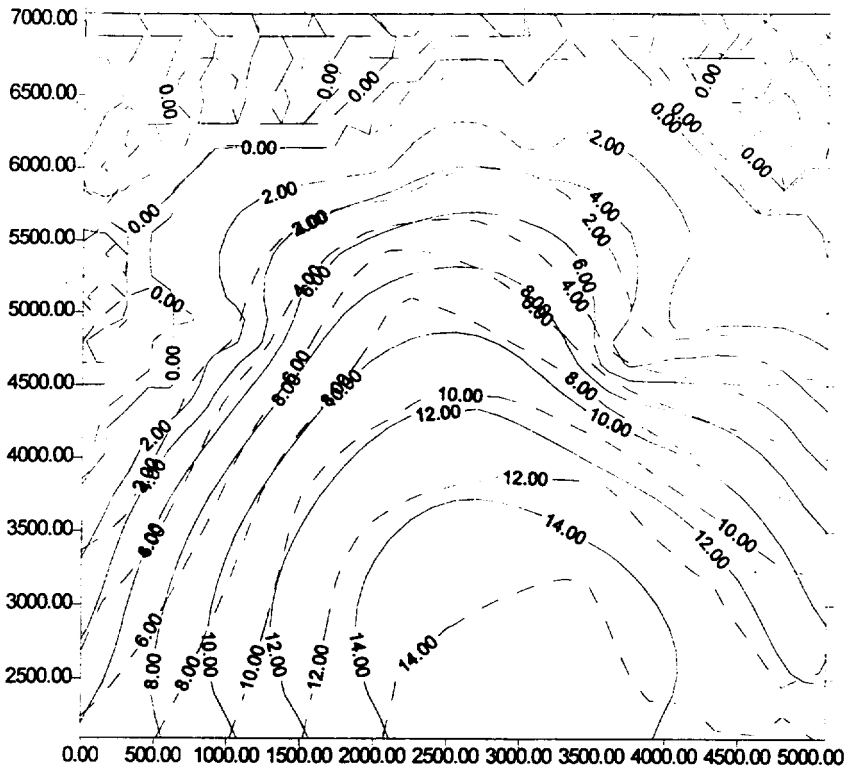


Figure 19 a. Calculated shallow potentiometric surface when layer 3 is 23 ft. thick. Countour **interval is 2.0** ft. Dashed lines **are observed potentiometric** contours. **Solid lines** are **calculated potentiometric** countours.

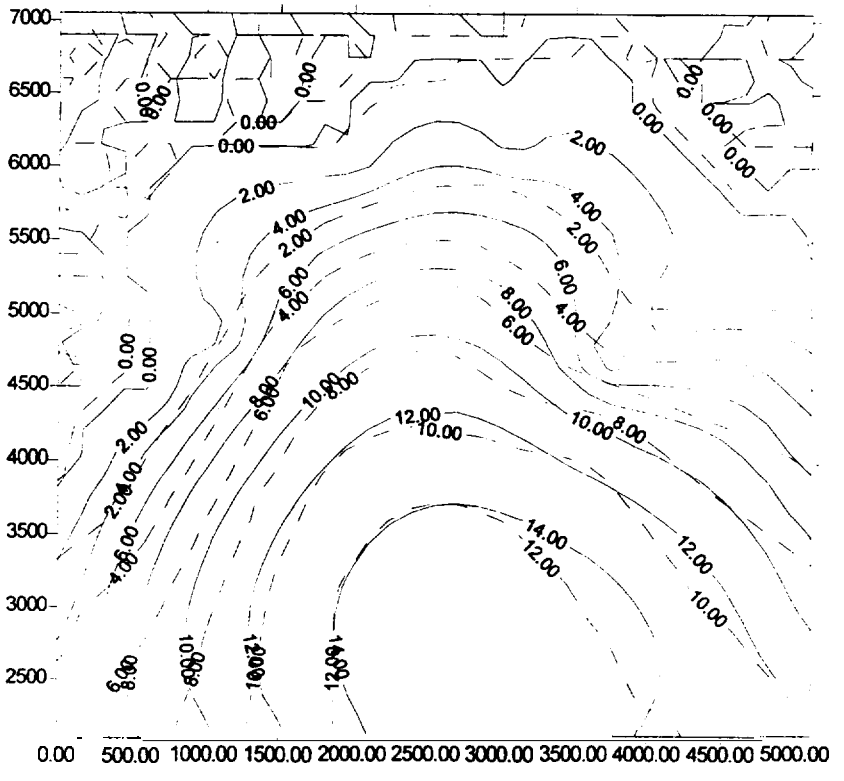


Figure 19 b. Calculated intermediate potentiometric surface when layer 3 is 23 ft thick. Contour interval is 2.0 ft. Dashed lines are observed **potentiometric contours. Solid lines are calculated** potentiometric **contours**

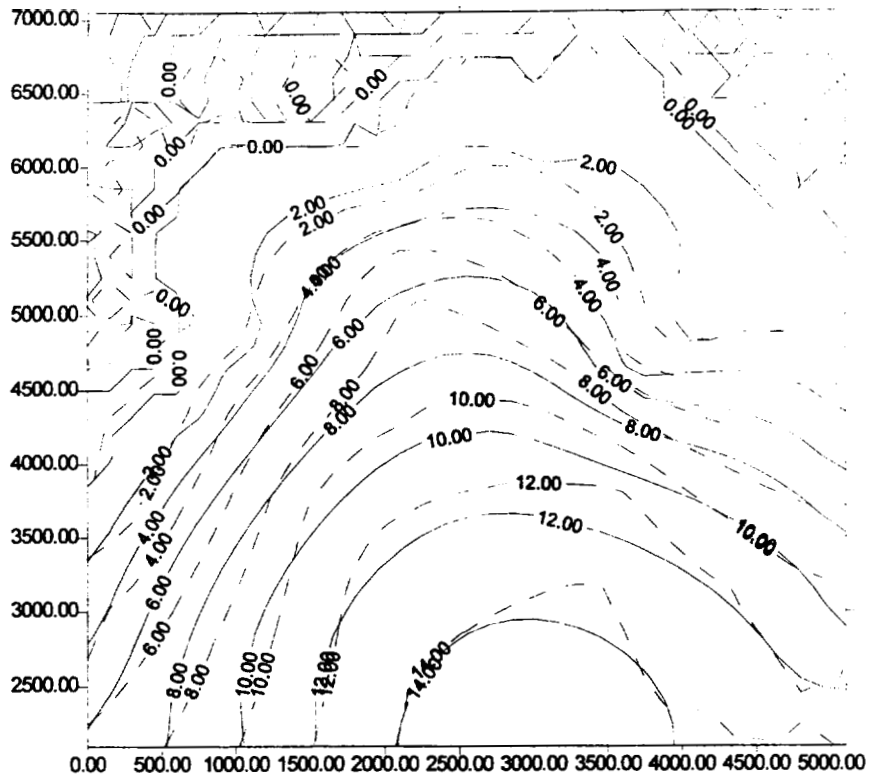


Figure 20 a Calculated shallow potentiometric surface when layer 3 is 0.0 A thick Contour interval is 2.0 ft. Dashed lines are observed potentiometric contours. Solid lines are calculated potentiometric contours

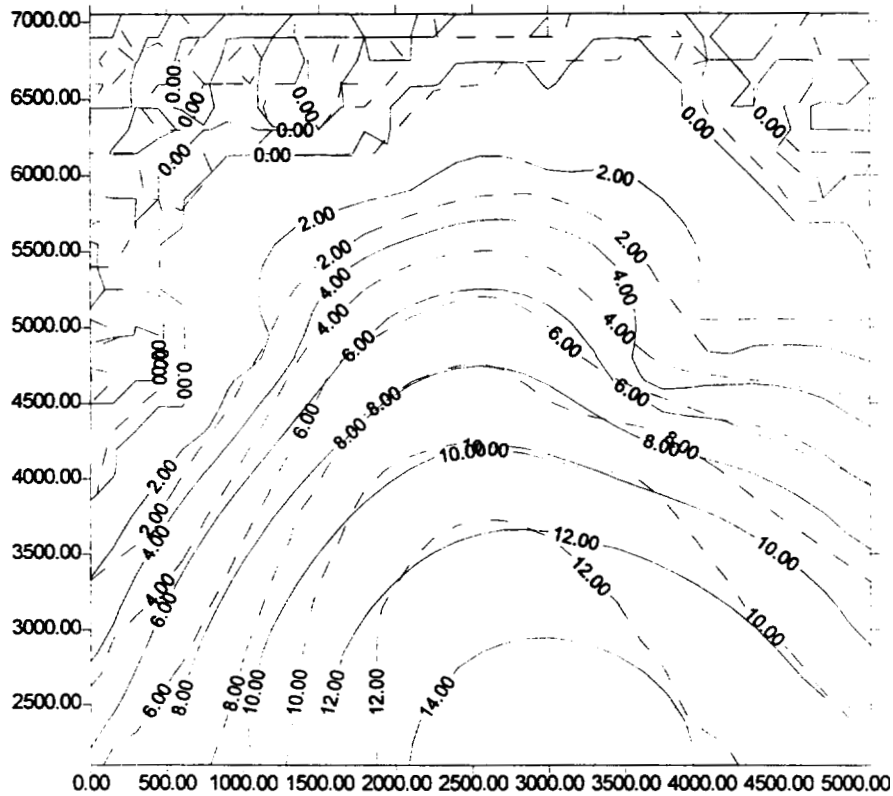


Figure 20 b. Calculated intermediate potentiometric surface when layer 3 is 0.0 ft thick. Contour interval is 2.0 ft. Dashed lines are observed potentiometric contours. Solid lines are calculated potentiometric contours

shallow calculated potentiometric surface. The major errors have been shifted to the boundaries while the interior regions between 6.0 and 12.0 ft have very small errors.

The sensitivity to layer thickness is low when layer two is between approximately 20 and 25 ft thick. Sensitivity is large when layer 2 exceed approximately 15 ft thick.

6.3 Variation in Hydraulic Conductivity

The range of hydraulic conductivities used during the sensitivity tests is small. This was done to check if the calibrated model error sits at a relative minimum when the hydraulic conductivities were varied slightly on either side of the calibrated value. Other relative minimums or an absolute minimum may exists at more extreme variation in hydraulic conductivity but probably would not be a realistic given the geologic setting and materials.

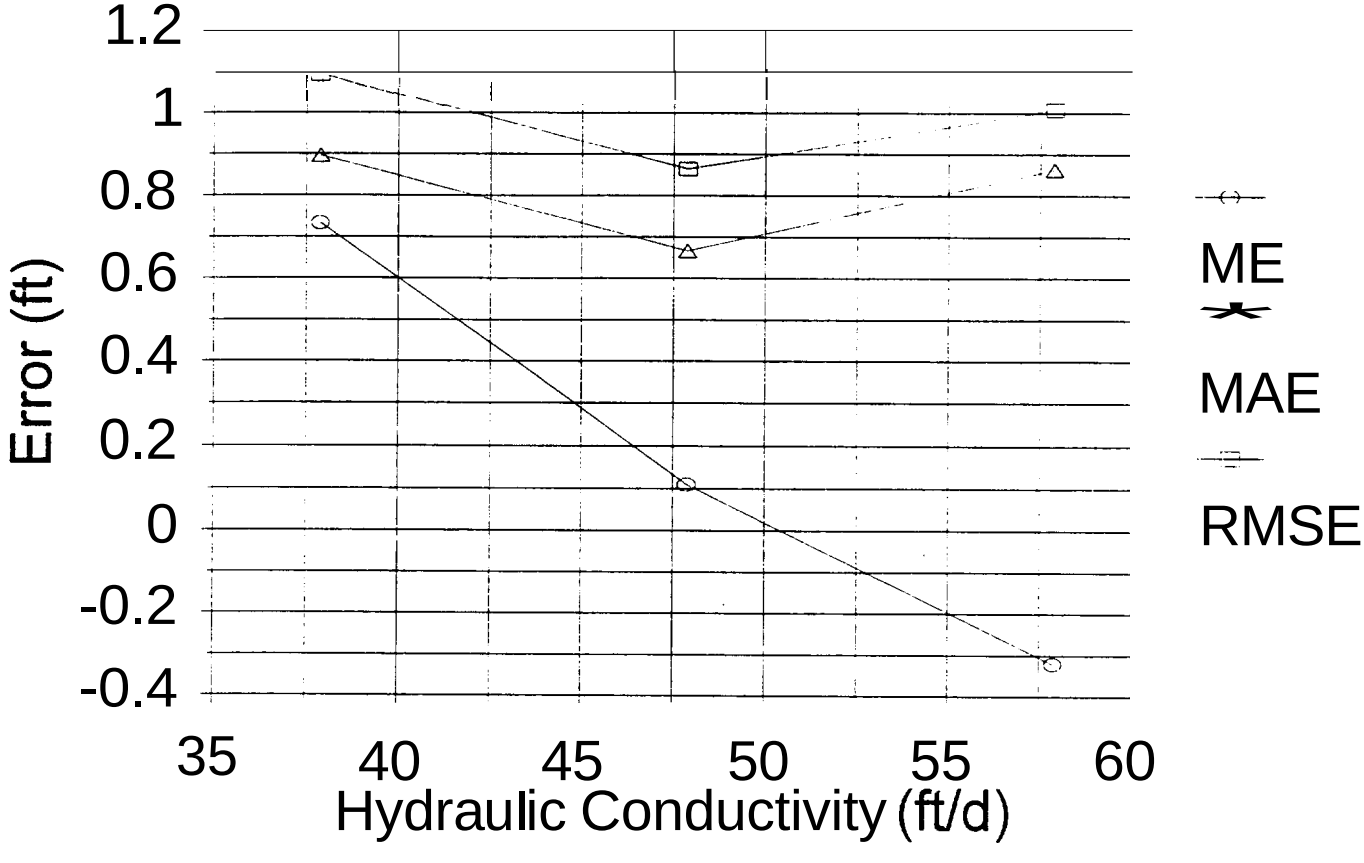
6.3.1 Hydraulic Conductivity Variations in Layers 1 and 2 (Shallow Interval)

The sensitivity to variations in hydraulic conductivity was examined by varying the hydraulic conductivity in layer 1-2 from 37.9 ft/d to 57.9 ft/d while leaving the conductivity in layer 3 constant at 24.2 ft/d (Figure 21). The mean absolute error and the standard deviation are minimized when the hydraulic conductivity is 47.9 ft/d. With the hydraulic conductivity of layer 1-2 set at 47.9 ft/d the entire suite of model parameters is set identically to those of the calibrated model and has identical error values.

A hydraulic conductivity in layer 1-2 of 37.9 ft/yr produces a mean absolute error and a standard deviation of 0.897 ft and 1.097 ft, respectively. The equipotential plot (Figure 22a) shows that a hydraulic conductivity of 37.9 ft/yr produces a shallow calculated potentiometric surface that is too high by up to 2.0 ft all over the model domain. Errors are slightly less near the shore line. This is most likely due to the large number of specified head cells in the shore line region. The calculated potentiometric surface in the intermediate region produces heads that are too high by approximately 2.0 ft. over the entire model domain (Figure 22b).

Variations in Shallow K's

Figure 21



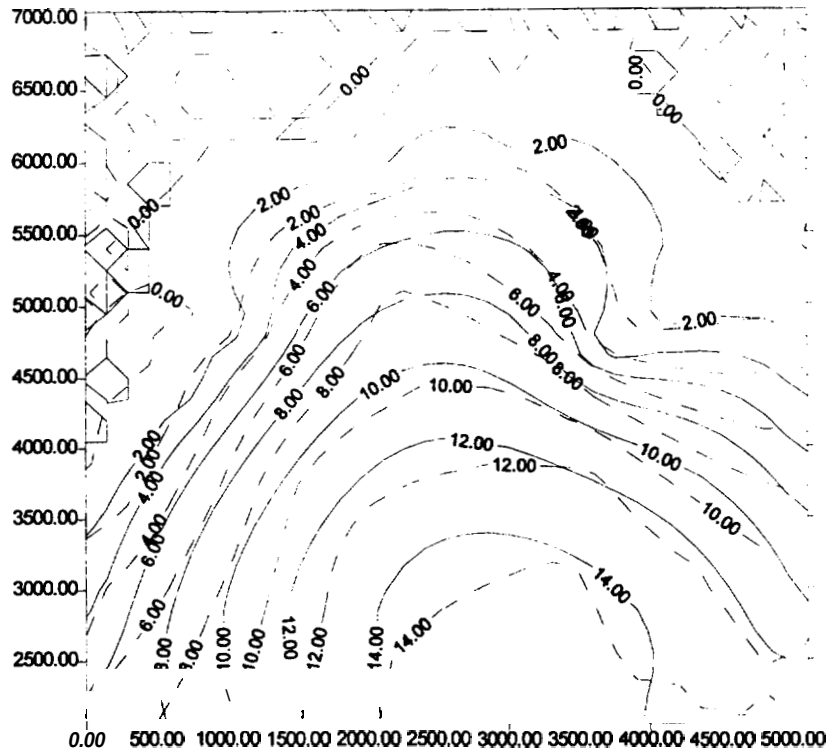


Figure 22 a Calculated shallow potentiometric surface when the hydraulic conductivity of layer 1-2 is 37.9 ft/d. Contour interval is 2.0 ft. Dashed lines are observed potentiometric contours. Solid lines are calculated potentiomtric contours.

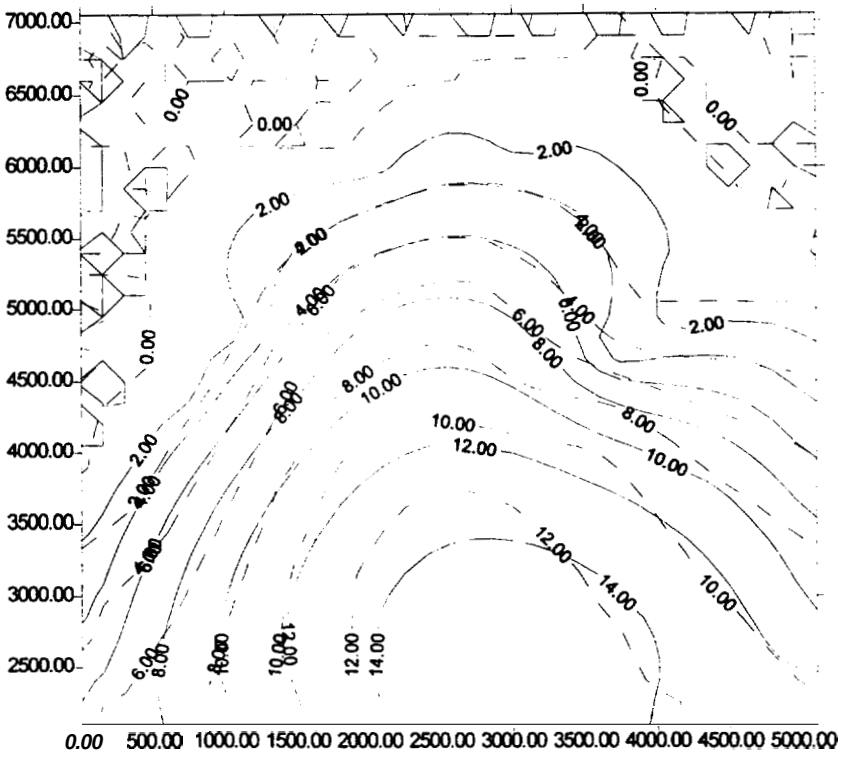


Figure 22 b. Calculated intermediate potentiometric surface when the hydraulic conductivity of layer 1-2 is 37.9 ft/d. Contour interval is 2.0 ft. Dashed lines are observed potentiometric contours. Solid lines are calculated potentiometric contours.

A hydraulic conductivity in layer 1-2 of 57.9 ft/yr produces a mean absolute error and a standard deviation of 0.8632 ft and 1.009 ft, respectively. The equipotential plot (Figure 23a) shows that a hydraulic conductivity of 57.9 ft/yr produces a shallow calculated potentiometric surface that is too high near the shore line and too low in the inland, southern portion of the domain. The calculated potentiometric surface in the intermediate region is in very good agreement with the observed intermediate potentiometric surface (Figure 23b). Deviations of approximately 1.0 ft exist very close to the southern boundary of the model.

The sensitivity of the model to variations in the shallow hydraulic conductivity is moderate.

6.3.2 Conductivity Variations in Layer 3 (Intermediate Interval)

The sensitivity to variations in hydraulic conductivity was examined by varying the hydraulic conductivity in layer 3 from 14.2 ft/d to 34.2 ft/d while leaving the conductivity in layer 1-2 constant at 47.9 ft/d (Figure 24). The mean absolute error and the standard deviation are minimized when the hydraulic conductivity is 24.2 ft/d. With the hydraulic conductivity of layer 3 set at 24.2 ft/d the entire suite of model parameters is set identically to those of the calibrated model and has identical error values.

A hydraulic conductivity in layer 3 of 14.2 ft/yr produces a mean absolute error and a standard deviation of 0.6695 ft and 0.8713 ft, respectively. The equipotential plot (Figure 25a) shows that a hydraulic conductivity of 14.2 ft/yr produces a shallow calculated potentiometric surface that is slightly too high along the shore line. The most extreme deviation is near Golf Course Pond where calculated heads exceed observed heads by up to approximately 2.0 ft. In the intermediate layer the largest deviation are found along the northern shore line (Figure 25b). The central, western, and lower eastern regions show the calculated potentiometric surface in closer agreement with the observed potentiometric surface.

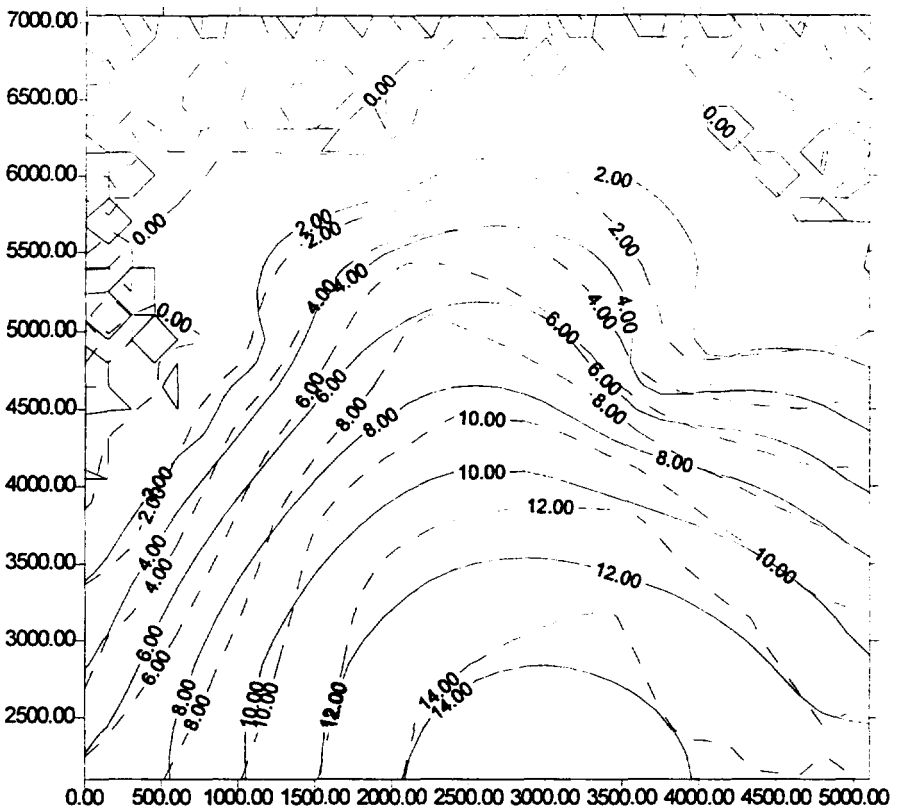


Figure 23 a. Calculated shallow potentiometric surface when the hydraulic conductivity of layer 1-2 is 57.9 ft/d. Contour interval is 2.0 ft. Dashed lines are observed potentiometric contours. Solid lines are calculated potentiometric contours.

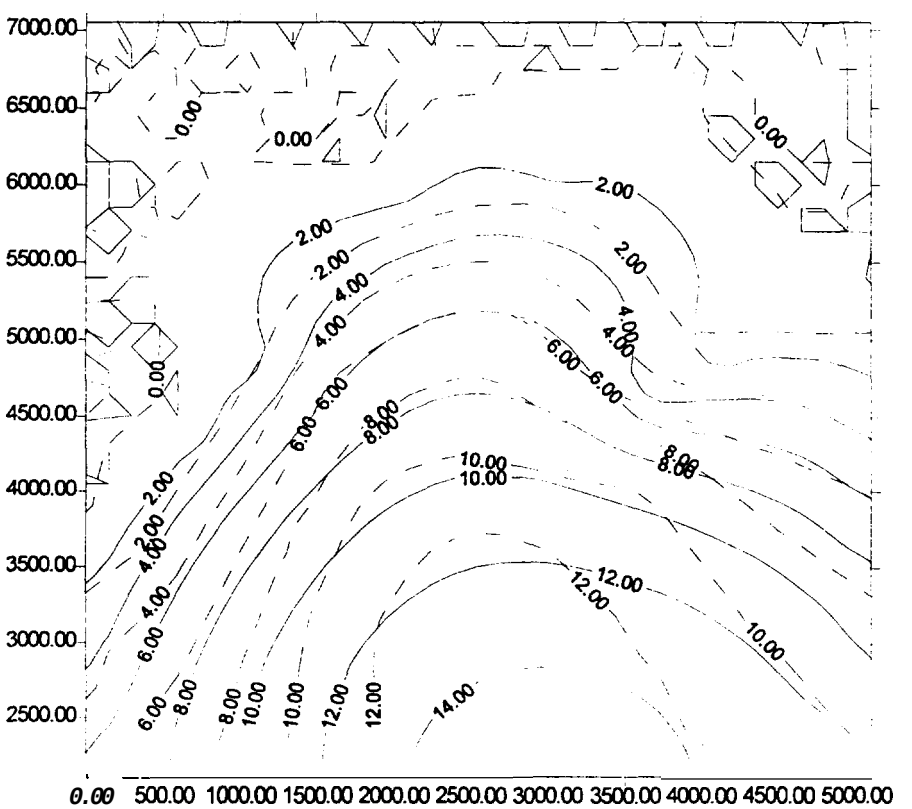
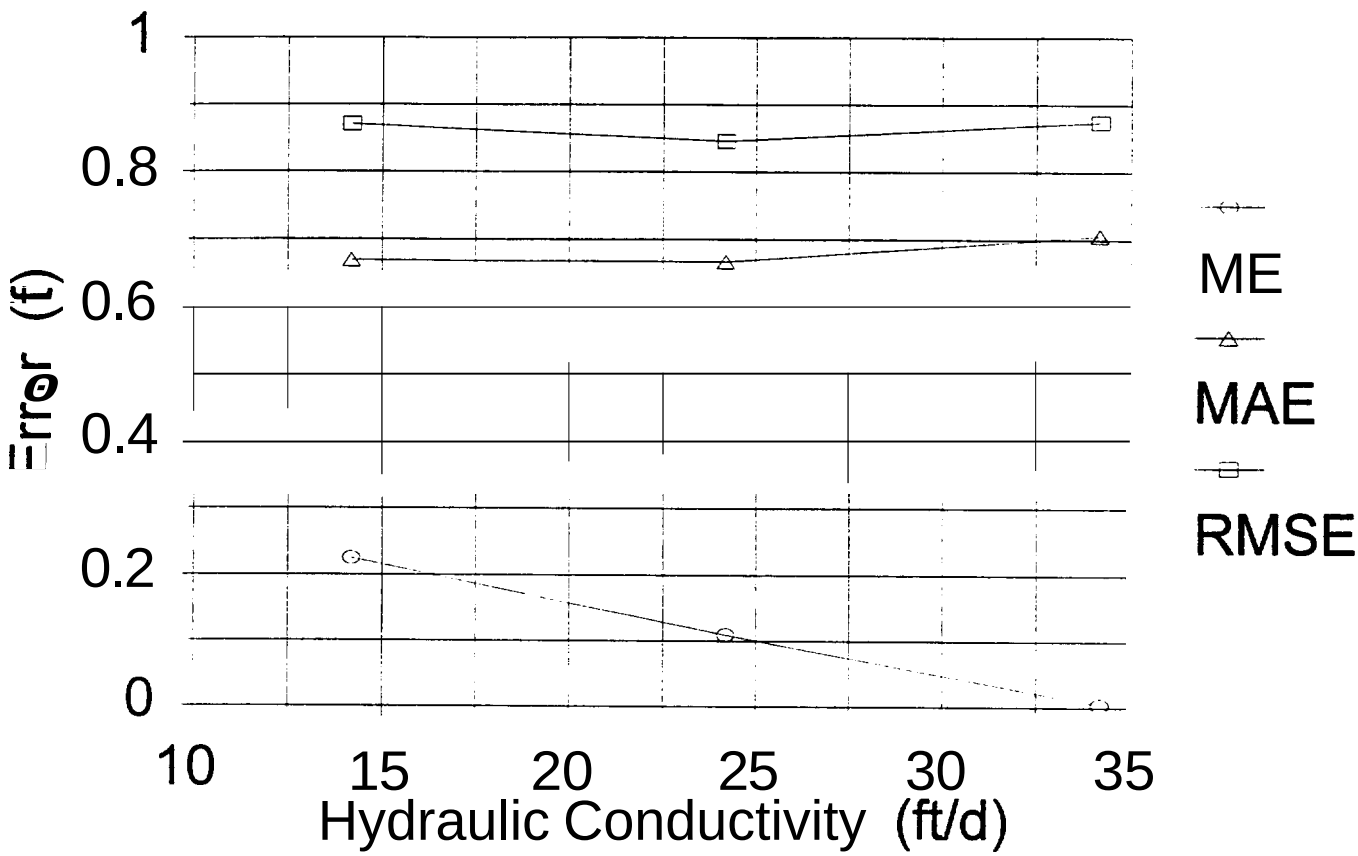


Figure 23 b. **Calculated intermediate potentiometric surface when the hydraulic conductivity in layer 1-2 is 57.9 ft/d. Contour interval is 2.0 ft. Dashed lines are observed potentiometric contours. Solid lines are calculated potentiometric contours.**

Variations in Intermediate K's

Figure 24



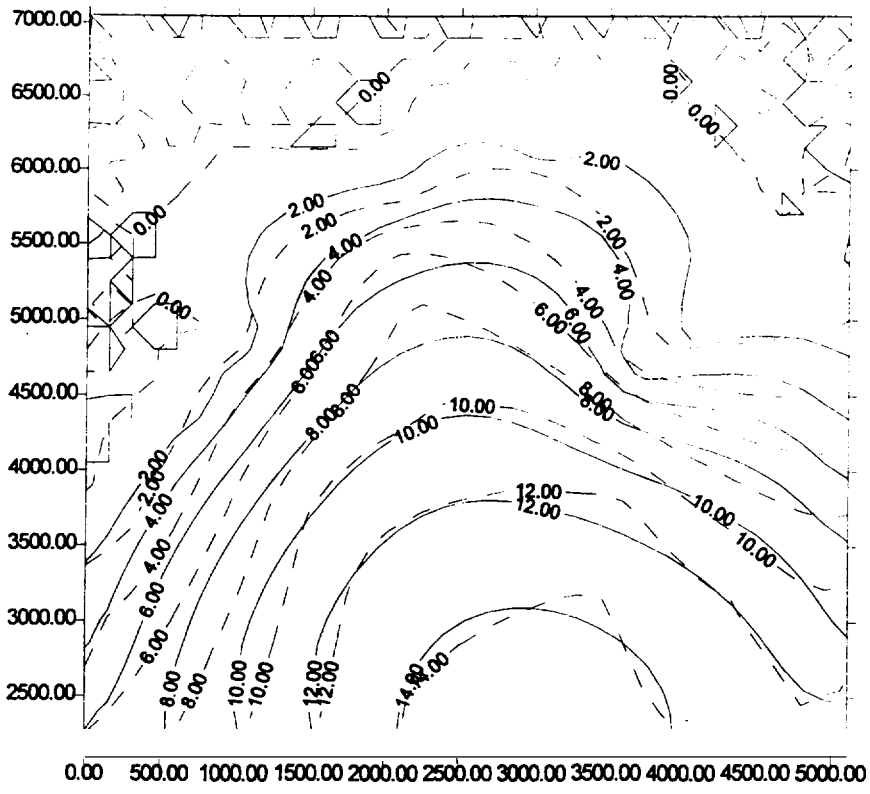


Figure 25 a Calculated shallow potentiometric surface when the hydraulic conductivity od layer 3 is 14.2ft/d. Contour interval is 2.0ft. Dashed lines are observed potentiometric contours. Solid lines are calculated contours.

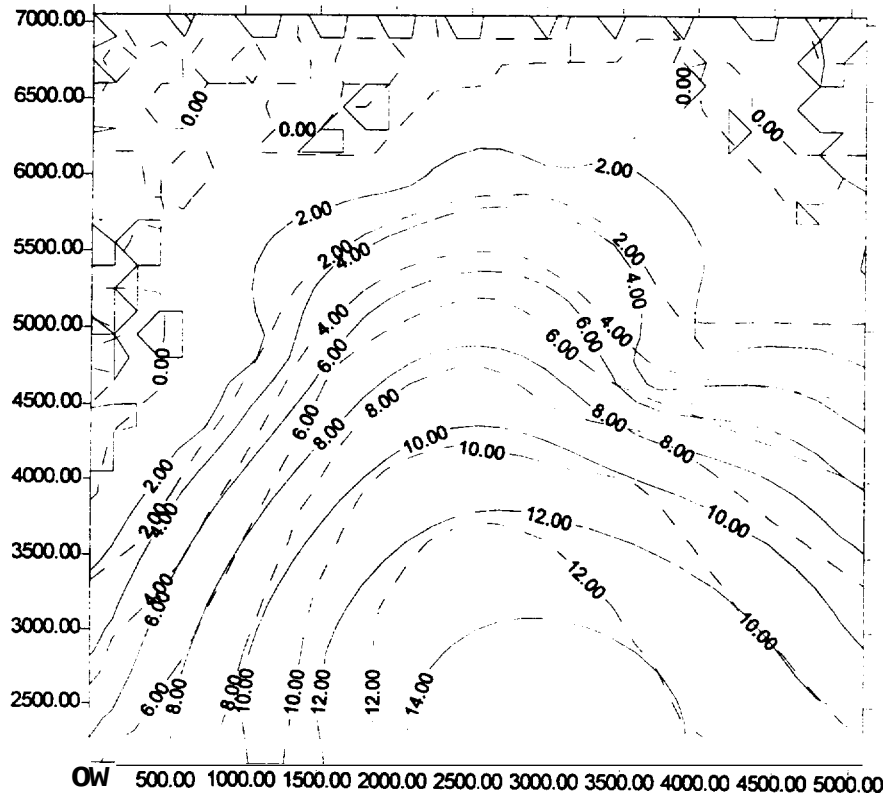


Figure 25 b. Calculated intermediate potentiometric surface when the hydraulic conductivity of layer 3 is 14.2 ft/d. Contour interval is 2.0 ft/d. Dashed lines are observed potentiometric contours. Solid lines are calculated potentiometric contours.

A hydraulic conductivity in layer 3 of 34.2 ft/yr produces a mean absolute error and a standard deviation of 0.7059 ft and 0.8747 ft, respectively. The equipotential plot (Figure 26a) shows that a hydraulic conductivity of 34.2 ft/yr produces a shallow calculated potentiometric surface that is slightly too high along the shore line. The most extreme deviation is near Golf Course Pond, where calculated heads exceed observed heads by up to approximately 2.0 ft. In the intermediate layer the largest deviation is found along the northern shore line (Figure 26b). The central, western, and lower eastern regions show the calculated potentiometric surface in closer agreement with the observed potentiometric surface.

The sensitivity of the model to variations in the shallow hydraulic conductivity is small.

7.0 EQUILIBRIUM PUMPING SIMULATIONS

Different extraction pump arrangements and pumping rates were investigated using the calibrated model of Site 1, NAS Pensacola. Modpath was used for particle tracking. All particle tracks are backwards-tracked starting from small rings of 10 particles placed around each proposed extraction well. The travel times depicted by the flow lines on Figures 27 through 30 are 2,000 days long. All particles tracks were started within 5 feet of the base of the model. All extraction wells are fully penetrating and fully screened.

The locations of the contaminated wells *can* be seen in Figure 27. The contaminants present include: benzene, bromoform, chlorobenzene, naphthalene, 1,1,2,2 - tetrachloroetheylene, vinyl chloride, and xylene. All transport is advective. No physio-chemical processes such as dispersion, diffusion, reaction, retardation, or decay are taken into account in these simulations. The simulations are considered conservative, thus giving worse-case scenario results.

7.1 Scenario I

Seven recovery wells are used in this scenario (Figure 28). Each well is extracting at 30 gpm. All extraction wells are situated downgradient of the contaminated well(s). Capture of the groundwater in regions around each contaminated well and the regions upgradient of the well is achieved by this extraction well design scenario.

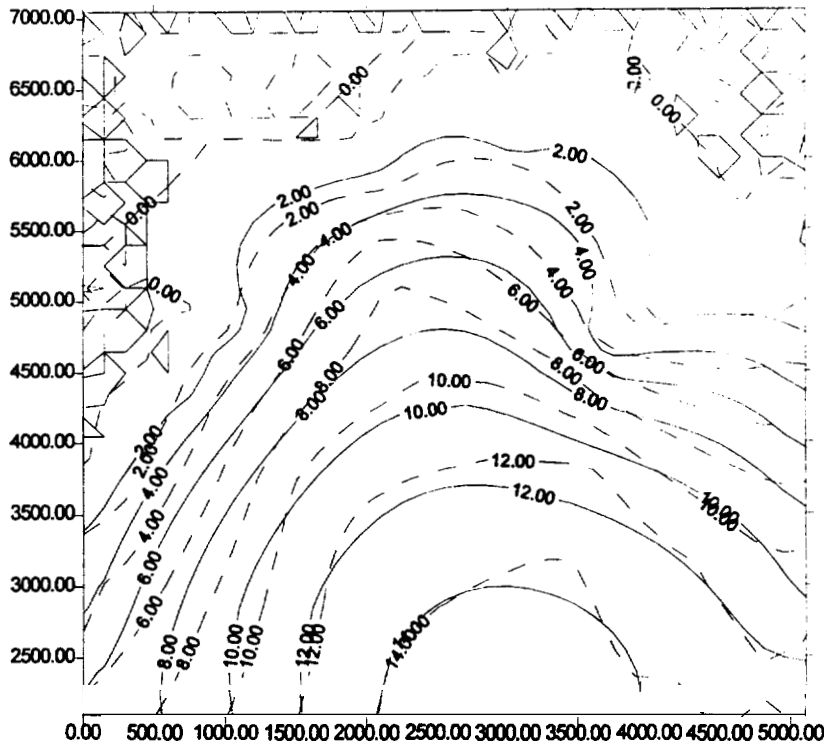


Figure 26 a. Calculated shallow potentiometric surface when hydraulic conductivity is 34.2 ft/d. Contour interval is 2.0 ft. Dashed lines are observed potentiometric surface contours. Solid lines are calculated potentiometric surface contours.

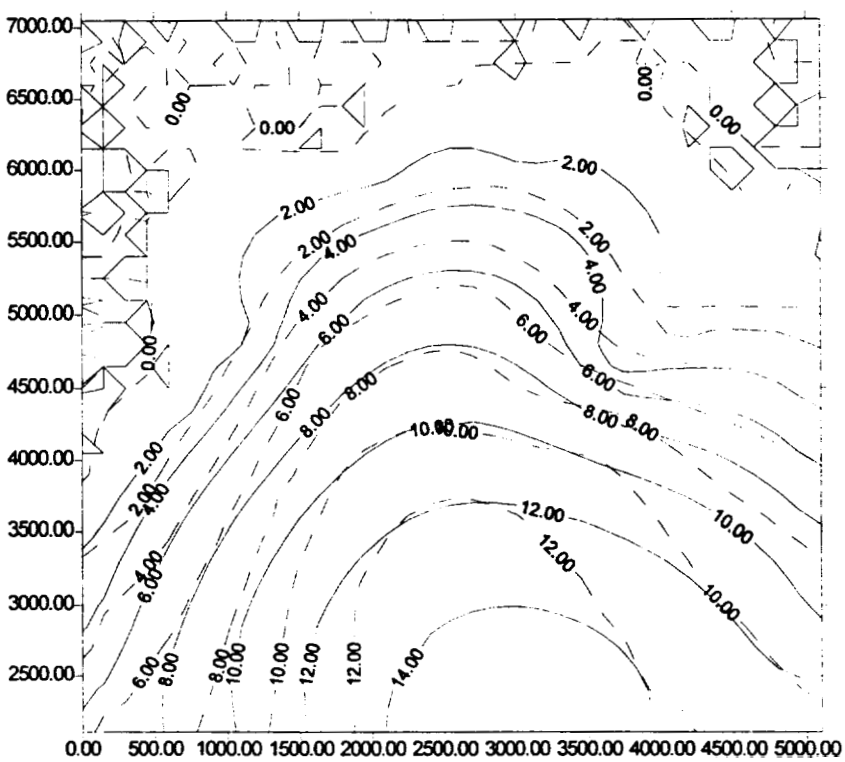


Figure 26 b. Calculated intermediate potentiometric surface when the hydraulic conductivity of layer 3 is 34.2 ft/d. Contour interval is 2.0 ft. Dashed lines are observed potentiometric contours. Solid lines are calculated potentiometric contours.

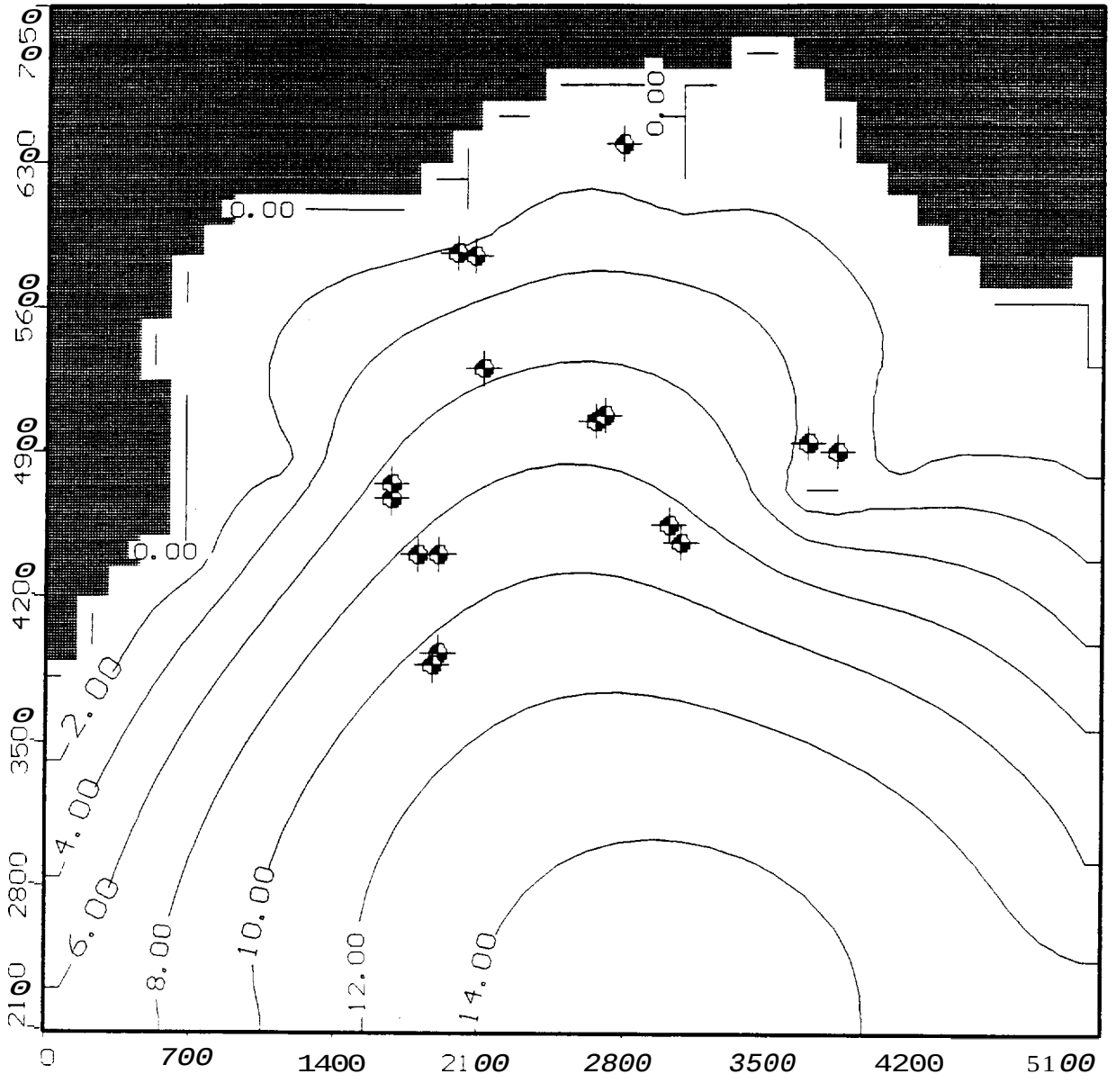


Figure 27 **Location of** contaminated **wells**

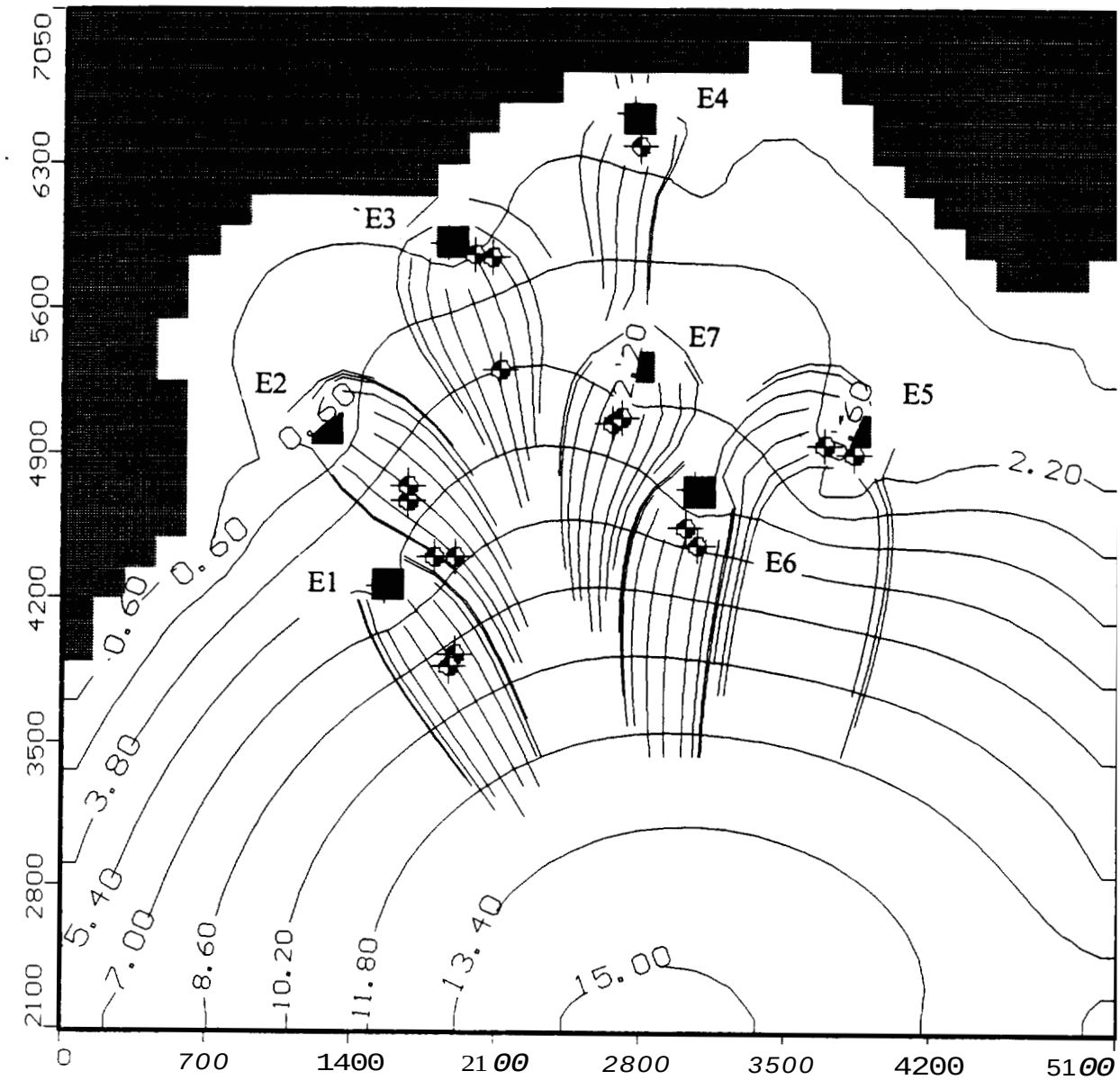


Figure 28 Backward particle tracks delineating the capture zones for Scenario I

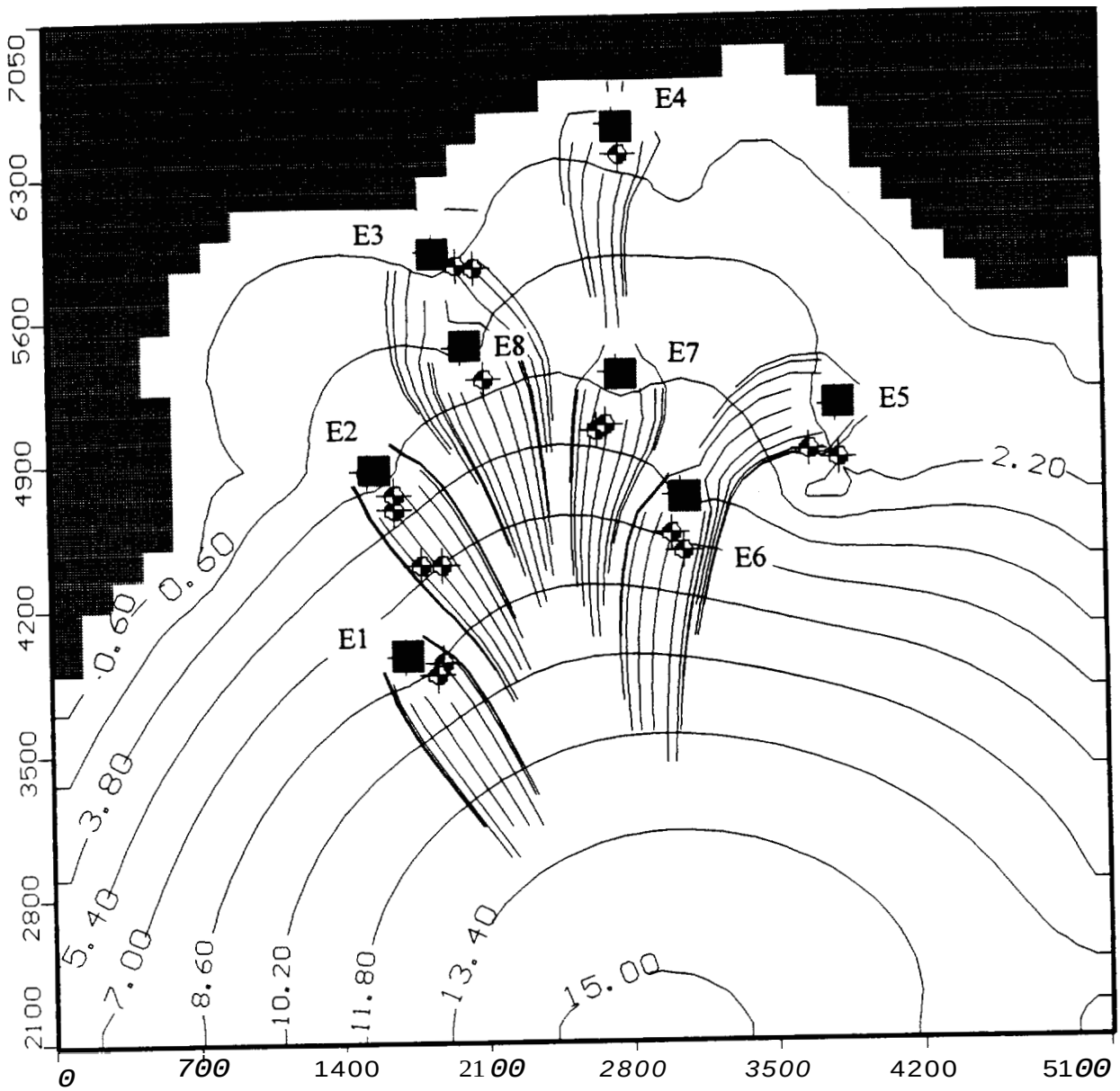


Figure 29 Backward particle tracks delineating the capture zones for Scenario II

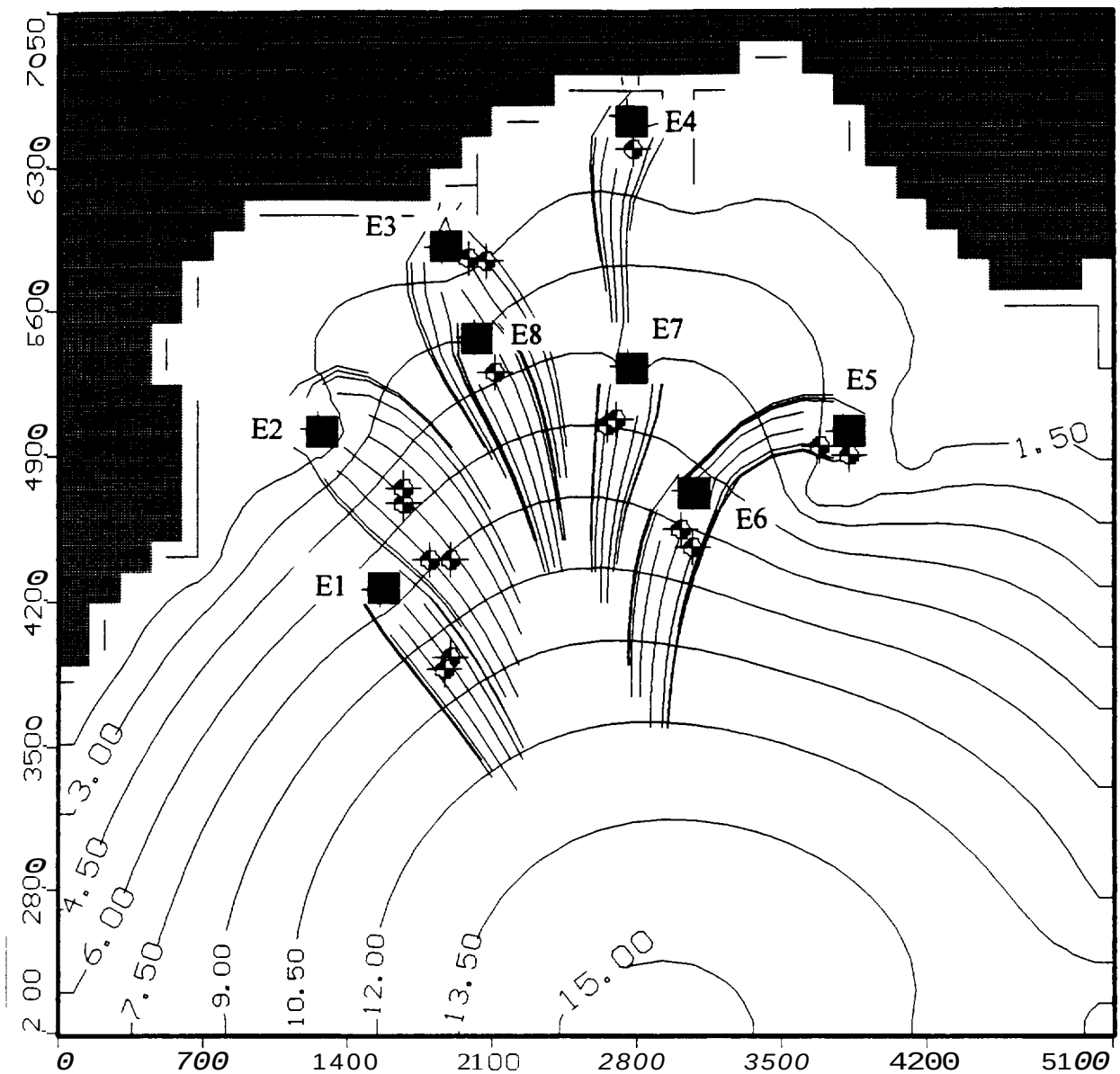


Figure 30 Backward particle tracks delineating the capture zones for Scenario III

7.2 Scenario II

Eight recovery wells are use in this scenario (Figure 29). One more well is added to the array of extractions wells in Scenario I. The extraction rate is dropped to 20 gpm without drastically decreasing the size of the capture zone. Capture at and around the contaminated wells is achieved.

7.3 Scenario III

Eight recovery wells are again used in this scenario (Figure 30). The extraction rates of E2 and E3 are 40 and 20 gpm, respectively. All other extraction wells are pumping at 10 gpm. This is done to increase the cross-sectional area of influence of wells E2 and E3. Several of the extraction wells have been moved farther downgradient to allow the capture of possible contaminants that have moved past the contaminated wells. Capture is achieved at overall lower pumping rates and volumes.

7.4 Scenario IV

Twenty wells are used in this scenario (Figure 31). The extraction rate of all wells is 4 gpm. Fifteen inner wells are located at approximately 150 ft. Intervals around the perimeter of the landfill (Figure 31). Five additional wells are placed in regions adjacent to the landfill targeting specific hotspots. The total time represented in Figure 31 is 10 years. The single hatch mark on the particle tracks represents 5 years. Capture of the groundwater from contaminated regions delineated by the border of the landfill and independent hot spots is achieved with this scenario.

8.0 DISCUSSION/CONCLUSION

The flow model constructed for Naval Air Station Site 1, Pensacola, Florida, is a general representation of the system and can be used to answer general question. Groundwater velocity vectors show a local flow system that is recharged in the southern-central portion of the model and flow radially outward to discharge at the shoreline (Figures 32 and 33). Equipotential lines appear to be vertical in cross-section, (Figure 34) this is merely due to the larger horizontal scale compression and verticle scale exaggeration. The model is kept very simple to keep it true to the data that have been collected to represent it and the processes within it. Calibration was

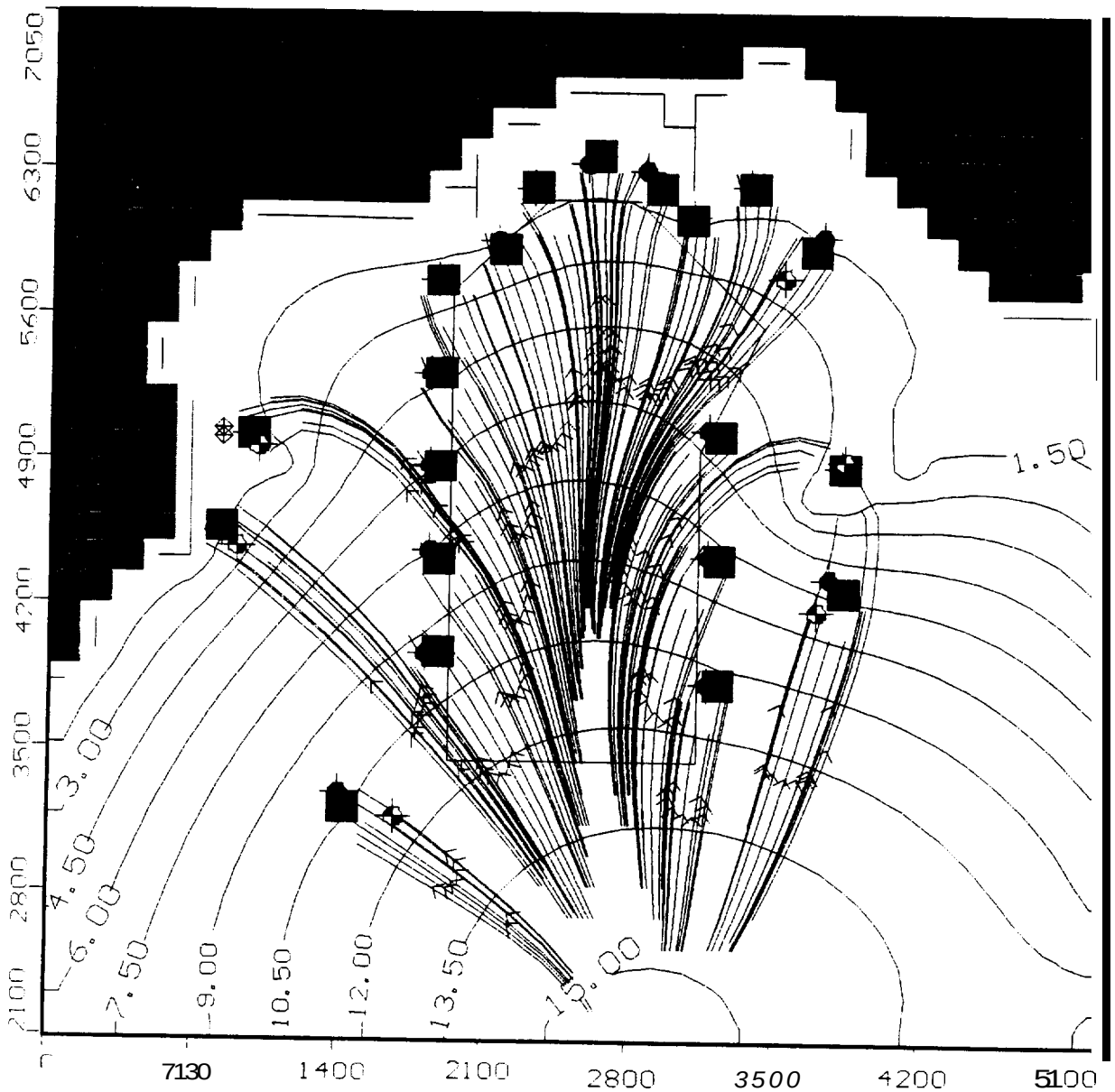


Figure 31 Scenario IV targeting all flow through the landfill along with hotspots outside the landfill. Total time represent by the backwards tracking simulation is 10 years with the hatch mark on the tracks representing 5 years.

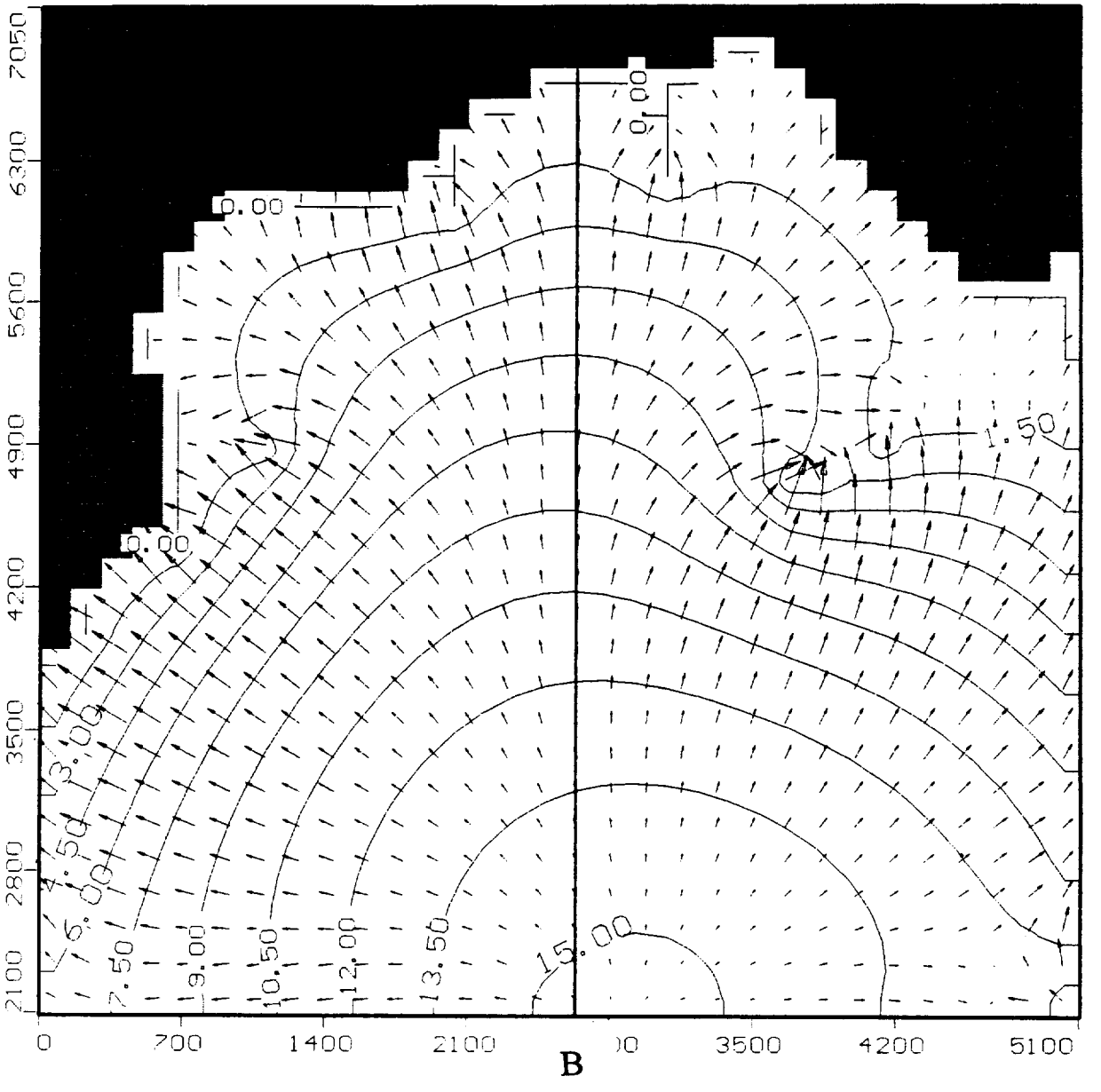


Figure 32 Map view of flow vectors as computed by VisualMODFLOW. Contour interval is 1.5 ft. The maximum velocity is 2.5 ft/day.

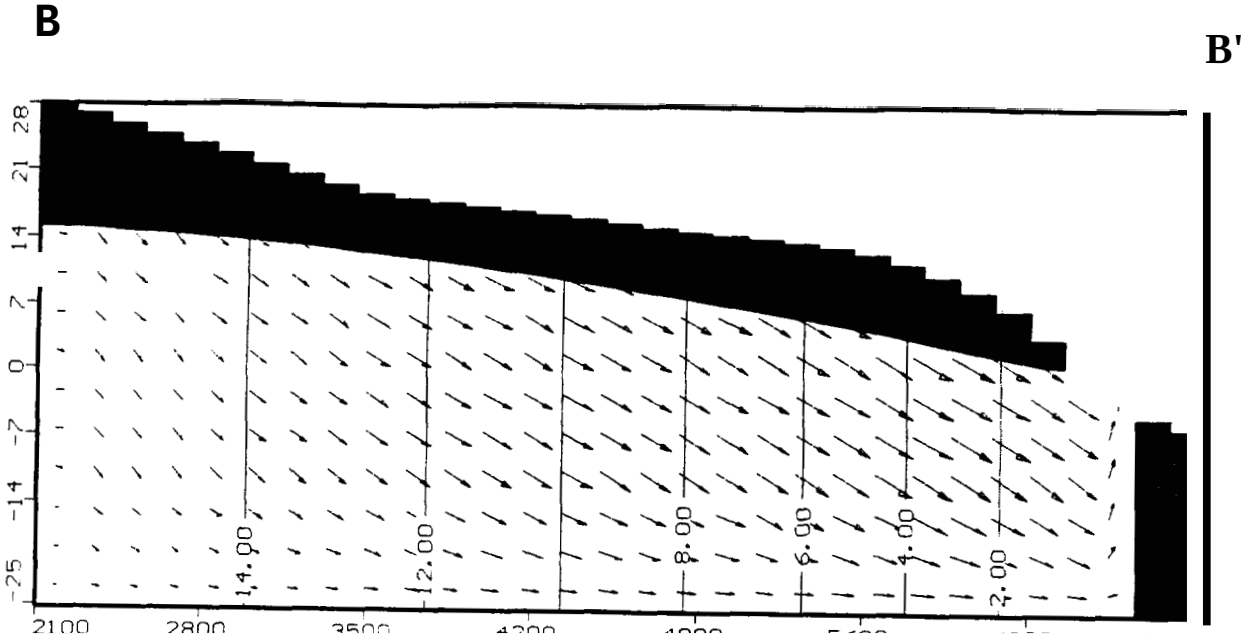


Figure 33 Cross sectional view (B-B', Figure 28) of flow vectors as computed by VisualMODFLOW. Contour interval is 2.0 ft. The maximum velocity is 0.809 ft/day.

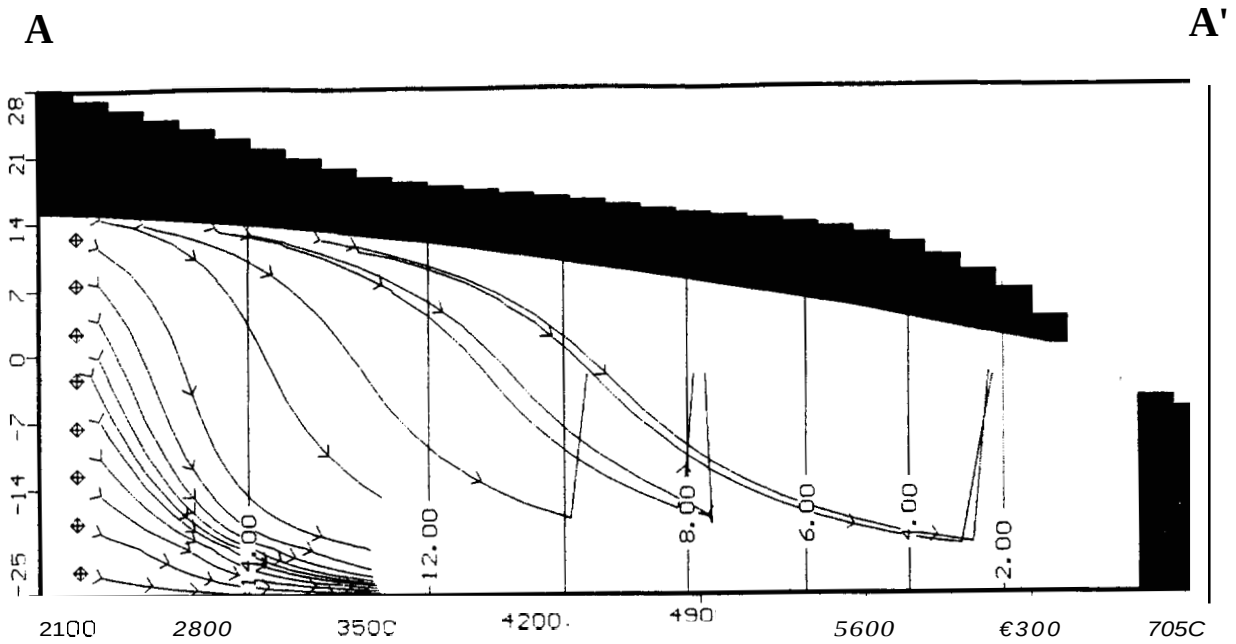


Figure 34 Cross sectional view (A-A*, Figure 26) pf particle pathways as computed by MODPATH. The contour interval on the map is 2.0 ft. The hatches on the particle pathways represent 2,000-day increments (– 5 years). The pathway of a particle is computed until it reaches a constant head cell or other groundwater sink within the model. Note: Pathways are not always in the plane of the page; vertical exaggeration is 40x.

achieved with minimal assumption (minimal assumption meaning little or no need to massage the field data to achieve calibration), which lends confidence that the model can be used to represent Site 1 hydrogeologically.

The remedial design simulations done with the completed flow model and MODPATH. Scenario IV is probably the best design due to the low flow rates of the extractions wells and their ability to intercept all flow through the landfill.

9.0 REFERENCES

Anderson, M.P., Woessner, W.W. (1992). *Applied Groundwater Modeling,* Academic Press, 381 p.

Domenico, P.A., Schwartz, F.W. (1990). *Physical and Chemical Hydrogeology,* John Wiley & Sons, Inc., 824 p.

Essaid, H.I. (1990). *The Computer Model Sharp, A Quasi-Three-Dimensional Finite-Difference Model To Simulate Freshwater and Saltwater Flow in Layered Coastal Aquifer Systems,* U.S.G.S. Water-Resources Investigations Report 904130, 181 p.

Fernald, E.A., Patten, D.J., edit., (1984). *Water Resource Atlas of Florida*, Institute of Science and Public Affairs, 291 p.

Fetter, C.W. (1988). *Applied Hydrogeology,* Macmillian Publishing Co., Inc. 592 p.

Guiguer, N., The, J., Franz, T. (1995). *Visual Modflow Users Manual,* Waterloo Hydrogeologic Software.

McDonald, M.G., Harbaugh, A.W., (1988). *A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model,* U.S.G.S.

Pollock, D.W., (1989). *Documentation of Computer Programs to Compute and Display Pathlines Using Results From the U.S. Geological Survey Modular Three-Dimensional Finite Difference Ground-Water Flow Model*, U.S.G.S. 81p.

Wang, H.F. Anderson, M.P. (1982). *Introduction to Groundwater Modeling*, W.H. Freeman and Company, 237 p.

Appendix D

Cash Out Computer Model Output

CASHOUT, VERSION 1.4

NASP SITE 1 NATURAL ATTENUATION APRIL 15, 1996

PRESENT VALUE OF CLEANUP COSTS AS OF COST COMMENCEMENT DATE:

RECURRING EXPENDITURES	$ -0
ONE-TIME EXPENDITURE	$ 444314
ANNUAL EXPENSE FOR 30 YEARS	$ 2596303
TOTAL AS OF 5, 1996	$ 3040617

PRESENT VALUE OF CLEANUP COSTS AS OF PRP PAYMENT DATE:

RECURRING EXPENDITURES	$ -0
ONE-TIME EXPENDITURE	$ 444314
ANNUAL EXPENSE FOR 30 YEARS	$ 2596303
TOTAL AS OF 5, 1996	$ 3040617

->->->->->-> THE SUPERFUND CASHOUT CALCULATION ABOVE <-<-<-<-<-<-
USED THE FOLLOWING VARIABLES:

USER SPECIFIED VALUES
---

1. SUPERFUND SITE NAME = NASP SITE 1 NATURAL ATTENUATION
2. RECURRING EXPENDITURES = $ 0 1996 DOLLARS
3. ONE-TIME EXPENDITURE= $ 442405 1996 DOLLARS
4. ANNUAL EXPENSE FOR 30 YEARS= $ 140710 1996 DOLLARS
5. PRP PAYMENT DATE= 5, 1996
6. SUPERFUND CLEANUP COSTS COMMENCEMENT DATE = 5,1996
7. ANNUAL INFLATION RATE= 1.30%
8. DISCOUNT RATE= 5.00%

CASHOUT, VERSION **1.4**

NASP **SITE** 1 SURFACE CAP ALTERNATIVE APRIL **16, 1996**

PRESENT VALUE OF CLEANUP COSTS AS OF COST COMMENCEMENT DATE:

RECURRING EXPENDITURES	$ -0
ONE-TIME EXPENDITURE	$ **10859847**
ANNUAL EXPENSE FOR **30** YEARS	$ **2590583**
TOTAL AS OF **5, 1996**	$ **13450430**

PRESENT VALUE OF CLEANUP COSTS AS OF PRP PAYMENT DATE:

RECURRING EXPENDITURES	$ -0
ONE-TIME EXPENDITURE	$ **10859847**
ANNUAL EXPENSE FOR 30 ***YEARS***	$ **2590583**
TOTAL AS OF 5, **1996**	$ **13450430**

->->->->->-> THE SUPERFUND CASHOUT CALCULATION ABOVE <-<-<-<-<-<-
USED THE FOLLOWING VARIABLES:

USER SPECIFIED VALUES
---

1. SUPERFUND SITE NAME = NASP SITE 1 SURFACE CAP ALTERNATIVE
2. RECURRING EXPENDITURES = $ 0 **1996** DOLLARS
3. ONE-TIME EXPENDITURE = $ **10813191 1996** DOLLARS
4. ANNUAL EXPENSE FOR **30** ***YEARS*** = $ **140400 1996** DOLLARS
5. PRP PAYMENT DATE = **5, 1996**
6. SUPERFUND CLEANUP COSTS COMMENCEMENT DATE = **5, 1996**
7. ANNUAL INFLATION RATE = **1.30%**
8. DISCOUNT RATE = 5.00%

CASHOUT, VERSION 1.4

NASP SITE 1 CONSTRUCTED WETLANDS *APRIL* 16, 1996

PRESENT VALUE OF CLEANUP COSTS AS OF COST COMMENCEMENT DATE:

RECURRING EXPENDITURES	$ -0
ONE-TIME EXPENDITURE	$ 1435138
ANNUAL EXPENSE FOR 30 YEARS	$ 995954
TOTAL AS OF 5, 1996	$ 2431091

PRESENT VALUE OF CLEANUP COSTS AS OF PRP PAYMENT DATE:

RECURRING EXPENDITURES	$ -0
ONE-TIME EXPENDITURE	$ 1435138
ANNUAL EXPENSE FOR 30 YEARS	$ 995954
TOTAL AS OF 5, 1996	$ 2431091

->->->->->-> THE SUPERFUND CASHOUT CALCULATION ABOVE <-<-<-<-<-<-
USED THE FOLLOWING VARIABLES:

USER SPECIFIED VALUES
.....

1. SUPERFUND SITE NAME = NASP SITE 1 CONSTRUCTED WETLANDS
2. RECURRING EXPENDITURES = $ 0 1996 DOLLARS
3. ONE-TIME EXPENDITURE = $ 1428972 1996 DOLLARS
4. ANNUAL EXPENSE FOR 30 YEARS = $ 53977 1996 DOLLARS
5. PRP PAYMENT DATE = 5, 1996
6. SUPERFUND CLEANUP COSTS COMMENCEMENT DATE = 5, 1996
7. ANNUAL INFLATION RATE = 1.30%
8. DISCOUNT RATE = 5.00%

CASHOUT, VERSION 1.4

NASP SITE 1 AIR STRIPPING ALTERNATIVE APRIL 16, 1996

PRESENT VALUE OF CLEANUP COSTS AS OF COST COMMENCEMENT DATE:

RECURRING EXPENDITURES	$ -0
ONE-TIME EXPENDITURE	$ 498638
ANNUAL EXPENSE FOR 30 YEARS	$ 1519385
TOTAL AS OF 5, 1996	$ 2018023

PRESENT VALUE OF CLEANUP COSTS AS OF PRP PAYMENT DATE:

RECURRING EXPENDITURES	$ -0
ONE-TIME EXPENDITURE	$ 498638
ANNUAL EXPENSE FOR 30 YEARS	$ 1519385
TOTAL AS OF 5, 1996	$ 2018023

->->->->->-> THE SUPERFUND CASHOUT CALCULATION ABOVE <-<-<-<-<-<-
USED THE FOLLOWING VARIABLES:

USER SPECIFIED VALUES
.....

1. SUPERFUND SITE NAME = NASP SITE 1 AIR STRIPPING ALTERNATIVE
2. RECURRING EXPENDITURES = $ 0 1996 DOLLARS
3. ONE-TIME EXPENDITURE = $ 496496 1996 DOLLARS
4. ANNUAL EXPENSE FOR 30 YEARS = $ 82345 1996 DOLLARS
5. PRP PAYMENT DATE = 5, 1996
6. SUPERFUND CLEANUP COSTS COMMENCEMENT DATE = 5, 1996
7. ANNUAL INFLATION RATE = 1.30%
8. DISCOUNT RATE = 5.00%

CASHOUT, VERSION **1.4**

NASP SITE 1 GROUNDWATER EXTRACTION **MAY 9, 1996**

PRESENT VALUE OF CLEANUP COSTS **AS** OF COST COMMENCEMENT DATE:

RECURRING **EXPENDITURES**	**$** -0
ONE-TIME EXPENDITURE	$ **756589**
ANNUAL EXPENSE FOR 30 YEARS	**$ 2441865**
TOTAL AS OF **5, 1996**	$ **3198454**

PRESENT VALUE OF CLEANUP COSTS AS OF PRP PAYMENT DATE:

RECURRING EXPENDITURES	**$** -0
ONE-TIME EXPENDITURE	$ **756589**
ANNUAL EXPENSE FOR **30** YEARS	$ **2441865**
TOTAL AS OF **5,1996**	$ **3198454**

->->->->->-> THE SUPERFUND CASHOUT CALCULATION **ABOVE** <-<-<-<-<-<-
USED THE FOLLOWING VARIABLES:

USER SPECIFIED VALUES
.....

1. SUPERFUND SITE NAME = NASP SITE 1 GROUNDWATER EXTRACTION
2. RECURRING EXPENDITURES = **$** 0 **1996** DOLLARS
3. ONE-TIME EXPENDITURE = $ **753339 1996** DOLLARS
4. ANNUAL EXPENSE FOR **30** YEARS = $ **132340 1996** DOLLARS
5. **PRP** PAYMENT DATE = **5, 1996**
6. SUPERFUND CLEANUP COSTS COMMENCEMENT DATE = **5, 1996**
7. ANNUAL INFLATION RATE = **1.30%**
8. DISCOUNT RATE = 5.00%