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NUMERICAL MODELING D
NAS PENSACOLA
PENSACOLA, FLORIDA

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SOUTHNAVFACENGCOM
CONTRACT NUMBER N62467-89-D-0318
CTO-119

Prepared for:

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

Prepared by:

EnSafe/Allen & Hoshall
5720 Summer Trees Drive, Suite 8
Memphis, Tennessee 38134
(901) 383-9115

February 13,1997

Release of this document requires prior notification of the Commanding Officer of the Naval Air Station, Pensacola, FL

NUMERICAL MODELING DESIGN CONCEPT
NAS PENSACOLA
PENSACOLA, FLORIDA

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

Date 2/12/97
Signature B. Caldwell
Name: Brian Caldwell
Title: Task Order Manager

February 13, 1997

Table of **Contents**

1.0 INTRODUCTION 1

2.0 CONCEPTUALMODEL 2

3.0 DATA COMPILATION AND REVIEW 4

4.0 DATA COLLECTION EFFORT 7

5.0 MODELING EFFORT 17
- 5.1 Code 17
- 5.2 Platform 18
- 5.3 Procedures/Sequence of Events 18
  - 5.3.1 Sequence of Events 18
  - 5.3.2 Data Organization/Conceptual Model 18
  - 5.3.3 Model Setup 18
  - 5.3.4 Calibration 19
  - 5.3.5 Sensitivity Testing 19
  - 5.3.6 Post-Audit 20

6.0 REPORT 20

7.0 TIMEFRAME 20

List of Figures

Figure 2-1 Cross Section of the Conceptual Model for NAS Pensacola 3

Figure 3-1 *Summary* of the Available and Proposed Hydrogeologic Data for the NAS Pensacola Numeric Model 5

Figure 7-1 Modeling Schedule 21

List of Tables

Table 4-1 Proposed Monitoring Well Network for NAS Pensacola Groundwater Flow Model 8

1.0 INTRODUCTION

Under the authority of the U.S. Navy Comprehensive Long-term Environmental Action Navy (CLEAN) program, a base-wide numerical groundwater model will be developed for Naval Air Station Pensacola (NASP). The resulting model will be used as a technical management tool to provide predictive and interpretive capabilities to decisions required during the progression of environmental work at the base. The model can be used to, but not limited to, perform the following tasks.

- Improve efficiency in locating sampling points during the course of investigation;
- Locate potential risk receptors;
- Provide a flow framework for the evaluation of contaminant transport;
- Allow accurate predictions/interpretations of flow characteristics BETWEEN sites;
- Provide the flow framework for design of remedial systems and interpretation of system efficiency.

Clearly, the model can be used as a tool for a myriad of purposes, and should not be considered limited to those listed above. A base-wide model additionally offers elements of validity over its site-specific counterpart in that it encompasses and accounts for many more of the natural hydraulic features present in the area.

This document outlines the conceptual approach to be employed for numerical groundwater modeling of Naval Air Station Pensacola. Section 2.0 presents the initial conceptual model of the site that will be used to gather further data needed for the modeling; Section 3.0 presents a compilation of available data generated to date from past environmental work; Section 4.0 outlines the procedures for data acquisition; Section 5.0 develops the progression of the modeling effort, including the platform, the procedures, the sequence and timing of events; Section 6.0 describes the reports to be generated; and Section 7.0 presents the anticipated time frame for the overall effort.

2.0 CONCEPTUAL MODEL

The conceptual model presented in this section is based primarily on the work conducted by Ecology and Environment (E&E, 1990-1992) and EnSafe/Allen and Hoshall (E/A&H, 1992-.present). Because of the volume of work conducted, and the plethora of data generated from it, it is expected that this conceptual model will experience very few changes.

The conceptual model will serve first to dictate the compilation and interpretation of existing data, and secondly will serve to dictate the collection of additional data. The near surface hydrogeology of the base *can* be adequately described using three layers (Figure 2-1). The first layer exposed at the surface is composed primarily of sand, is approximately 20 feet thick; is characterized by relatively high conductivities; and is referred to as the "shallow" zone. Layer 2, immediately below Layer 1, experiences a 100% hydraulic connection with Layer 1, is composed primarily of sand with increasing clay near its base, is approximately 20 feet thick; is characterized by relatively low permeabilities; and is referred to as the "intermediate zone". Groundwater in both Layer 1 and 2 occurs under unconfined conditions, and there is a downward vertical potential between the layers. Layer 3, below Layer 2, is composed primarily of clay; and is characterized by conductivities which would classify it as functionally impermeable. All documented groundwater contamination at NASP is restricted to Layers 1 and 2. Given this and the low permeability of Layer 3, it then becomes the lower limit of the modeling effort.

Regional upgradient direction for both Layer 1 and 2 is to the west. In addition to upgradient flux, recharge to Layer 1 is presumed to be the result of direct infiltration of precipitation minus transpiration and evaporation; except for paved areas, runoff is expected to be minimal. Discharge is expected to occur in on-base wetlands which are floored with organic-rich sediments and are bottomed in Layer 1, and to the north in Bayou Grande and to the south and east in Pensacola Bay. Regional flow is expected to be from west to east. In addition to upgradient flux, recharge to Layer 2 is presumed to be leakage from Layer 1, and discharge is

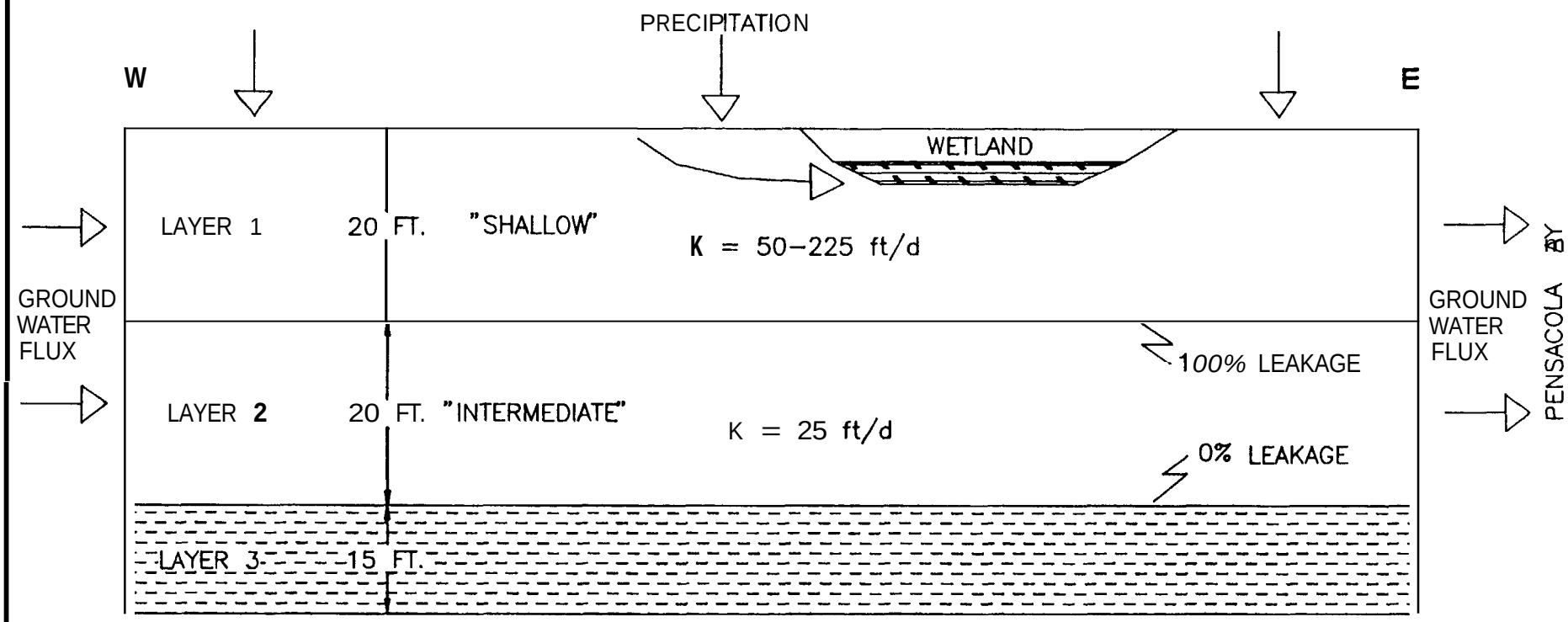

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FIGURE 2.1
CROSS SECTION OF THE
CONCEPTUAL MODEL FOR
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PENSACOLA, FLORIDA

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expected to occur to Bayou Grande and Pensacola Bay. Regional flow is expected to be from west to east.

3.0 DATA COMPILATION AND REVIEW

Data from the following sources will be reviewed to provide the most complete network possible.

- Installation Restoration (IR) Program work (Geraghty and Miller, E&E, E/A&H)
- Underground storage tank (UST) work (ABB)
- Public Works Center (PWC) UST work

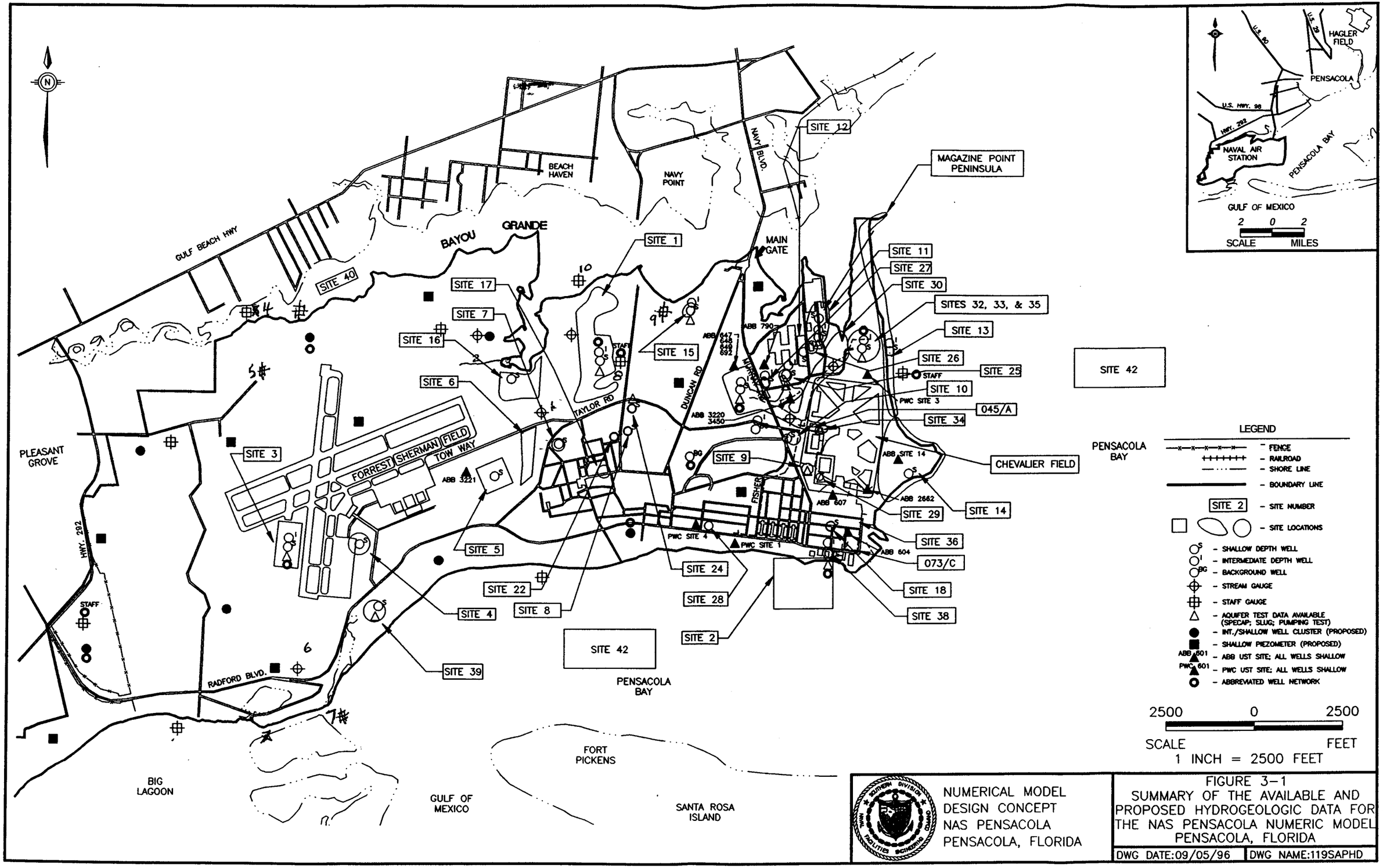
Data sources 2 and 3 will primarily be used to provide wells at locations where there are no IR wells. Data source 1 will be the primary supplier of wells for providing the monitoring well network, and to provide hydraulic data.

Figure 3-1 compiles features important to the modeling effort. This figure provides both the location of existing data and locations of proposed sampling points to be installed/measured during data acquisition for this effort. The following discussion provides the relevance of the data presented on the figure; the specifics of these (nos., procedures, etc.) will be presented in Section 5.

Existing Data

IR/UST Sites

The location of all IR and UST (both ABB and PWC) sites are shown on Figure 3-1. These sites provide the coverage of existing data; it is evident that the coverage is more dense on the eastern side of the base where the bulk of the environmental sites are located. It is anticipated that at least one existing well on each site will be used to establish the monitoring well network. In addition to the site location, the figure is keyed to show which sites contain shallow (Layer 1)



NUMERICAL MODEL
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FIGURE 3-1
SUMMARY OF THE AVAILABLE AND PROPOSED HYDROGEOLOGIC DATA FOR THE NAS PENSACOLA NUMERIC MODEL
PENSACOLA, FLORIDA

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and/or intermediate (Layer 2) wells available for measurement. Because most investigations targeted Layer 1, Layer 1 possesses many more available sampling points than Layer 2.

Aquifer Test Data

For the locations keyed, there is some amount of aquifer test data available. These data include single-and multi-well pumping tests, slug tests, and specific capacity tests. These data will be used to provide first estimates for conductivity and storativity for the initial calibration parameters.

Proposed Data Locations

There are a number of additional data locations proposed on this figure. These data are proposed to fill data gaps that are present in the existing data.

Additional Piezometers

Due to the biased areal coverage of the base (model domain), a number of additional piezometers are proposed to be installed. These additional points will provide head data for the modeling in areas of limited information. In every instance where a Layer 2 piezometer is to be installed, it will be nested with a Layer 1 piezometer.

Aquifer Testing Location

Due to the sparsity of aquifer test data over a large portion of the base, the relative homogeneity of the layers, and the uncertainty over how each layer will respond over a relatively long-term high stress period, 24-hour aquifer tests are proposed for Layer 1 and Layer 2. In order to reduce investigation derival wastes, the aquifer test location is in an area presumed to be unaffected by contamination. In addition to the production well for each layer, there are also piezometers scheduled to be installed at this location to serve as observation points.

Staff Gauges/Stream Gauging Stations

Currently, there are no staff gauges nor stream gauging stations operational on NASP. Due to the uncertainty regarding the relationship(s) between groundwater and surface water, there are a number of stream gauges proposed. These are located at regular distances around the perimeter of the base (to monitor Bayou Grande and Pensacola Bay) and at locations on-base where groundwater discharge is thought to be occurring, or where significant streamflow has been observed.

4.0 DATA COLLECTION EFFORT

This section outlines the specifics of the data collection effort. This effort is divided into several categorical tasks, including:

Task 1	Establishment of a monitoring well network
Task 2	Installation of additional wells/piezometers
Task 3	Installation of staff gauges and stream gauging stations
Task 4	Establishment of an abbreviated well network
Task 5	Aquifer testing
Task 6	Long-term water level measurement
Task 7	Synoptic water level measurements

Task 1 — Establishment Of a Monitoring Well Network - Existing Wells

A representative number of wells from each site will be chosen to provide a reasonable areal coverage for each layer. This task can be divided into two phases: the choosing of the wells, and the field checks of the wells for accessibility. The first phase of this task has been completed, and Table 4-1 presents a compendium of the wells chosen for inclusion in the network. These wells were chosen based on their depths and their location on each individual site. In all cases, attempts were made to choose nested wells (wells adjacent to each other, but completed at

Table 4-1
Proposed Monitoring Well Network for NAS Pensacola
Groundwater Flow Model

Site Number	Well Number	Well Depth	Comment
Site 1	01GI35	intermediate	
	01GI36	intermediate	
	01GI38	intermediate	
	01GI44	intermediate	
	01GI48	intermediate	
	01GI59	intermediate	
	01GI63	intermediate	
	01GI65	intermediate	
	01GI66	intermediate	
	01GS39	shallow	
	01GS53	shallow	
	01GS62	shallow	
	01GS64	shallow	
Site 3	GI01	Intermediate	
	GS01	shallow	
	GI04	intermediate	
	GI06	intermediate	
	GS06	shallow	
Site 4	04GS01	shallow	
	04GS02	shallow	
	04GS03	shallow	
Site 5	05GS01	shallow	
	05GS03	shallow	
Site 7	07GS01	shallow	
	07GS03	shallow	

Table 4-1
Proposed Monitoring Well Network for NAS Pensacola
Groundwater Flow Model

Site Number	Well Number	Well Depth	Comment
	07GS04	shallow	
Site 8	08GR03	shallow	
	08GR04	shallow	
Site 1 0	10GS01	shallow	
	10GM06	shallow	
	10GS05	shallow	
	10GS04	shallow	
Site 11,25/27,30	11GI102	intermediate	
	11GI106	intermediate	
	11GI108	intermediate	
	11GI114	intermediate	
	I1GI115	intermediate	
	25GI01	intermediate	
	27GI05	intermediate	
	30GI19	intermediate	
	30GI47	intermediate	
	30GI58	intermediate	
	30GI111	intermediate	
	30GI113	intermediate	
	30GI126	intermediate	
Site 13/OU 1 0	TW002	shallow	temporary
	TW007	shallow	temporary
	TW011	shallow	temporary
	TW016	shallow	temporary
	33G10	intermediate	

Table 4-1
Proposed Monitoring Well Network for NAS Pensacola
Groundwater Flow Model

Site Number	Well Number	Well Depth	Comment
	33G11	intermediate	
	13G06	shallow	
	33G13	intermediate	
	33G04	shallow	
	33G01	shallow	
	33G15	intermediate	
	PCI 1	intermediate	
	PCS 1	shallow	
	GM 81	shallow	
Site 14	14GS01	shallow	
	14GS02	shallow	
Site 15	015GGM60	shallow	
	015GGR01	shallow	
	015GGR04	shallow	
	015GGR28	shallow	temporary
	015GGR38	shallow	temporary
	015GGR65	shallow	temporary
	015GGR66	shallow	temporary
Site 16	16GS01	shallow	
	16GS04	shallow	
	16GS05	shallow	
	16GS06	shallow	
	16GS08	shallow	
Site 17	01GR03	shallow	temporary
	17GR05	shallow	temporary

Table 4-1
Proposed Monitoring Well Network for NAS Pensacola Groundwater Flow Model

Site Number	Well Number	Well Depth	Comment
	17GR07	shallow	temporary
Site 18	18GS02	shallow	
Site 22	22GR02	shallow	
	22GR03	shallow	
Site 24	024GS08	shallow	
	O24GR09	shallow	temporary
	024GS03	shallow	
	024GSO1	shallow	
	024GS05	shallow	
Site 38	18GS02	shallow	
	36GR52	shallow	temporary
	36GR54	shallow	temporary
	36MW75C	–	
	36MW79C	–	
	38GI01	intermediate	
	38GI02	intermediate	
	38GI03	intermediate	
	38GI07	intermediate	
	38GI08	intermediate	
	386109	intermediate	
	38GS01	shallow	
	38GS02	shallow	
	38GS03	shallow	
	38GS07	shallow	
	38GS09	shallow	

Table 4-1
Proposed Monitoring Well Network for NAS Pensacola Groundwater Flow Model

Site Number	Well Number	Well Depth	Comment
	38GS11	shallow	
	38GS16	shallow	
	38GS20	shallow	
	38GS25	shallow	
	38GS28	shallow	
	38GS30	shallow	
	38GS32	shallow	
Site 39	39GI05	intermediate	
	39GI07	intermediate	
	39GS01	shallow	
	39GS03	shallow	
UST SITE 5	05GS04/MW-4	shallow	
	MW-1	shallow	
	MW-11	shallow	
	MW-7	shallow	
ABB UST SITE 3221 SW	MW-1•	shallow	
	MW-6•	shallow	
	MW-7•	shallow	
ABB UST SITE 3450 W	MW-1	shallow	
ABB UST SITE 14	MW-6	shallow	
	MW-11D	shallow	
PWC UST SITE 1	MW-1	shallow	
PWC UST SITE 3	MW-6	shallow	
	MW-7	shallow	

Table 4-1
Proposed Monitoring Well Network for NAS Pensacola
Groundwater Flow Model

Site Number	Well Number	Well Depth	Comment
PWC UST SITE 1	MW-1	shallow	
	MW-3	shallow	
	MW-5	shallow	

Note:
- * – These wells may not be available due to Chevalier Field construction.
- ** – Well included in abbreviated well network.

different depths). Currently, there are 87 shallow and 38 intermediate wells scheduled for inclusion in the network.

Task 2 – Additional Well/Piezometer Installations

To supplement the existing well network, seven intermediate wells and 15 shallow wells will be installed at the proposed locations shown on Figure 3-1. The majority of these wells will be installed at locations chosen to enhance areal coverage of the site, and each intermediate well will be nested with a shallow. In addition to the production wells for each layer, two intermediate and two shallow piezometers will be installed at the aquifer tests location to support that activity.

With the exception of the aquifer test production well, which will be 4-inch diameter, the intermediate wells will be installed as permanent 2-inch PVC wells with ten foot screens using standard hollow-stem auger techniques. These wells will be approximately 45 feet deep terminating at the clay, Layer 3. Well installation, development and wellhead surveying will be conducted in accordance with the NASP Comprehensive Sampling and Analysis Plan (CSAP).

The shallow wells will be installed as temporary using 1-1/2 inch galvanized steel piezometers with 2-feet screens. These will be installed by hand using either hand augers to complete the borehole, or percussion-driven by hand to the target depth. These wells will be installed to seat the screen immediately below the water table. Well head surveying of these will be conducted in accordance with the NASP CSAP.

The overall monitoring well network will include both the chosen existing wells and the newly installed wells. Heads will be measured in these wells in association with Tasks 6 and 7.

Task 3 — Installation of Staff Gauges and Stream Gauging Stations

To enhance the understanding of groundwater/surface water interactions, nine staff gauges are to be installed at the locations shown on Figure 3-1. In addition, at six locations where streamflow has been observed to occur, stream gauging stations will be established. Installation of the staff gauges will be conducted in accordance with CSAP. For the stream gauging stations, a section of streambank parallel to flow will be temporarily measured off, and the cross-sectional area of the stream channel along this section will be calculated. During gauging, flow velocity will be physically measured using a float, and the stream discharge volume will be calculated.

Task 4 — Establishment of an Abbreviated Well Network

This task involves choosing a subset of the overall monitoring well network for water level measurements associated with Task 6. These measurements will be needed to establish long-term water level trends. To hold down costs, there will be ten nested well pairs and three staff gauges/stream gauging stations in the abbreviated network. These points will be chosen to provide a reasonable aerial coverage of the facility. Given that they will be used to establish long-term water level trends, it is anticipated that the majority of these points will be located away from potential tidal influence. A limited number, however, will be located near shore

within influence of tidal fluctuations. Figure 3-1 presents the wells chosen for inclusion in the abbreviated well network.

Task 5 — Aquifer Testing

Two long-term pumping tests will be conducted, one test on each layer, for hydrologic characterization. The purpose of the testing is to provide data on the stressed behavior of both the shallow and intermediate zones, to provide reliable estimates of conductivity and storativity for each layer, to assess the relationships between vertical and horizontal conductivity, and to assess the connection between layers.

The aquifer testing location is shown on Figure 3-1. This area is not associated with any environmental site, so there will be no disposal concerns with the test discharge waters. Currently, these are expected to be discharged directly to the surface water of Bayou Grande.

This task will involve the installation of the production wells for each zone test, as well as piezometers for each zone to serve as observation points. The production wells will nested together, and will each be 4-inch PVC wells, with 20 feet of screen. The shallow well will be approximately 25 feet deep, and the intermediate well will be approximately 45 feet deep. Two shallow piezometers, identical in construction to those planned to be installed as part of the well network, will be installed by hand. Two intermediate piezometers, each with 20 feet of screen, will be installed using HSA techniques. Initial distance-drawdown analysis indicates that these piezometers should be set at approximately 5 feet and 30 feet radial distance from the production well nest in an across-gradient direction. Partial penetration effects will have to be accounted for in the shallow zone piezometers, but the intermediate piezometers will be fully-penetrating. The drilled wells will be installed in accordance with the *CSAP*, and all wells and piezometers will developed in accordance with the *CSAP*.

For the aquifer testing, data loggers will be set up in the observation piezometers and monitored on an hourly basis for one week. This will establish the ambient diurnal and longer-term trends in ambient water levels which may need to be corrected for in the resulting aquifer test data. Following this monitoring period, the pumping test apparatus will be installed and tested for a period of approximately one hour, followed by a one hour recovery period. During this and all subsequent testing, water levels in the production well will be measured using an electronic water level indicator, while data loggers will be used in the observation piezometers.

A step drawdown test will be conducted on each production well following this recovery period. The purpose of the step test is two-fold: first, the data will be used to determine the well-loss coefficient, and secondly the data will be used to determine the maximum yield that the well is capable of sustaining for the subsequent aquifer test. During the step test, water levels will also be measured in the observation piezometers to obtain first estimates of their response to pumping. It is anticipated that the step discharge rates will be approximately 10, 20 and 30 gpm, and that each step will be tested for approximately .5 to 1 hour. The step test will be followed by a 24-hour recovery period.

After the recovery period, the aquifer tests will be conducted. For each production well, the test will consist of withdrawing groundwater at a maximum rate determined from the step tests. Initial calculations indicate that the discharge phase for each test should be conducted for a period of 24 hours (by this time delayed gravity yield effects should be negligible). After 24 hours, the pump will be shut down, and recovery will be monitored for a period of 12 hours.

Data compilation and pumping test analysis will be conducted in accordance with the CSAP. It is anticipated that a commercially available software package will be used to analyze the data, such as **AQTESOLV** or **AQUITEST.** The resulting data will be used in assigning initial calibration run parameters to the model.

Task 6 — Long-Term Water Level Measurements

Long-term water level trends will be assessed in both layers. Using the wells and surface water stations included in the abbreviated well network, water levels will be measured weekly over a three month period. Additionally, precipitation data will be collected from the Navy's control station at Forrest Sherman Field. This data will be used to interpret flux into the system, and will be used to attempt transient calibrations of the model. Water levels will be measured in accordance with the CSAP.

Task 7 — Synoptic Water Level Measurements

Three sets of synoptic water level measurements will be made using the monitoring well/surface water station network. The first set will be made as soon as possible after well installation/aquifer testing, and will be used to attempt a static calibration of the system. The second set will be collected approximately three months later, and will be used along with flux information to attempt a transient calibration of the model. The third set will be collected approximately three months after the second, and will be used for the same purpose as the second, as well as to conduct a post audit of the model. If transient calibrations prove to be inappropriate given the data, then model parameters (e.g., specified head cell values) may be altered consistent with the water level measurements, and post-audits of the model will be conducted using the these data.

5.0 MODELING EFFORT

5.1 Code

The code used in the modeling effort will be the U.S.G.S.'s MODFLOW. MODFLOW is a modular three dimensional finite-difference groundwater flow model, and has been extensively tested and validated.

5.2 Platform

It is anticipated that the modeling platform to be used will be VISUAL MODFLOW. This platform will output native MODFLOW files such that they can be input into any executable version of MODFLOW.

5.3 Procedures/Sequence of Events

5.3.1 Sequence of Events

The sequence of events will be data acquisition/conceptual model refinement, model calibration, sensitivity testing, post audit and report. The general procedures for carrying out each task is presented below.

5.3.2 Data Organization/Conceptual Model

The conceptual model will be refined as relevant geologic and hydrogeologic data is compiled. This information includes boring logs, aquifer test data, hydraulic head measurements (both spatial and temporal), topographic and geological maps, precipitation data, and evapotranspiration rates. The effects of man-made structures such as pumping wells, drainage systems or large structures may also be accounted for. In addition, hydraulic boundaries will be conceptualized to constrain the model.

After all the necessary data has been compiled and the conceptual model complete the data will be manipulated such that it is in a form readily transportable into the modeling platform. In the case of aquifer test data, hydraulic head data and surficial and sub-surface topography, the scattered data points will be gridded to be input into MODFLOW. Gridding the data will be achieved by using geostatistical software such as GSLIB or Surfer.

5.3.3 Model Setup

Once all of the data, including the first synoptic water level set, has been collected and compiled, the model setup will commence. This will include establishing the model domain,

the model layers and their relationship, definition of hydraulic sources and sinks, and definition of hydraulic parameters internal to the model domain. Once the model setup is complete for initial review, the setup and initial calibration parameters will be presented to the Navy for review and approval. Any changes as a result of this review will be incorporated prior to conducting calibration efforts.

5.3.4 Calibration

Calibration will be done manually by varying the model parameters to achieve a modeled head distribution that resembles the observed head distribution on the site. This will be achieved by varying the initial input parameters within reasonable limits dictated by the site geology. The model will be considered calibrated when the difference between the observed heads and the head values generated by the model differ less than a prescribed percentage. This percentage will be agreed upon during the initial modeling meeting. Statistics such as mean error, absolute mean error and root mean square (standard deviation) are used to evaluate the above percentage. Calibration will also be quantified by groundwater flux into the model as compared to groundwater flux out. Initially, calibration will be to the first set of static heads, subsequent calibrations will attempt to use flux information to accomplish transient calibrations.

5.3.5 Sensitivity Testing

For each calibration effort, sensitivity testing will be conducted. Sensitivity testing will be done to gauge on the model as a whole the effects due to the systematic variation of input parameter values. This will test the validity of the calibration. By varying one input parameter at a time, the residual statistics will start to increase as the numeric value of the parameter moves away from the optimum value, (the optimum value being defined as the value that minimizes the error between observed and computed head while still being hydrogeologically plausible), All input parameters, such as hydraulic conductivities, precipitation rates and layer thicknesses will be tested this way. The effects of variations in more than one parameter at a time is cost and time prohibitive. The sensitivity test results will help to optimize the model for predictive purposes.

5.3.6 Post-Audit

Post-audits are done to assess the models ability to predict the future. A post-audit will be done on the NAS Pensacola model. This will be done by changing the type or amount of stress on the hydrogeologic model to reflect real changes in the environment over time. Then the observed heads at the future time are compared to the calculated heads at the future time.

A post-audit of the Pensacola model will be accomplished using the third synoptic set of water levels. Prior to collection, the heads will be predicted. These predicted heads will then be compared to those actually measured during the third synoptic collection event.

6.0 REPORT

Following the calibration process associated with the second set of synoptic water level measurements, the modeling report will be generated and the input files made available for use. The report will document all of the data compilation/data acquisition efforts, and all of the modeling efforts.

Following post-audit, a Model Verification Addendum will be prepared and submitted which details the post-audit processes and results.

7.0 TIME FRAME

Figure 7-1 presents the anticipated time frame for execution of the modeling effort.

FLORIDA PROFESSIONAL GEOLOGIST SEAL

I have read and approve of this Numerical Modeling Design Concept for the Naval Air Station in Pensacola, Florida, 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**

BE

Brian E. Caldwell

2/12/97

Date