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C-49-09-5-055

September 5, 1995

Project Number 5082

Mr. Mark Evans
Northern Division (Code 1823)
Naval Facilities Engineering Command
Mail Stop 82, 10 Industrial Highway
Lester, PA 19113-2090

Reference: CLEAN Contract N62472-90-D-1298
Contract Task Order No. 203

Subject: Draft Groundwater/Leachate Modeling Study Letter Work Plan
Area A Landfill Design
Naval Submarine Base New London, Groton, Connecticut

Dear Mr. Evans:

In confirmation of our facsimile of today, please find attached a hard copy of the referenced draft letter work plan for the Area A Landfill Groundwater/Leachate Modeling Study. The attached document contains the oversized figures and detailed standard operating procedures (SOPs) which were not included in today's facsimile.

As soon as you have had a chance to review the attached document, please call me at (412) 921-8568 or Al Briggs at (412) 921-8361 to let us know if it can be sent to U.S. EPA.

Very truly yours,

Jean-Luc Glorieux, P.E.
Project Manager

JLG/jlg

Attachment
cc: Mr. Roger Boucher, NORTHDIV (letter only)
Mr. Jim Briggs, NORTHDIV (1 copy)
Mr. John Trepanowski, Halliburton NUS, Wayne (letter only)
Mr. Daryl Hutson, Halliburton NUS, Pittsburgh (letter only)

LETTER WORK PLAN
GROUNDWATER/LEACHATE MODELING STUDY
AREA A LANDFILL REMEDIAL DESIGN
NAVAL SUBMARINE BASE NEW LONDON
GROTON, CONNECTICUT

Submitted by Halliburton NUS
September 6, 1995

1.0 INTRODUCTION

1.1 Project Background

This letter work plan describe the proposed activities of the Groundwater/Leachate Modeling Study for the Area A Landfill at Naval Submarine Base New London (NSB NLON) in Groton, Connecticut. This modeling study is performed in support of and as part of Contract Task Order (CTO) 0203 for the design of a cover system (cap) for the Area A Landfill under the Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract Number N62472-90-D-1298.

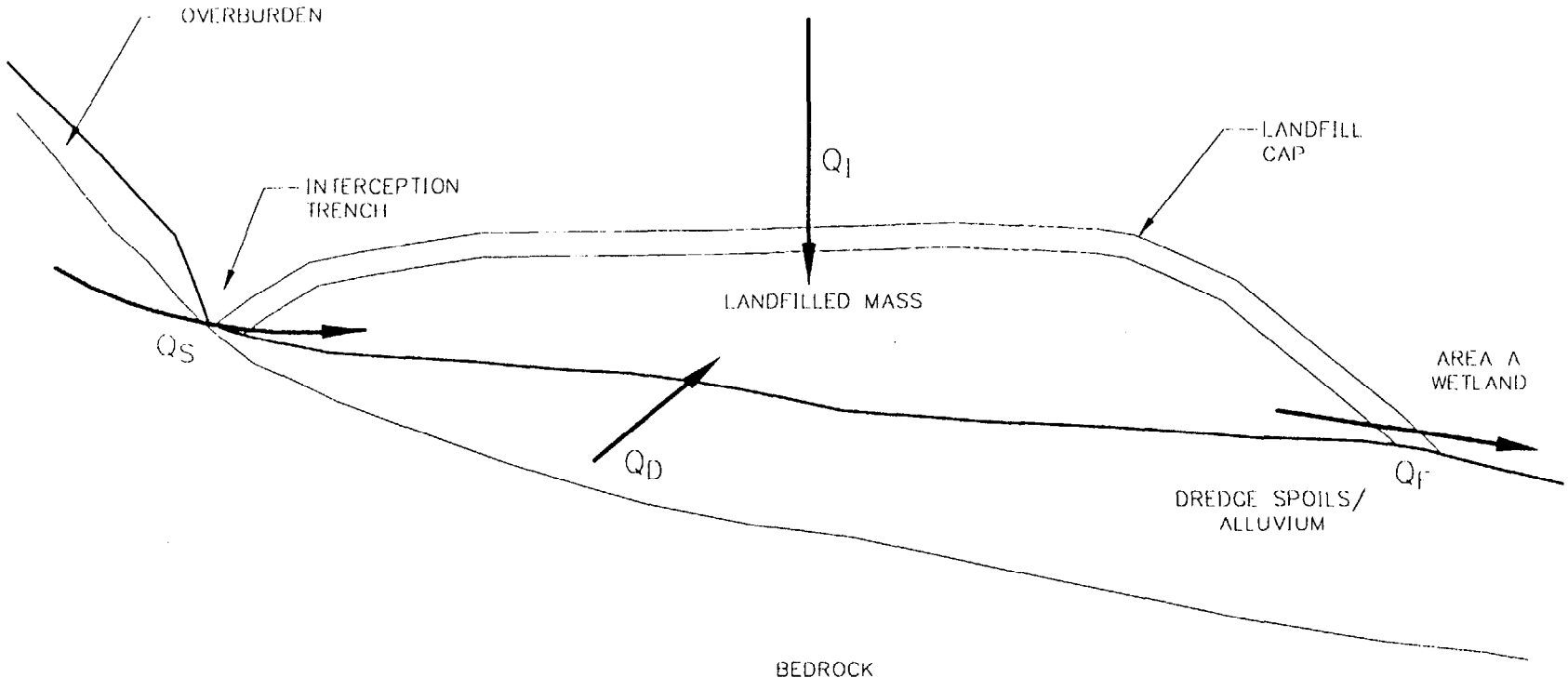
The Area A Landfill is located in the northeastern/north-central section of NSB NLON, encompassing an area of approximately 9.5 acres. The Area A landfill is a relatively flat area bordered to the south by a steep wooded hillside, to the west by a steep wooded ravine, and to the north by the Area A Wetland. The landfill opened for disposal of non-salvageable materials generated by submarines and base operations prior to 1957 and was closed during 1973. Several structures/functions including salt and sand storage, deployed parking, and crane testing are still currently active at the landfill.

A Phase I and Phase II Remedial Investigation (RI) were conducted by Atlantic Environmental Services, Inc. (Atlantic, August 1992) and Halliburton NUS (HNUS, March 1995), respectively. A Focused Feasibility Study (FFS, May 1995), Proposed Remedial Action Plan (PRAP, June 1995) were also prepared by Atlantic and HNUS. A draft Record Of Decision (ROD) was also prepared for this site and is currently under final review for signature by the Navy and U.S. EPA Region I (EPA). A Remedial Design was also prepared by Atlantic (July 1994) for the proposed landfill cap. This design was subsequently amended and finalized by HNUS (May 1995).

1.2 Modeling Study Objectives and Approach

The primary objective of the Groundwater/Leachate Modeling Study is to predict the impact upon the flow rate and quality of the groundwater/leachate discharge at the toe of the Area A Landfill as a result of the installation of an impervious cap and upgradient interception trench. The secondary objective of the modeling study is to compare the slope stability effectiveness and cost of the gabion-reinforced toe of the current landfill cap design with those of a cap featuring a toe drain system. Also as part of this study the dredge spoil stability and cap settlement analyses will be refined based upon additional site-specific geotechnical data.

As shown on Figure 1-1, the groundwater and leachate outflow from the Area A Landfill (Q_F) is the result of three main components including: the precipitation infiltrating through the ground surface to the water table (Q_I), the upgradient groundwater and surface run-off inflow (Q_S), and the groundwater upflow gradient from bedrock through the overburden (dredge spoils or alluvium) into the landfilled mass (Q_D). Depending on which component is predominant, the impact of installing an impervious landfill cap and upgradient interception trench on Q_F may or may not be significant since such a system will greatly reduce Q_I and, to a lesser extent, Q_S but will leave Q_D mainly unaffected.



$$Q_F = Q_I + Q_S + Q_D$$

GROUNDWATER/LEACHATE FLOW SCHEMATIC
AREA A LANDFILL
NAVAL SUBMARINE BASE NEW LONDON
GROTON, CONNECTICUT

FIGURE 1-1

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The sequence of activities for the Groundwater/Leachate Modeling Study is shown on Figure 1-2 and will consist of three main steps:

The first step will consist of gathering the necessary site-specific geological, hydrogeological, geotechnical, and analytical data to fulfill the objectives of the Groundwater/Leachate Modeling Study. This information includes pertinent data from previous site investigations as well as new data which will be obtained from an additional field investigation.

The second step will consist of the modeling effort itself. The site-specific information gathered during the first step will be fed into proven electronic softwares (HELP and MODFLOW) to develop a realistic representation of the existing and future hydrogeological conditions in and around the Area A Landfill.

The third step will consist of using the models developed during the second step to predict changes in hydrogeological conditions and contaminant migration as a result of the installation of an upgradient interception trench and impervious landfill cap, with or without a toe drain system. These predictions will then replace previous assumptions and the slope stability analysis of the gabion-reinforced toe of the current landfill cap design will be refined and compared to that of a cap featuring a toe drain system. As part of the modeling study's third step, some of the new geotechnical data gathered during the first step will also be used to refine the dredge spoils stability and cap settlement analyses.

1.3 Work Plan Organization

This letter work plan includes seven (7) sections. Section 1 is this brief introduction. Section 2 discussed the review of the existing data and the determination of additional data requirements. Section 3 describes the field investigation which will be performed to obtain the additional site-specific data required to support the modeling effort. Section 4 describes the modeling effort itself. Section 5 discusses the interpretation of the modeling results and the comparison of cap design options. Section 6 provides an outline of the Groundwater/Leachate Modeling Study report. Section 7 describes the sequence and purpose of the technical meetings and presentations associated with the Groundwater/Leachate Modeling Study. A Field Sampling and Analysis Plan (FSAP) is attached to the work plan as Appendix A to describe the well and piezometers installation, sampling, and geotechnical and analytical testing procedures for the field investigation. Oversize figures illustrating the field investigation are attached as Appendix B.

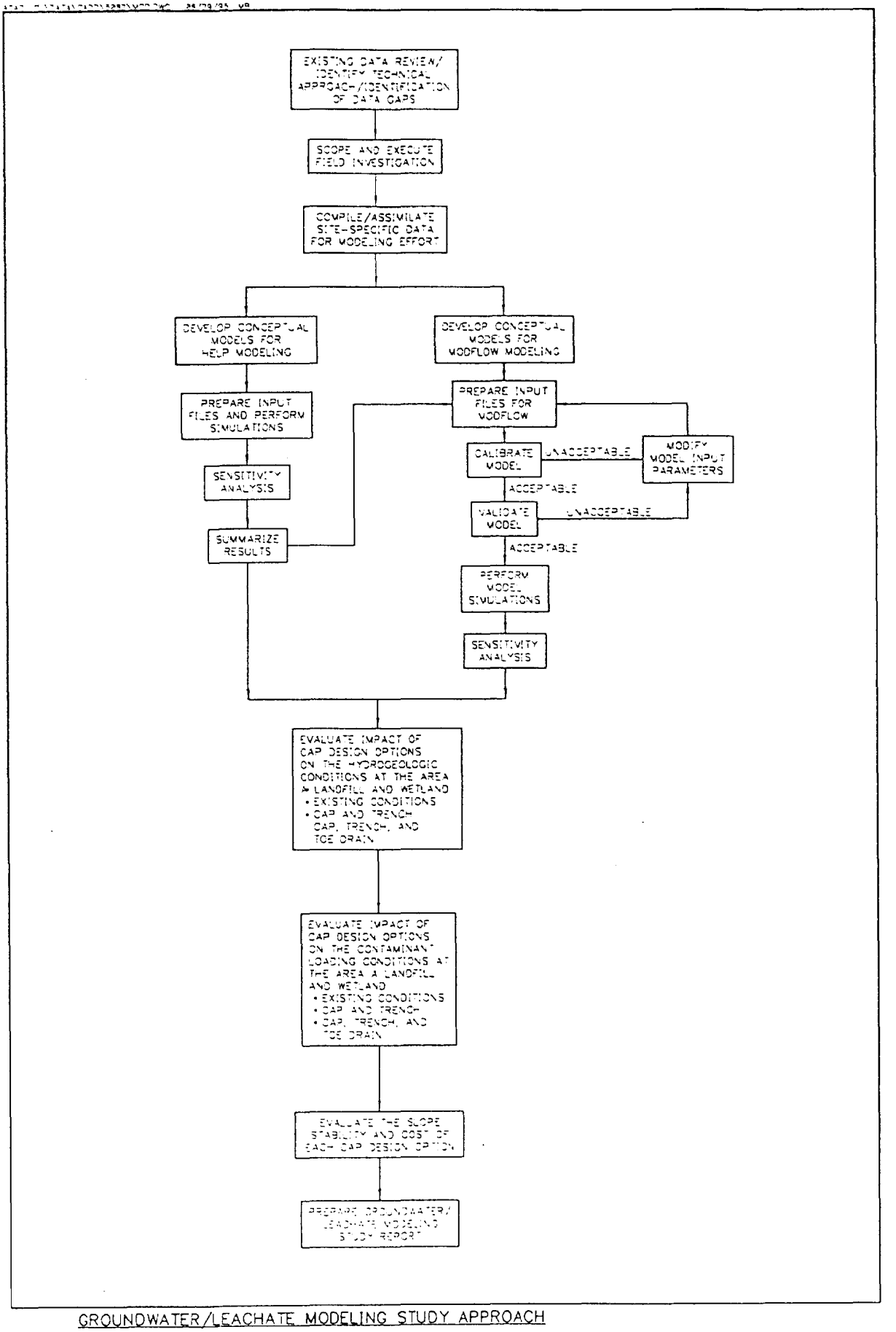
2.0 EXISTING DATA REVIEW

The existing geological and hydrogeological data from the previous above-mentioned site investigations was reviewed for use as modeling input and to determine additional data requirements.

The results of this review, which is essentially complete, revealed that the following additional data was required to support the modeling effort:

- Surface permeability data to model Q_I under existing conditions
- Horizontal hydraulic conductivity data to model Q_S
- Groundwater elevation and horizontal and vertical hydraulic conductivity data to model Q_D
- Geologic data to refine site stratigraphy and define model layers
- Upgradient groundwater hydrogeological data to determine modeling boundary conditions
- Groundwater and surface water elevation data to calibrate the groundwater model
- Groundwater/leachate quality data to compute contaminant transport and loading

In addition, it was determined that additional geotechnical data was required to refine the stability and settlement analyses of the dredge spoil in structurally sensitive areas of the currently designed landfill cap.



GROUNDWATER/LEACHATE MODELING STUDY APPROACH
AREA A LANDFILL
NAVAL SUBMARINE BASE – NEW LONDON
GROTON, CONNECTICUT

FIGURE 1-2

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3.0 FIELD INVESTIGATION

3.1 Objectives, Approach, and Rationale

The objective of the field investigation is to obtain the additional site-specific data identified in Section 2.0 above.

The site-specific surface permeability data required to model Q_I will be obtained by performing percolation tests at locations selected as representative of current landfill cover conditions.

The site-specific horizontal hydraulic conductivity data required to model Q_S will be obtained by performing slug tests in existing and new wells installed in the landfilled mass and underlying overburden along transects selected as representative of the most significant site hydrogeological conditions.

The site-specific groundwater elevation and vertical and horizontal hydraulic conductivity data required to model Q_D will be obtained by measuring groundwater level in newly installed upgradient bedrock wells and dredge spoil/alluvium wells and by testing for permeability samples of dredge spoil or alluvium collected from the above-mentioned new wells installed in the overburden underneath the landfilled mass.

The site-specific geological data required to refine site stratigraphy and define model layers will be obtained from the boring logs of the new piezometers, wells, and soil boring.

The site-specific data required to develop groundwater/leachate model boundary conditions will be obtained by performing slug tests in newly installed upgradient bedrock wells and by measuring the flow of the groundwater seep in the dike at the western end of the landfill into the OBDA.

The site-specific data required to calibrate the groundwater/leachate model will be obtained by taking groundwater elevation measurements for newly installed piezometers and existing and newly installed staff gauges and overburden and bedrock wells.

The site-specific geotechnical data required to refine the dredge spoil stability and settlement analyses will be obtained by testing for triaxial compression samples of dredge spoil collected from a new soil boring installed at the proposed location of the crane test pad and from that of the above-mentioned new overburden wells with the weakest dredge spoils strength as determined by the lowest blow count.

The site-specific data required to develop a conceptual mass flux model for contaminant transport will be obtained by collecting and analyzing the groundwater seep in the dike at the western end of the landfill into the OBDA.

The surface water level in the wetland will be measured by installing new staff gauges along the wetland-landfill boundary.

As part of the field investigation, the location of all new piezometers, wells, and staff gauges will also be surveyed.

3.2 Description

3.2.1 Percolation Tests

Percolation tests will be performed in locations deemed to be most representative of the following five types of existing landfill cover:

- Roadway surfaces
- Graveled areas near roadway surfaces

- Sand storage area
- Deployed parking area
- Vegetated areas

Two percolation tests will be performed for each of the above-listed type of surface soil for a total of ten (10) percolation tests. Percolation tests will be performed in accordance with the U.S. Department of Interior (DOI) Bureau Of Reclamation, Method Des-E.18 (Earth Manual, 2nd. Edition, 1974). A detailed description of the percolation test procedures is also provided in the FSAP attached to this work plan as Appendix A.

3.2.2 Installation Of New Piezometers, Wells, and Staff Gauges

As shown on Figure 3-1, new piezometers, wells, and staff gauges will be installed along three transects on and around the Area A Landfill, including A-A' crossing the west end of the landfill, B-B' crossing the deployed parking, and C-C' crossing the east end of the landfill. Cross sections of transects A-A', B-B', and C-C' are shown on Figures 3-2, 3-3, and 3-4, respectively. Figures 3-1 through 3-4 are attached to this work plan as Appendix B.

It is important to gather information along three transects because of geological and hydrogeological differences across the landfill. For example, the depth to bedrock and alluvium thickness are greater along transects B-B' and C-C' than along transect A-A'. While the total thickness of the landfilled mass is fairly consistent (based on existing boring logs), the saturated thickness of that mass is less along transect A-A' than along transects B-B' or C-C'. Another example is that a comparison of the groundwater level measurements taken in March, 1994 to those taken in August, 1994 (Phase II RI) shows a variation of 7 feet upgradient of transect B-B' but of only about 2 to 3 feet upgradient of transects A-A' and C-C'.
The location of each transect was selected as being representative of significant and site-specific hydrogeological conditions and to maximize the use of existing data points.

Transect A-A'is located at the west end of the landfill because in this area there is little evidence of groundwater or leachate discharge from the toe of the landfill into the adjacent wetland which is most often relatively dry. Also, in this area existing upgradient overburden/bedrock well clusters (4MW1S, 4MW1D, 4MW4S, 4MW4D) are available for testing and there are a large number of existing soil borings data points.

Transect B-B' is located across the deployed parking because in this area, in contrast to the west end of the landfill, surface water is most often present in the wetland immediately adjacent to the landfill toe. In this area there is also evidence of a much greater thickness of alluvium in the overburden underneath the dredge spoil and landfilled mass. Finally, an existing upgradient overburden/bedrock well cluster (2LMW8S, 2LMW8D) is available in this area for testing.

Transect C-C' is located at the east end of the landfill because, in this area, it is not known if dredge spoil materials are present and there is also evidence of a great thickness of alluvium in the overburden underlying the landfilled mass. An existing upgradient overburden/bedrock well cluster (2LMW20S, 2LMW20D) is also available in this area for testing.

Along each transect, it is important to gather information from at least two well clusters so that the shallow groundwater flow gradient toward the wetland and the upward gradient from materials beneath the landfilled mass can be established. Along each transect the following new data points will be installed:

- One (1) staff gauge in the wetland at the wetland-landfill interface
- One (1) drive-point piezometer at the wetland-landfill interface
- Two (2) overburden wells installed in the landfilled mass
- Two (2) overburden wells installed in the dredge spoil or alluvium underlying the landfilled mass

A total of three (3) new piezometers, twelve (12) new overburden wells, and three (3) staff gauges will be installed along transects A-A', B-B', and C-C'. An additional five (5) new staff gauges will also be installed along the wetland-landfill boundary between the transects.

In addition, to establish hydrogeological boundary conditions, two (2) new upgradient bedrock wells will be installed near Wahoo Avenue at the top of the hill overlooking the landfill.

Finally, to determine dredge spoil strength under the proposed new location for the crane test pad, one (1) new soil boring will be installed at that location.

Staff gauges and piezometers will be hand-driven, overburden wells and soil boring will be drilled with a hollow stem auger, and bedrock wells will be drilled with a rotary roller bit. Detailed information regarding piezometers and wells size, construction, and installation procedure is provided in the FSAP which is attached to this Work Plan as Appendix A.

3.2.3 Groundwater and Surface Water Elevation Measurements

One (1) round of groundwater elevation measurements will be taken from each existing well and each new piezometer and well. A total of fifty-two (52) groundwater elevation measurements will be taken, including:

- Thirty-five (35) in existing wells,
- Fourteen (14) in new wells, and
- Three (3) in new piezometers,

Groundwater elevation measurements will be taken in accordance with the procedure described in the FSAP attached to this work plan as Appendix A.

One (1) round of surface water measurements will be taken from the existing staff gauge located at the discharge of the wetland into the Area A Downstream and from each new staff gauge installed at the wetland-landfill boundary. A total of nine (9) surface water elevation measurements will be taken in accordance with the procedure described in the FSAP attached to this work plan as Appendix A.

3.2.4 Slug Tests

One slug test will be performed in the each of the two existing bedrock wells located along transects B-B' (2LMW8D) and C-C' (2LMW20D), each of the twelve new overburden wells located along transects A-A', B-B' and C-C', and each of the two new upgradient bedrock wells. A total of sixteen (16) slug tests will be performed in accordance with the procedure described in the FSAP attached to this work plan as Appendix A.

3.2.5 Shelby Tube Samples Collection and Testing

Shelby Tube samples of dredge spoil material will be collected from the new overburden wells installed in the dredge spoil or alluvium along transects A-A', B-B', and C-C'. A Shelby Tube sample will also be collected from the new soil boring installed at the proposed location of the crane test pad. A total of nine (9) Shelby Tube samples will be collected, including one sample from each of the six new overburden wells and one sample from the new soil boring plus a second sample from one of the wells and from the soil boring. Shelby Tube samples will be collected in accordance with the procedure described in the FSAP attached to this work plan as Appendix A.

One Shelby Tube sample from each new dredge spoils/alluvium overburden well will be tested for permeability. A total of six (6) Shelby Tube samples will be tested for permeability in accordance with ASTM 5084 and as further described in the FSAP attached to this work plan as Appendix A.

Two (2) of the nine Shelby Tube samples collected will be tested for triaxial compression. One of these samples will be collected from the new soil boring installed at the proposed new location of the crane test pad and the other sample will be collected from the new overburden well which exhibits the lowest blow count in the dredge spoil/alluvium strata. Triaxial compression testing will be performed in accordance to ASTM D 4318 and as further described in the FSAP attached to this work plan as Appendix A.

3.2.6 Groundwater Seep Flow Measurement, Sampling, and Analysis

One (1) flow measurement will be taken on the groundwater seep discharging from the western landfill dike into the OBDA. The flow of this seep shall be measured with a flume or weir system in accordance with the procedure described in the FSAP attached to this work plan as Appendix A.

One (1) grab sample will be collected from this groundwater seep and analyzed for TCL VOCs, TCL SVOCs, TCL Pesticides/PCBs, and TAL Metals. Sampling and analyses will be performed in accordance with the procedures described in the FSAP attached to this work plan as Appendix A.

4.0 MODELING

4.1 Approach and Rationale

Infiltration (HELP) and three-dimensional groundwater flow modeling (MODFLOW) will be conducted to verify the effects of the proposed landfill cap, upgradient interception trench, and potential toe drain system on the hydrogeologic conditions at the Area A Landfill. In addition, a simple mass flux model will be used to estimate the quality of the leachate which would be discharged from the landfill into the adjacent wetland.

Infiltration and groundwater flow modeling are frequently used to evaluate the effects of design alternatives. Various models exist and can be applied to a variety of natural conditions. Typically, models are selected based on their technical applicability, cost-effectiveness, and ease-of-use and all of these criteria have been considered for this task. U. S. EPA's Hydrologic Evaluation of Landfill Performance (HELP) model will be used to conduct the modeling task as well as the United States Geological Society's MODFLOW model and mass flux equations. A brief description of each model's capabilities is provided in the following section.

The sequence of modeling activities is summarized on Figure 1-2 and will be as follows:

1. Develop conceptual models and the actual HELP models necessary to adequately describe the infiltration conditions under existing and proposed scenarios. Use rainfall data from the local airport and any other available site-specific data as input. Perform model runs.

2. Perform sensitivity analysis on key HELP model parameters to determine a range of predicted infiltration rates. Use worst-case and average infiltration predictions as input to the MODFLOW model.

3. Develop conceptual model and MODFLOW model input file for existing conditions.

4. Calibrate the MODFLOW model for existing conditions by comparing predicted steady-state heads against one comprehensive round of water level measurements and by matching flow gradients between the bedrock and overburden material. Calibration targets are discussed below.

5. Validate the MODFLOW model for existing conditions by comparing predicted steady-state heads against another round of water level measurements. The model should be able to predict the heads within a predetermined goal. If not, the model will be re-calibrated and then validated until it is acceptable. Details on the validation procedure are discussed below.

6. Using the calibrated and validated MODFLOW model for existing conditions, perform sensitivity analysis on key parameters to determine the upper and lower bounds of the predicted water table. Further discussion of the sensitivity procedure is given below.

7. Using the existing conditions MODFLOW model as a base, create separate MODFLOW models to simulate the conditions resulting from landfill cap, upgradient interception trench, and potential toe drain system. Perform simulations.

8. If necessary, use the MODFLOW model results in MODPATH (particle tracking) to verify the capture zone of the proposed interception trench and/or the OBDA leachate breakout.

9. Using the modeling results, estimate the surface infiltration rate, the saturated thickness of fill material, and the total groundwater/leachate flow from the landfill before and after installation of the landfill cap, upgradient interception trench, and potential toe drain system. Using the leachate rate and mass-flux equations, estimate a worst-case scenario of the quality and contaminant loading rate of the leachate.

4.2 Models Description

The models which will be used include HELP, MODFLOW, and possibly MODPATH. A brief description of the models and their capabilities are given below.

4.2.1 HELP Model

The Hydrologic Evaluation of Landfill Performance (HELP) model (U.S. EPA) is a quasi two-dimensional hydrologic model of water movement across, into, through, and out of a waste area. The model accepts climatologic, soil and design data and simulates a number of hydraulic processes including surface storage, runoff, infiltration, percolation, evapotranspiration, soil moisture storage and lateral drainage. The systems that can be modeled by HELP include various combinations of vegetation, cover soil, waste cells, special drainage layers and relatively impermeable barrier soil.

The identification of each layer used in the model is critical because the program models water flow through the various types of layers in different ways. Runoff is computed using the Soil Conservation Service (SCS) runoff curve number method by considering daily precipitation totals. Percolation and vertical water routing are modeled using Darcy's Law for saturated flow with modifications for unsaturated conditions. Evapotranspiration is estimated by a modified Penman method adjusted for limiting soil moisture conditions.

4.2.2 MODFLOW Model

The modular three-dimensional finite-difference groundwater flow model know as MODFLOW was developed by the U.S. Geological Survey to simulate groundwater flow in a variety of situations. MODFLOW uses a block-centered grid for solving the finite-difference equations. This model can be used for two- or three-dimensional applications, and can simulate the effects of aquifers with anisotropic, heterogeneous hydrogeologic properties, spatially varying aquifer thickness and/or aquifer bottom elevation, distributed aerial recharge, wells, drains, rivers as well as, a variety of boundary conditions. This model has been used extensively at Superfund sites and industrial hazardous water sites for simulation of groundwater flow, evaluation of remedial alternatives and can be used in conjunction with other modular programs to model contaminant transport (MT3D) and particle tracking (MODPATH). The model has been reviewed and accepted by many regulatory agencies.

4.2.3 MODPATH Model

MODPATH is a three-dimensional particle tracking code that was developed by the U.S. Geological Survey. MODPATH utilizes hydraulic heads calculated by MODFLOW to determine the flow path of a particle from

its initial position to its final position. MODPATH can also indicate time of travel from one point to another point and can use reverse particle tracking to determine the source of water extracted from wells. Particle tracking is done under steady-state conditions and simulates advection-based transport.

4.3 Conceptual Models

Conceptual models are useful tools which summarize the modeler's understanding of a natural system. It is proposed that conceptual models be created to understand the natural systems to be modeled by the infiltration, groundwater flow, and contaminant mass flux models. Conceptual model development includes summarizing available data, interpreting the data and creating a representative figure of the system to be modeled.

Existing data, as well as, newly collected data will be used to create the conceptual models of the existing hydrologic system at the Area A Landfill. The existing hydrologic system includes groundwater flow, surface water/runoff flow, infiltration, evapotranspiration and interception/storage. The existing contaminant migration system includes leachate generation from source material, leachate migration to the aquifer, adsorption/desorption of contaminants to and from the aquifer media, transport of the contaminants via advection and dispersion in the groundwater, and natural decay of contaminants.

Conceptual models of the proposed conditions at the landfill after construction will also be created to account for the landfill cap, upgradient interception trench, and potential toe drain system. As with the existing conditions, separate conceptual models will be created for the infiltration, groundwater flow, and contaminant mass flux systems for proposed conditions.

Conceptual models for the Area A Landfill hydrologic system were developed as part of the existing data review and scoping of the field investigation. These models are shown on Figures 3-2 through 3-4. These models were developed using only existing data and will be updated with the new data obtained from the field investigation. Contaminant transport conceptual models have not yet been developed but will be developed as part of this modeling effort.

4.4 Model Calibration

4.4.1 HELP Model

A limited calibration of the HELP model will be performed. Model parameters such as hydraulic conductivity, soil type and layer thickness will be fixed for the modeling. Initial moisture content of the soil however is typically not known and is usually calibrated using the HELP model. This involves several iterations of the model with updated estimates of the initial moisture content until equilibrium conditions are reached (i.e., the initial moisture content and the final moisture content for a layer are equal).

4.4.2 MODFLOW Model

The MODFLOW model simulating existing conditions will be calibrated by comparing predicted steady-state heads to measured steady-state heads. The comparison will include calculating the head difference (measured versus predicted) at selected points within the model boundary. It is likely that head measurements from monitoring wells will be translated to model grid block centers to make the comparisons. Model parameters will be adjusted to minimize the overall deviation between the predicted and measured heads. Model input such as hydraulic conductivity and boundary conditions are typical model data which can be modified during calibration. As a target for calibration, the deviation between the modeled and measured heads should be less than the natural fluctuation seen in the water table over time. Water levels have been measured over a year in several wells in the Area A Landfill for the Phase II RI and this data will be used to estimate the natural variation of the groundwater table elevation.

In addition to calibration of the heads, the predicted flow directions of the 3-dimensional MODFLOW model will also be verified against the actually measured flow gradients between the bedrock and overburden. Modifications will be made to model parameters (most likely vertical hydraulic conductivity) until the predicted flow directions and gradients reasonably match the existing conditions.

4.5 MODFLOW Model Validation

Validation is the process of comparing the calibrated model to another, independent, data set for the groundwater regime. This data set should be from another historical period, but lacking data for two historical periods, a single data set can be split up to provide both calibration and validation data sets. The validation procedure will demonstrate the predictive capability of the calibrated site model. The use of two data sets, if they corroborate each other, add a degree of confidence to the model.

The calibrated MODFLOW model will be validated by using it to predict steady-state heads under different conditions for comparison against actual water level measurements taken under the different conditions. The model should be able to predict the heads within a predetermined goal without changing any model parameters with the exception of model boundary conditions. The natural fluctuation of the groundwater table will be used as the goal for the validation procedure. If the model can not, the model will be re-calibrated and then validated until it is acceptable. A detailed review of the initial calibration data set will be made to determine if a significant process was ignored or improperly defined.

4.6 Sensitivity Analyses

Sensitivity analyses will be conducted on model parameters for both the HELP and MODFLOW models. Model parameters will be modified independently to determine their individual impact on model predictions. A final sensitivity simulation will also be conducted to determine a worst-case scenario. This scenario will evaluate the impact of all of the parameters within one model simulation.

Model parameters which have the most uncertainty and/or have the biggest influence on model results will be targeted for sensitivity analysis. For example, in the HELP model parameters such as vegetative conditions, Soil Conservation Service Curve Number (SCS CN), layer thickness, and vertical hydraulic conductivity will most likely be targeted for sensitivity analysis. For the MODFLOW model, boundary conditions, recharge, horizontal and vertical hydraulic conductivity, and layer thicknesses are typical input data which will be targeted for sensitivity analysis.

4.7 Contaminant Transport and Landfill Discharge Quality

Contaminant transport and the quality of the landfill discharge will be estimated using a mass-flux equation and the results of the HELP and MODFLOW models. Existing contaminant data for the soil and groundwater in the Area A landfill area will be summarized and average concentrations in each media will be determined. Only the most significant Contaminants Of Concern (COCs) from the Phase II RI will be evaluated. Contaminant loading from the vadose zone will be estimated from the soils concentrations, default leaching coefficients and HELP model output. The estimated contaminant concentration and flow rates will be combined to determine the mass loading rate under existing and proposed conditions. Contaminant loading from the saturated landfill material to the wetland will be estimated in a similar manner as the vadose zone. The average concentration of contaminant in the groundwater will be used with the estimated groundwater discharge rate from MODFLOW to determine the mass loading rate to the wetland under existing and proposed conditions. Details of the proposed calculations are presented in Section 5.1 below.

5.0 DATA ANALYSIS

5.1 Evaluation Of Modeling Results

5.1.1 Impact Of Cap Configuration On Hydrogeologic Conditions

The results of the HELP and MODFLOW modeling will be used to determine the impact of cap configuration on hydrogeologic conditions at the Area A Landfill. The HELP results will be used to determine areal infiltration rates around the Area A Landfill and the impact the cap configuration has on the quantity of infiltration recharging the aquifer. Estimates of the leachate discharge rate from the saturated fill of the Area A Landfill, the flow rate in the proposed interception trench, the flow rate in the proposed toe drain, and the vertical recharge rate of the dredge spoils to the fill material will be made using the MODFLOW results. Figures 3-2, 3-3, and 3-4 represent the conceptual models of the hydrogeologic system for the Area A Landfill.

Estimates of the existing infiltration rates at the Area A Landfill will be made using the HELP model. Six zones will be selected to represent the Area A Landfill infiltration conditions (5 on plateau of landfill and one on toe) and infiltration rates will be estimated for each. A description of the five ground cover types that represent the existing landfill cover is presented in Section 3.2.1. The HELP model will also be used to estimate the existing infiltration rate for the bedrock hillside upgradient of the Area A Landfill. This infiltration rate is not included in the following calculations. A total infiltration rate ($Q_{I\ existing}$) will be estimated for the entire landfill by summing the infiltration rates for each of the six zones as per Equation 5-1:

$$Q_{I\ existing} = \sum_{i=1}^{i=6} Q_{I_{Zone_i}} \qquad (5\text{-}1)$$

Where: $Q_{I\ existing}$ = Total Existing Infiltration Rate (m^3/yr)
$Q_{I\ Zone\ i}$ = Zone i Existing Infiltration Rate (m^3/yr)

Estimates of the infiltration rate at the Area A Landfill after capping will also be made using the HELP model. Two zones will be selected to represent capped infiltration conditions at the Area A Landfill. The first zone will be the main portion of the landfill which will be covered with a uniform cap. The second zone will be the toe of the capped landfill, which will have a steeper slope compared to the main portion of the landfill. A total infiltration rate ($Q_{I\ capped}$) will be estimated for the entire landfill by summing the infiltration rates for the two zones as per Equation 5-2:

$$Q_{I\ capped} = \sum_{i=1}^{i=2} Q_{I_{Zone_i}} \qquad (5\text{-}2)$$

Where: $Q_{I\ capped}$ = Total Capped Infiltration Rate (m^3/yr)
$Q_{I\ Zone\ i}$ = Zone i Capped Infiltration Rate (m^3/yr)

The impact of the cap configuration on the infiltration rate will be determined by taking the ratio of the difference of the two total infiltration rates to the total existing infiltration rate and the impact will be presented as a percent reduction as per Equation 5-3:

$$\%\ Reduction = \frac{Q_{I existing} - Q_{I capped}}{Q_{I existing}} \times 100 \qquad (5\text{-}3)$$

Increased runoff due to the cap and infiltration intercepted by the cap drainage layer will be discharged directly into the Area A Wetland. The approximate increase in quantity of discharge due to the cap would be the difference between $Q_{lexisting}$ and $Q_{lcapped}$.

Estimates of the groundwater/leachate discharge rate from the saturated landfilled mass of the Area A Landfill will be made using the MODFLOW results. In addition, the modeling results will be used to estimate the quantity of groundwater to be intercepted by the upgradient interception trench and a potential toe drain system.

Using the MODFLOW-predicted steady-state water table elevation for existing conditions, an estimate of the current groundwater/leachate discharge rate to the Area A Wetlands will be made. The estimate will require the following procedures:

(1) Estimate the hydraulic gradient for each MODFLOW model block adjacent to the toe of the landfill using the predicted heads of two adjacent MODFLOW model blocks as per Equation 5-4:

$$i_{i,j} = \frac{H_{i,j+1} - H_{i,j}}{X} \qquad (5\text{-}4)$$

Where: i = Hydraulic Gradient between Block (i,j) and (i,j+1) (m/m)
$H_{i,j}$ = Hydraulic Head in Block (i,j) (m)
$H_{i,j+1}$ = Hydraulic Head in Block (i,j+1) (m)
X = Distance Between Block (i,j) and (i,j+1) (m)

(2) Using the hydraulic gradient, the hydraulic conductivity for the block, and Darcy's Equation, estimate the groundwater velocity for each block as per Equation 5-5:

$$V_{i,j} = i_{i,j} \times K_{i,j} \qquad (5\text{-}5)$$

Where: $V_{i,j}$ = Darcy's Velocity for Block (i,j) (m/yr)
$K_{i,j}$ = Horizontal Hydraulic Conductivity for Block (i,j) (m/yr)

(3) Using the MODFLOW predicted water table elevation estimate the thickness of the saturated fill material and the discharge area in the direction of flow as per Equation 5-6:

$$A_{i,j} = T_{i,j} \times W_{i,j} \qquad (5\text{-}6)$$

Where: $A_{i,j}$ = Discharge Area for Block (i,j) (m^2)
$T_{i,j}$ = Thickness of Saturated Landfilled Mass in Block (i,j) (m)
$W_{i,j}$ = Width of Block (i,j) perpendicular to groundwater flow direction (m)

(4) Estimate the leachate discharge rate for an individual block as per Equation 5-7 and then estimate the total discharge rate along the length of the landfill as per Equation 5-8:

$$Q_{F_{i,j}} = A_{i,j} \times V_{i,j} \qquad (5\text{-}7)$$

Where: Q_{Fij} = Groundwater/Leachate Discharge Rate for Block (i,j) (m^3/yr)

$$Q_F = \sum_{i=1}^{i=x} Q_{F_{i,j}} \tag{5-8}$$

Where: Q_F = Total Groundwater/Leachate Discharge Rate from Area A Landfill (m^3/yr)
x = Total Number of Blocks (dimensionless)

A similar procedure will be conducted using MODFLOW-predicted future conditions to estimate the groundwater/leachate discharge rate.

The quantity of groundwater to be collected by the interception trench and the quantity of groundwater/leachate collected by a potential toe drain system will be estimated in a similar manner as the one presented above for the total groundwater/leachate discharge rate. For both the interception trench and the potential toe drain system, the MODFLOW-predicted heads for capped conditions will be used to estimate Darcy's groundwater velocity for a model block. The bottom elevation of the trench and toe drain will be used to estimate the thickness and discharge area for a model block along each channel. Individual groundwater discharge rates will be estimated from each model block along the interception trench and toe drain ($Q_{trench\ i,j}$ and $Q_{toe\ i,j}$), respectively and then a total groundwater discharge rate will be estimated for each channel (Q_{trench} and Q_{toe}) by summing the individual flow rates. A cross-sectional flow net analysis will be used to check the estimates of Q_{trench} and Q_{toe}.

It should be noted that the groundwater flow rates (Q_{trench} and Q_{toe}) are not total flow rates and do not account for surface water runoff from the upgradient slope which will be collected by the interception trench or runoff from the landfill which could be collected by the toe drain. To determine a total flow rate for these two trenches, runoff would have to be accounted for. The runoff flow rates to the trench and toe drain will be substantially greater than the groundwater flow rates and the runoff flow rates should be used to size the trenches. The groundwater flow rates should be considered as the base flow in each of the trenches.

The vertical recharge rate of the dredge spoil/alluvium to the landfilled mass will also be estimated in a similar manner as the one presented above for the total groundwater/leachate discharge rate with several minor differences. The MODFLOW-predicted heads for the dredge spoil/alluvium layer and the fill layer will be used to calculate the vertical hydraulic gradient between the two layers. The vertical gradient and the vertical hydraulic conductivity for a block will be used in Darcy's equation to estimate the vertical groundwater flow velocity. The velocity will be used with the surface area of the block to determine the block-specific vertical recharge rate ($Q_{Di,j}$). The total vertical recharge rate from the dredge spoil/alluvium (Q_D) will then be estimated by summing the block-specific rates.

As a final step, a mass balance will be performed on the estimated flow rates to determine if there is agreement in the flow rates and to determine the magnitude of each flow rate's contribution to the overall groundwater/leachate discharge rate. This calculation will be performed for existing and future conditions. The flow rates discussed above (Q_D, Q_F, $Q_{I\ capped}$, $Q_{I\ existing}$, Q_{trench} and Q_{toe}) will be used in the calculations, in addition to, the estimated shallow groundwater flow rate from the upgradient overburden into the landfilled mass (Q_S). Q_S will vary from existing conditions to proposed conditions due to the upgradient interception trench. Equations 5-9 through 5-10 summarize the mass balances which will be performed for the conditions to be evaluated. Equation 5-9 summarizes the mass balance for existing conditions:

$$Q_{F_{existing}} = Q_{D_{existing}} + Q_{S_{existing}} + Q_{I_{existing}} \tag{5-9}$$

Equation 5-10 summarizes the mass balance for proposed conditions without the toe drain:

$$Q_{F_{capped}} = Q_{D_{capped}} + Q_{S_{capped}} + Q_{I_{capped}} \tag{5-10}$$

Equation 5-11 summarizes the mass balance for proposed conditions if a toe drain system were installed:

$$Q_{F_{capped}} = Q_{D_{capped}} + Q_{S_{capped}} + Q_{I_{capped}} - Q_{toe} \tag{5-11}$$

5.1.2 Impact Of Cap Configuration On Contaminant Migration

The impact of the proposed cap configuration will be evaluated by using the infiltration and groundwater flow modeling results, currently available analytical data, and literature parameters. Calculations will be performed to estimate average COC concentrations using current groundwater and soil analytical data. Estimates of current and future average contaminant mass loading rates from source material in the unsaturated zone to the saturated fill zone will also be made. Finally, current and future average contaminant mass loading rates from the saturated fill zone to the Area A Wetland will be estimated.

Groundwater and soil analytical data from the draft Phase II Remedial Investigation Report (Halliburton NUS, February 1995) and the Focused Feasibility Study for the Area A Landfill (Atlantic, May 1995) will be reviewed and summarized. An appropriate average concentration will be determined for each of the COCs in each media. COCs that contribute significantly to the risk of the site, are the most prevalent, and are most mobile will be the focus of the calculations. An average landfilled mass concentration for COC "i" (C_{Si}) will be used to estimate the average mass loading rate of the COC to the aquifer. The average groundwater concentration for COC "i" (C_{gwi}) will be used to calculate the average mass loading rate of the COC to the Area A Wetland.

<u>Estimate Contaminant Loading from Landfilled Mass</u>

The mass loading rate of COC "i" from the landfilled mass will be calculated using estimated flow rates, C_{Si} and K_L, which is a contaminant- and soil-specific source leaching coefficient. This coefficient is a measure of a contaminants mobility due to dissolution and desorption from the source. Values of K_L will be determined from site-specific data, if available, or from literature sources. C_{Si} and K_L can be used to define the initial aqueous loading of a contaminant and the following equation will be used:

$$C_{L_i} = \frac{C_{s_i}}{K_L} \tag{5-12}$$

Where: C_{Li} = Initial Leachate Concentration for COC "i" (mg/L)
C_{Si} = Average Soil Concentration for COC "i" (mg/kg)
K_L = Source Leaching Coefficient (L/kg)

To be conservative (i.e., neglecting contaminant transport through the vadose zone, decay, and source depletion), the average mass loading rate for the COC will be estimated by Equation 5-13:

$$M_{COC_{S\,i}} = \frac{C_{L_i} \times Q_{I_{existing}}}{1000} \qquad (5\text{-}13)$$

Where: $M_{COC\,Si}$ = Average Mass Loading Rate of COC "i" from Source (kg/yr)
C_{Li} = Initial Leachate Concentration For COC "i" (mg/L)
$Q_{Iexisting}$ = Total Existing Infiltration Rate (m^3/yr)

A similar calculation will also be made for the proposed cap conditions. The two estimated mass loading rates (existing and capped) will be compared to determine the percent reduction in mass loading to the aquifer that is attributable to the cap.

Estimate Contaminant Loading from Groundwater

The mass loading rate of COC "i" from the groundwater (i.e., saturated fill layer of the Area A Landfill) to the Area A Wetland will be calculated using estimated flow rates and C_{gwi}. In addition, an estimate of the current mass of COC "i" in the aquifer material (saturated fill material) will be made using C_{gwi} and K_d, which is a contaminant- and soil-specific distribution coefficient. This coefficient is a measure of a contaminant's affinity to adsorb/desorb from aquifer medium. Values of K_d will be determined from site-specific data, if available, or from literature sources.

As a reasonable estimate (i.e., accounting for limited contaminant transport through the aquifer and neglecting decay), the average mass loading rate for the COC from the fill material of Area A Landfill under existing flow conditions will be estimated by Equation 5-14:

$$M_{COC_{gw\,i}} = \frac{C_{gw_i} \times Q_{F_{existing}} \times 1000}{R_d} \qquad (5\text{-}14)$$

Where: $M_{COC\,gwi}$ = Average Mass Loading Rate of COC "i" from Groundwater (kg/yr)
C_{gwi} = Average Groundwater Concentration For COC "i" (mg/L)
$Q_{Fexisting}$ = Total Existing Groundwater/Leachate Discharge Rate (m^3/yr)
R_d = COC- and Soil-Specific Retardation Factor (unitless)

R_d can be estimated by Equation 5-15:

$$R_d = 1 + \frac{\rho(\frac{K_d}{1000})}{n} \qquad (5\text{-}15)$$

Where: ρ = Bulk Density of Material (kg/m^3)
K_d = Distribution Coefficient (L/kg)
n = porosity

A similar calculation will be made to estimate the average mass loading rate under proposed groundwater flow conditions.

The current mass of COC "i" in the aquifer material (saturated fill material) will be made using Equation 5-16:

$$M_{COC_{aq}} = \frac{C_{gwi} \times K_d \times \rho \times V_F + 1000 \times (C_{gwi} \times n \times V_F)}{1x10^6} \quad (5\text{-}16)$$

Where: $M_{COC\,aq\,i}$ = Mass of COC "i" in Saturated Fill Material (kg)
C_{gwi} = Average Concentration of COC "i" in Groundwater (mg/L)
K_d = Distribution Coefficient for COC "i" (L/kg)
ρ = Bulk Density of Fill Material (kg/m^3)
V_F = Volume of Fill Material (m^3)
n = porosity

The previously described methods will adequately evaluate the effects the proposed cap configuration will have on both the hydrogeologic conditions and contaminant migration at the Area A Landfill. All results and calculations will be presented and discussed in the study report.

5.2 Revised Slope Stability Analysis

Modeling results, together with the blow count measurements from wells and soil borings installation and the results from the triaxial compression testing of the Shelby Tube dredge spoil samples, will be evaluated to determine the need for revision of the previously performed landfill slope stability analyses.

5.2.1 Groundwater Table Conditions

The previously performed stability analyses for the northern sideslope portion of the Area A Landfill were based upon an assumed groundwater condition, corresponding to approximately four (4) feet above the toe of the slope. The basis for this conservative assumption was the result of a stormwater routing analysis, performed for the adjacent Area A Wetlands, that indicated a maximum surface water level increase of four (4) feet during a 100-year, 24-hour storm event. In practice, it is improbable that even such a storm event could maintain a pool condition within the wetland for a sufficient period to saturate the landfilled mass to a height of four feet, yet recede rapidly enough that the increased piezometric head would not at least partially dissipate. As such, the previously performed stability analyses represent a conservative groundwater condition, with respect to the prediction of slope stability along the northern slope of the landfill. To refine the accuracy of the slope stability analysis, results of the MODFLOW groundwater model will be compared to the groundwater table conditions assumed for the previous stability analyses, and additional slope stability analyses will be performed, in the event that the conditions as predicted by the model deviate significantly from those previously assumed.

Results from the groundwater modeling will provide a refined approximation of the groundwater table following installation of the landfill cap and the upgradient groundwater interception trench. Analyses will be performed to estimate long-term, steady-state groundwater conditions, as well as the groundwater conditions resulting from a 100-year, 24-hour storm event. The higher resultant groundwater table condition will be compared to the previously assumed condition, and if the difference is greater than one (1) foot in elevation, the stability analyses will be re-run, using the groundwater table condition obtained from the groundwater model. Only the critical failure surfaces/modes, as determined from the previous analyses, will be re-evaluated.

Additional stability analyses will also be performed, using the results of groundwater modeling based upon the possible installation of a toe drain system. The stability analysis results will be utilized to quantify the effect of the toe drain system on slope stability, if any.

5.2.2 Geotechnical Conditions

A detailed evaluation will be performed of the strength characteristics of the dredge spoil material, based upon the triaxial compression test result and well/boring blow counts from the proposed field investigation as well as those currently available. Several stratigraphic cross sections through the landfill will be developed, utilizing the logs of nearby test borings. Blow counts (within the dredge spoil layer) will be plotted on the cross sections, such that any continuous, extensive zones of anomalously low-strength dredge spoil material can be identified. In addition, the locations of all pertinent triaxial compression test results will be plotted on the same cross sections. If it is judged that continuous, extensive zones of anomalously low-strength dredge spoil material exist, a correlation will be made between the triaxial compresion test results and the weaker materials. Additional stability analyses will then be conducted, that model the weaker dredge spoils as a separate substrata. Based upon a less rigorous review of relevant test boring data, it is HNUS' opinion that extensive zones of anomalously low-strength dredge spoil material are nor apparent beneath the landfill.

5.2.3 Crane Test Pad Area

THe dredge spoil traxial compression test results and blow counts measurements will be evaluated for the new soil boring installed at the proposed location of the crane test pad. If it is judged that anomalously low-strength dredge spoil material exist at this location, revised stability analyses will be performed at this location. Based upon a past review of test boring data variability across the landfill, it is HNUS' current opinion that the previously performed stability analyses are valid, and that no additional analyses will be required..

5.3 Revised Settlement Analysis

The previously performed settlement analysis for the Area A Landfill cover system will be revised, based upon the long-term, steady-state groundwater conditions determined from the MODFLOW groundwater model. HNUS anticipates that the adjustment to the assumed groundwater table condition will we relatively minor, and that the resultant revised settlement analysis will not vary significantly from the previous evaluation. Therefore, it is also anticipated that the currently proposed cover system grades will be adequate to satisfy minimum grade requirements, considering settlement effects.

5.4 Cost Estimates

In order to compare the merits and costs of a cover system only versus a cover system with a toe drain, a construction and operation/maintenance cost estimate will be prepared for the toe drain, based upon the predicted leachate collection rates for a toe drain system. The cost estimate will incorporate provisions required for transmission, storage and treatment/disposal of leachate, in addition to the construction costs associated with installation of the toe drain itself. Since a downgradient barrier would be required to minimize dewatering of the wetland by the toe drain, construction costs for a low permeability barrier will be included.

5.5 Comparison of Alternatives

Following completion of all modeling efforts and development of a cost estimate for the cover system/toe drain scenario, the two options will be compared on the basis of:

- Overall resultant stability of the northern slope of the landfill
- Effectiveness in reducing the discharge of contaminants to the adjacent wetland
- Costs associated with construction and operation/maintenance of each closure approach

Based upon the comparison, a preferred closure alternative will be recommended.

6.0 REPORT PREPARATION

A Groundwater/Leachate Modeling Study Report will be prepared. This report will include the following elements:

- Description of the existing data review and summary of that data
- Description of the field investigation activities, including data points installation, taking of measurements, and sample collection and analysis.
- Summary of the field investigation results
- Description of the HELP modeling activities, including development of a conceptual model and performance of sensitivity analysis
- Presentation of the HELP model results
- Description of the MODFLOW model results, including development of a conceptual model, calibration and validation of the model, and performance of sensitivity analysis
- Presentation of the MODFLOW model results
- Description and results of the contaminant mass flux computations
- Discussion of the predicted impact of installation of an impervious landfill cap and upgradient interception trench upon the landfill discharge flow and quality
- Description and results of and conclusions from the re-computed slope stability analysis for the current gabion-reinforced landfill toe design and of the slope stability analysis for a cap featuring a toe drain system
- Comparison of the slope stability and cost of the current gabion-reinforced landfill toe design with those of a cap featuring a toe drain system
- Description and results of and conclusions from the dredge spoil stability analyses for the crane test pad area and the area of weakest strength

Report appendices will include this work plan, a field activities log, boring logs, field measurements and sampling log sheets, laboratory geotechnical and analytical results, and modeling and geotechnical computations.

Three (3) iterations of the Groundwater/Leachate Modeling Study Report will be prepared. The first iteration will be a preliminary draft report for internal review by the Navy. The second iteration will be a draft report incorporating responses to the internal comments on the preliminary draft report and will be submitted to EPA and the Connecticut Department Of Environmental Protection (CTDEP). The third iteration will be a final report incorporating responses to EPA's and CTDEP's comments on the draft report and will be submitted to EPA, CTDEP, and members of the Remedial Action Board (RAB).

7.0 TECHNICAL MEETINGS AND PRESENTATIONS

An internal technical meeting was held in Pittsburgh, PA on August 23, 1995 between the Navy and their architect/engineer (A/E), HNUS, to discuss the approach and scope of the Groundwater/Leachate Modeling Study. This work plan is the outcome of this meeting.

Two (2) additional meetings and technical presentations will be held. The first meeting will be a one-day event and will be held in Boston, MA between the Navy and their A/E, EPA, and CTDEP to discuss and agree upon this work plan prior to initiation of the field investigation. The second meeting will be a one-day event held in Boston, MA between the Navy and their A/E, EPA, and CTDEP to discuss the draft Groundwater/Leachate Modeling Study Report.

APPENDIX A

FIELD SAMPLING AND ANALYSIS PLAN

APPENDIX B

FIELD INVESTIGATION FIGURES

APPENDIX A

FIELD SAMPLING AND ANALYSIS PLAN

A.0 FIELD SAMPLING PLAN (FSAP)

A.1 SUMMARY OF APPROACH AND FIELD TASKS

A field investigation is needed to support the modeling effort. Figure 3-1 shows the Area A Landfill and the upgradient hillside to the south and downgradient wetlands to the north. Proposed and existing data point locations are shown. Proposed monitoring wells, piezometers, and staff gauges are located along three transects, A-A', B-B', and C-C'. Cross-sectional views of the transects are depicted on Figures 3-2, 3-3, and 3-4. Each of these figures has two views: one of the existing conditions, and one of the post-construction condition of the landfill cap and interceptor trench. The water table was estimated from measured water levels from August, 1994 (Phase II RFI) at existing wells along or near each transect and an estimated wetland elevation.

The field tasks that are needed for the modeling effort are summarized as follows:

- Perform ten (10) surface infiltration tests
- Install eight (8) staff gauges
- Install three (3) drive point piezometers
- Install twelve (12) overburden wells (in the landfilled mass, dredge spoil, or alluvium)
- Drill one (1) soil boring into dredge spoil
- Perform permeability test on seven (7) dredge spoil samples
- Perform triaxial compression test on two (2) dredge spoil samples
- Install two (2) bedrock wells
- Perform sixteen (16) slug tests, including one each for all new wells and two existing bedrock wells
- Measure water level at fifty-two (52) locations, including new and existing monitoring wells and staff gauges
- Construct a weir to measure the flow of seep discharge from the western dike of the Area A Landfill into the OBDA
- Collect one (1) seep sample and analyze for full TCL/TAL analytes
- Survey all new staff gauges; drive point piezometers, and monitoring wells

Each of these tasks are described in Sections A.2 through A.10. The item and sample nomenclature is summarized in Section A.11. Equipment calibration, decontamination, waste handling, and record keeping are described in Sections A.12 through A.15.

Halliburton NUS (HNUS) Standard Operating Procedures (SOPs) and ASTM Methods will be followed during the field work activities and referenced in the text where applicable. All SOPs required for these field investigations are included at the end of the FSAP.

All field activities will be conducted in accordance with the Health and Safety Plan (HASP) previouly developed by HNUS for the Phase II Remedial Investigation.

A.2 SURFACE INFILTRATION TESTS

Ten surface infiltration tests, 2LIT1 through 2LIT10, will be performed across the Area A Landfill to estimate the vertical hydraulic conductivity of the vadose zone materials. Two surface infiltration test will be performed at each of 5 ground surface types: roadway, graveled area near roadway, sand storage area, deployed parking, and vegetated areas. The locations of the infiltration tests will be determined during the field activities. The infiltration test procedure described in the Earth Manual (Bureau of Reclamation) will be used. For each test, a description of the ground surface, location of the test, measured flow rate, height of water in the pipe, and the pipe diameter/radius will be recorded on a sample log sheet. The vertical hydraulic conductivity is estimated according to the Bureau of Reclamation method, which requires the flow rate, height of water maintained in the pipe, and pipe radius as inputs. The method and a sample calculation are included at the end of this FSAP.

A.3 STAFF GAUGES

Eight staff gauges, SG-7 through SG-14, will be installed to assess the presence or amount of surface water along the wetland boundary. The proposed locations are shown on Figure 3-1. Three of the staff gauges are located at transects A-A', B-B', and C-C'. Each staff gauge will be surveyed for location and water level reference measurement.

A.4 DRIVE POINT PIEZOMETERS

Three (3) drive point piezometers, 2LPZ1DS through 2LPZ3DS, will be installed along the wetland boundary to assess the potential or degree of discharge from the underlying dredge spoil to the wetland. The proposed locations are shown on Figure 3-1 along at transects A-A', B-B', C-C' along the wetland boundary. Each piezometer will consist of a 1¼-inch inner diameter (ID) drive point with a 2.5-foot slotted interval at the base. The piezometers will be driven with a sledge hammer or if necessary, an electric jack hammer. The piezometers will be driven to a depth such that the slotted interval resides within the dredge spoil in the saturated zone. Anticipated depths are 5 to 10 feet.

A.5 OVERBURDEN MONITORING WELLS

Six (6) monitoring well clusters, 2LMW28 through 2LMW33, each with two 2-inch ID monitoring wells, will be installed in unconsolidated materials. At each cluster, one well will be installed such that the 5-foot screened interval resides in the landfilled mass and intercepts the water table. The second well at each cluster will be installed such that the 5-foot screened interval resides in the saturated material immediately below the landfilled mass, i.e., the dredge spoil or alluvium. If dredge spoil is not encountered below the landfilled mass or the dredge spoil is too thin to accommodate a 5 foot well screen, then the well should be screened in the alluvium below the landfilled mass material or thin dredge spoil. Each well will be installed such that the screened interval monitors only one type of material. The nomenclature for each well at a well cluster ends with a "F", "DS", or "A" to indicate whether the well is screened in the landfilled mass, the dredge spoil, or the alluvium, respectively (refer to Table A-2). The proposed locations of the 12 wells are shown on Figure 3-1 and depicted on Figures 3-2, 3-3, and 3-4 along transects A-A', B-B', and C-C'.

The borings will be drilled using hollow stem auger drilling techniques, in accordance with SOP GH-1.4. The hollow stem augers will have a minimum inside diameter of 3-3/4 inches. Two-inch diameter split spoon samples will be collected continuously from each boring to the bottom of the boring in accordance with SOP GH-1.3. Soil characteristics and geotechnical information from each split-spoon sample will be recorded on boring logs. Samples obtained from the boreholes will be monitored for organic vapors with an HNu (or equivalent) in accordance with the SOP ME-01. The readings will be recorded on the boring logs.

For each well, after the 2-inch PVC well casing is installed, the borehole will be filled with a sand pack around and to approximately 2 feet above the well screen. A bentonite seal will be emplaced above the sand pack, and the remaining borehole will be filled to the ground surface with a cement-bentonite grout. Each well will be completed with a protective casing and cap.

A.6 DREDGE SPOIL SOIL BORING AND PERMEABILITY AND TRIAXIAL TESTS

A dredge spoil sample will be collected from each of the 6 dredge spoil/alluvium monitoring well locations along Transects A-A', B-B', and C-C'. The undisturbed samples will be collected with 3-inch O.D. thin-walled (Shelby) tubes in accordance with SOP GH-1.3. The Shelby tube samples will be collected immediately after the dredge spoil material is encountered by split-spoon sampling.

One soil boring, 2LTB32DS, will be drilled in the middle of the crane testing pad (refer to Figure 3-1 for location). A Shelby tube sample will be collected from that test boring immediately after the dredge spoil material is encountered by split-spoon sampling.

Two additional dredge spoil Shelby Tube samples will be collected from the new monitoring wells and/or soil boring. Selection of the well or boring where an extra sample is collected will be based upon field observations.

One dredge spoil Shelby Tube sample from each new monitoring well and soil boring will be tested for permeablity. Two dredge spoil Shelby Tube samples will also be tested for triaxial compression, including one collected from the new soil boring installed at the location of the crane test pad and one collected from the new data point with the lowest blow count in the dredge spoil. If the lowest blow count occurs in the soil boring installed at the location of the test pad, the second sample to be tested for triaxial compression will be that collected from the test point with the second lowest blow count in the dredge spoil.

The samples will be sealed, packed, and transported in an upright position to a lab for testing. Refer to Table A-1 for a summary of analytical testing and Table A-2 for sample nomenclature.

A.7 BEDROCK MONITORING WELLS

Two open hole wells, 2LMW34B and 2LMW35B, will be drilled into bedrock along the top of the hillside, south of the Area A Landfill, to assess the groundwater potential significantly upgradient of the landfill and proposed interceptor trench. The proposed locations of the wells are shown on Figure 3-1 and depicted on Figures 3-2, 3-3, and 3-4. The wells will be drilled by air rotary methods in accordance with SOP GH-1.4. Bedrock characteristics will be recorded on boring logs. The wells will be advanced into bedrock approximately 5 feet, then a 4 or 6-inch diameter steel casing will be set and grouted into place. Then the wells will be advanced (nominal 4 or 6-inch hole) until adequate water-yielding zones are encountered (i.e., > 1 gpm) to monitor the groundwater head in the bedrock. Anticipated depths are 50 to 70 feet.

TABLE A-1
ANALYTICAL PROGRAM - AREA A LANDFILL
NSB-NLON, GROTON, CONNECTICUT

MEDIA	ANALYSIS	METHOD	NUMBER OF SAMPLES	RINSATE BLANK	TOTAL SAMPLES
Dredge Spoil	Permeability	ASTM D5084	7	-	7
Dredge Spoil	Triaxial Compression	ASTM D4767	2	-	2
Seep Water	TCL/TAL Suite	OLM01.8 ILM02.0	1	1	2

TABLE A-2

SUMMARY OF NOMENCLATURE AREA A LANDFILL
NSB-NLON, GROTON, CONNECTICUT

ITEM	NUMBER	NOMENCLATURE	COMMENT
Infiltration Tests	10	2LIT1 through 2LIT10	Require description of ground surface, flow rate, height of water, and radius of pipe.
Staff Gauges	8	SG-7 through SG-14	Hand driven.
Drive Point Piezometers	3	2LPZ1DS through 2LPZ3DS	Hand or jack driven. "DS" means dredge spoil.
Overburden Monitoring Wells	12	2LMW28F through 2LMW33F 2LMW28DS through 2LMW33DS	"F" means Fill; "DS" means dredge spoil. If dredge spoil is not present, well will be screened in alluvium and designated by "A".
Soil Boring	1	2LTB32DS	"DS" means dredge spoil. Located at crane testing pad.
Dredge Spoil Permeability Tests	6	2LMW28DS-P-XXXX through 2LMW33DS-P-XXXX 2LTB32DS-P-XXXX	"P" means permeability test. XXXX is collection depth defined by field personnel, e.g. 0810 means 8 to 10 foot interval.
Dredge Spoil Triaxial Compression Tests	2	2LTB32DS-T-XXXX and 2LMW??DS-T-XXXX	?? means location will be field determined. "T" means triaxial test. XXXX is collection depth defined by field personnel, e.g. 0608 means 6 to 8 feet deep.
Bedrock Monitoring Wells	2	2LMW34B, 2LMW35B	"B" means bedrock.
Seep Sample	2	3MSP01, 3MSP01-R	"R" means rinsate blank.

A.8 WELL DEVELOPMENT, AQUIFER TESTING, AND WATER LEVELS

All new overburden monitoring wells will be developed in accordance with SOP GH-1.7. Wells will be developed with a small submersible pump. Field measurements of pH, specific conductivity, and temperature will be obtained with a Horiba monitoring instrument and recorded on sample log sheets.

All new monitoring wells (12 unconsolidated and 2 bedrock) will be slug tested to estimate the hydraulic conductivity of the screened intervals. Additionally, 2 existing bedrock wells, 2LMW8D and 2LMW20D will be slug tested. Slug tests will be performed in accordance with SOP GH-2.4.

One round of water levels will be obtained at existing and new monitoring wells, piezometers, and staff gauges in and around the Area A Landfill. Water levels will be obtained from the following 35 existing monitoring wells:

- 1MW2S
- 2DMW11S/11D
- 2LMW7S/7D through 2LMW9S/9D
- 2LMW13S/13D, 2LMW14S
- 2LMW17S/17D through 2LMW20S/20D
- 2LPW1S, 2LOW1S, 2LOW1D, 2LOW2S, 2LOW3S, 2LOW4S
- 2WMW3S/3D
- 3MW12S/12D
- 4MW1S, 4MW2S, 4MW3S, 4MW4S, 4MW4D

Water levels will be obtained at 3 new piezometers, 12 new overburden wells, and 2 new bedrock wells. Surface water levels will be collected at existing staff gauge, SG-6, and 8 new staff gauges, SG-7 through SG-14.

Water level measurements will be taken in accordance with SOP GH-2.5 with an M-Scope using the top of the inner casing (monitoring wells) as the reference point for determining depths-to-water. Measurements will be recorded to the nearest 0.01 foot in the field logbook and on a groundwater level measurements form.

A.9 SEEP SAMPLING

A flume or weir will be constructed at the location of seep discharge in the OBDA (refer to Figure 3-1) to estimate the flow rate. Methods to determine the discharge are provided in SOP GH-2.7. The field personnel will determine the most appropriate means to measure the discharge depending on the seep flow conditions.

One seep sample, 3MSP01 (refer to Figure 3-1), will be collected and analyzed for the full TCL/TAL suite of analytes (refer to Table A-1). Additionally, one rinsate blank, 3MSP01-R, will be analyzed for the same analytes. Samples will be preserved in accordance with SOP SF-1.2. Samples will be packaged and shipped in accordance with Halliburton NUS SOP SA-6.2.

A.10 SURVEYING

Each new monitoring well, piezometer, and staff gauge location will be surveyed by a licensed surveyor. The horizontal location, ground surface elevation, and water level reference elevation will be noted. Elevations will be reported in feet above mean sea level. Surveying will utilize pre-existing reference points and/or existing survey monuments from previous surveying events.

A.11 SUMMARY OF NOMENCLATURE

Table A-2 shows a summary of the field items, number of each item, recommended nomenclature, and comments for the field personnel.

A.12 EQUIPMENT CALIBRATION

An organic vapor monitor (HNu or equivalent) will be used during field activities. It will be calibrated daily or according to the manufacturer's operating manual (refer to SOP ME-01).

Calibration will be documented in the field logbook and on calibration logsheets. During calibration an appropriate maintenance check will be performed on the equipment. If damaged or defective parts are identified during the maintenance check and it is determined that the damage could have an impact on the instrument's performance, the instrument will be removed from service until the defective parts are repaired or replaced.

A.13 DECONTAMINATION

All downhole drilling equipment will be steam cleaned prior to beginning work, between well borings, anytime the drilling rig leaves the site prior to completing a boring, and at the completion of the drilling and excavation program. Decontamination activities will take place at the designated decontamination area. Additional requirements for drilling equipment decontamination can be found in Halliburton NUS SOP GH-1.6.

All sampling equipment used for collecting samples (e.g. split-spoons) will be decontaminated both prior to field sampling and between samples, in accordance with SOP SF-2.3. Decontamination requires a Liquinox wash and potable water rinse.

A.14 WASTE HANDLING

All decontamination liquids, purge water, and drill cuttings will be collected and stored on-site in Department of Transportation (DOT)-approved (Specification 17-C), 55-gallon drums. Drums will be sealed and labeled with drum contents, boring number, site or origin, volume, and date. The drums will be stored on wooden pallets at the Area A Landfill. Halliburton NUS understands that the Navy will arrange for the waste to be disposed in an appropriate manner.

A.15 RECORD KEEPING

In addition to the previously mentioned forms, notebooks and a logbook will be maintained. A field notebook will be maintained by the field crew. All information related to sampling or field activities will be recorded in the field notebook. A site logbook will be maintained by the field operations leader (FOL). This book will contain a summary of the day's activities and will reference the field notebooks when applicable. At the completion of field activities, the FOL will submit to the Project Manager (PM) all field records, data, field notebooks, logbooks, chain-of-custody receipts, sample logsheets, and boring logs.

APPENDIX B

FIELD INVESTIGATION FIGURES