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GROUNDWATER MODELING EVALUATION REPORT AND IMPROVEMENT PLAN APRIL 1993 REVISION 0

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REPORT

Groundwater Modeling Evaluation Report and Improvement Plan

Fernald Environmental Management Project
April 1993
Revision No. 0

Submitted by:
U.S. Department of Energy
Fernald Office
P.O. Box 398705
Cincinnati, Ohio 45239-8705

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Submitted by:
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Groundwater Model Evaluation Report and Improvement Plan

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LIST OF ACRONYMS AND ABBREVIATIONS

A&W	Albright & Wilson Americas Co.
ACL	Alternate Concentration Limit
AWWT	Advanced Wastewater Treatment Plant
CCDF	Complementary Cumulative Distribution Function
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CRARE	Comprehensive Response Action Risk Evaluation
CRU	CERCLA/RCRA Unit
DGW	Department of Groundwater (Ohio)
DMEPP	Design, Monitoring, and Evaluation Program Plan
DOE	United States Department of Energy
EE/CA	Engineering Evaluation/Cost Analysis
ESD	Explanation of Significant Difference
FEMP	Fernald Environmental Management Project
FERMCO	Fernald Environmental Restoration Management Corporation
FMPC	Feed Materials Production Center
GMA	Great Miami Aquifer
gpm	gallons per minute
GWQAP	Groundwater Quality Assessment Plans
IAWWT	Interim Advanced Wastewater Treatment
IEEE	Institute of Electrical and Electronics Engineers
LLW	Low-Level Waste
$\mu g/\ell$	micrograms per liter
NRC	United States Nuclear Regulatory Commission
Ohio EPA	Ohio Environmental Protection Agency
PRRS	Paddy's Run Road Site
PWS	Public Water Supply
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SDWA	Safe Drinking Water Act
SLF	Sanitary Landfill Facility
SOWC	Southwestern Ohio Water Company
SPFTM	South Plume Fate and Transport Model
SPMR	South Plume Removal Action Groundwater Modeling Report
SRP	Standard Review Plan
SWIFT	Sandia Waste Isolation Flow and Transport
TOT	Total Time of Travel
TSD	Treatment, Storage, Disposal
UCL	Upper Confidence Limit
US EPA	United States Environmental Protection Agency
WEMCO	Westinghouse Environmental Management Company of Ohio
WHP	Well Head Protection
WHPA	Well Head Protection Area

EXECUTIVE SUMMARY

Under contract to the United States Department of Energy (DOE), International Technology Corporation (IT) developed a groundwater flow and transport model to support Remedial Investigations (RIs), Feasibility Studies (FSs), and Remedial Design activities of the remediation program at the Fernald Environmental Management Project (FEMP) site. This document evaluates this model and presents a model improvement program plan. In addition to this document, a stand-alone groundwater modeling report that defines the historical development of the model has also been prepared. Activities are underway to implement the tasks identified in this improvement plan. The overall approach to model improvement is set by the accuracy needs of the eventual users of the model.

Regulatory criteria applicable to the modeling process at the FEMP were identified from the review of applicable regulations and guidance from the United States Environmental Protection Agency (US EPA), Ohio Environmental Protection Agency (Ohio EPA), DOE, and United States Nuclear Regulatory Commission (NRC). No agency has developed comprehensive criteria for modeling; nevertheless, these combined criteria provide some direction for modeling activities. These criteria cover the code selection, the model-oriented collection of data from site characterization activities, model application, evaluation of model results, and maintenance of a modeling quality assurance program.

The evaluation of the present groundwater model resulted in these significant findings:

1) The tasks outlined in the 1988 IT Work Plan for development of the present FEMP flow and transport model have been completed.

2) The Ohio and US EPAs have many concerns about the accuracy and appropriate use of the present FEMP flow and transport groundwater model.

3) The current conceptual model represents a reasonable hypothesis of the natural system but uncertainties do exist (i.e., heterogencits, geochemistic). The most uncertain parameter in the model development is the source term.

US and Ohio EPA comments on three FEMP model application reports and an assessment of the present model to applicable regulatory criteria were used to develop the improvement plan. The following major improvement tasks are recommended:

1) Model Design - Expand the domain of the solute transport model to the east and create higher vertical resolution. Key model parameter values need to be refined with site-specific data.

2) Model Comparisons with Field Data - Review the distribution factor, recalibrate the flow and solute transport models, and perform periodic model performance evaluations.

3) Model Uncertainty Analysis - perform geostatistical analysis on water level and chemical data and sensitivity analysis on transport parameters.

4) Model Applications - perform capture zone analysis for major water supply wells, define report content, and define a post-audit program.

These improvement tasks are divided into short-term and long-term efforts based on schedule requirements for different applications. The short-term effort is driven by the need to have an improved model for the CRU5 risk assessment process by September 1993. The long-term activities are additional performance evaluations, and post-audit activities to continue to check the accuracy of the model. The short-term part of the plan covers the use and improvement of the model between now and August 1993. The long-term part of the plan starts in September 1993 and continues throughout the remediation process. It is also recommended that there needs to be close communication with the US EPA and the Ohio EPA during the model improvement and future applications.

SECTION 1

INTRODUCTION

A groundwater flow and transport model has been developed to support Remedial Investigations (RI), Feasibility Studies (FS), and Remedial Design activities at the Fernald Environmental Management Project (FEMP - formerly the FMPC) site. The plan for development of this model (referred to as the "present model" in this report) is refined in the *Work Plan-Groundwater Flow/Solute Transport Modeling* (IT 1988). A description of model development is recorded in the *Groundwater Modeling Report - Summary of Model Development* (DOE 1993b).

This report presents a formal evaluation of the present model which is the flow and transport model using the SWIFT code and calibrated to 1986 flow data and 1990 uranium data. This evaluation focuses on modeling issues identified by the United States Environmental Protection Agency (US EPA), the Ohio Environmental Protection Agency (Ohio EPA), and internally by the United States Department of Energy (DOE) and its contractors during applications of the model over the last 3 years. This evaluation results in a model improvement program that recommends activities for improving the present groundwater model. By evaluating the FEMP flow and solute transport models, model limitations and uncertainties are better defined and an approach to using the present model to support FEMP activities is established.

1.1 Study Objectives and Approach

The objectives of this evaluation are:

1) To identify model application limitations and to establish acceptable applications (and methodology for these applications) of the present groundwater model. This is necessary because the present model will continue to be used for acceptable applications while improvement activities are in progress.

2) To establish a program of model improvement activities that will lead to acceptance of the FEMP groundwater model and all necessary model applications by the Ohio and US EPAs.

3) To set a baseline for further modeling efforts.

The approach taken in this report for meeting these objectives consists of the following steps:

1) The FEMP groundwater model development and applications to date are summarized for background information. In addition, the requirements identified in the *Work Plan - Groundwater*

Flow/Solute Transport Modeling (Modeling Work Plan - IT 1988) are summarized and compared to the program that was actually implemented to determine whether the objectives have been met.

2) Modeling criteria is established through a review of regulations, regulatory guidance, modeling literature, and previous US and Ohio EPA comments. These criteria set the basis for the model evaluation and improvement activities.

3) Based upon these reviews and a summary of model development to date (DOE 1993b), the present groundwater model is evaluated. This evaluation compares the present model with the identified modeling criteria to determine if the criteria have been met and to conceptualize additional modeling tasks.

4) Plans for short- and long-term model improvement activities are developed and documented. These plans define the additional tasks necessary to meet project goals.

1.2 Groundwater Fate and Transport Modeling

Figure 1-1 shows the present groundwater fate and transport modeling domain for the FEMP. The fate and transport model defines the transport of contaminants from the source through the applicable pathways to the theoretical receptors. The conceptual model consists of three primary processes:

1) source term definition
2) vadose zone transport
3) saturated zone transport

Figure 1-2 shows the modeling process with more detail on the current methodology for modeling and the proposed CERCLA/RCRA Unit 5 (CRU5) improvements. The source term development process will be the same for CRUs 1, 2, 4, and 5. For input terms for vadose zone transport, the current process uses the HELP model to define infiltration rate and EQ3/6 to determine leachate concentration. The proposed CRU5 modeling process will use a new glacial till model for determining infiltration rate and will rely on direct leachate or TCLP data for leachate term definition. For vadose zone transport, the one dimensional codes ST1D and ODAST will be replaced by a more sophisticated glacial till model. SWIFT input will be improved by using a model of Paddy's Run to define loading rates. Finally, saturated zone transport will be refined by improving the present SWIFT model (i.e., the subject of this report).

Figure 1-3 presents the approach that will be taken to complete the fate and transport modeling for CRU5. Over the last several months, groundwater modeling and risk assessment issues have been reviewed and integrated. Based upon this review, three primary categories of activities have been identified:

Current Modeling Domain

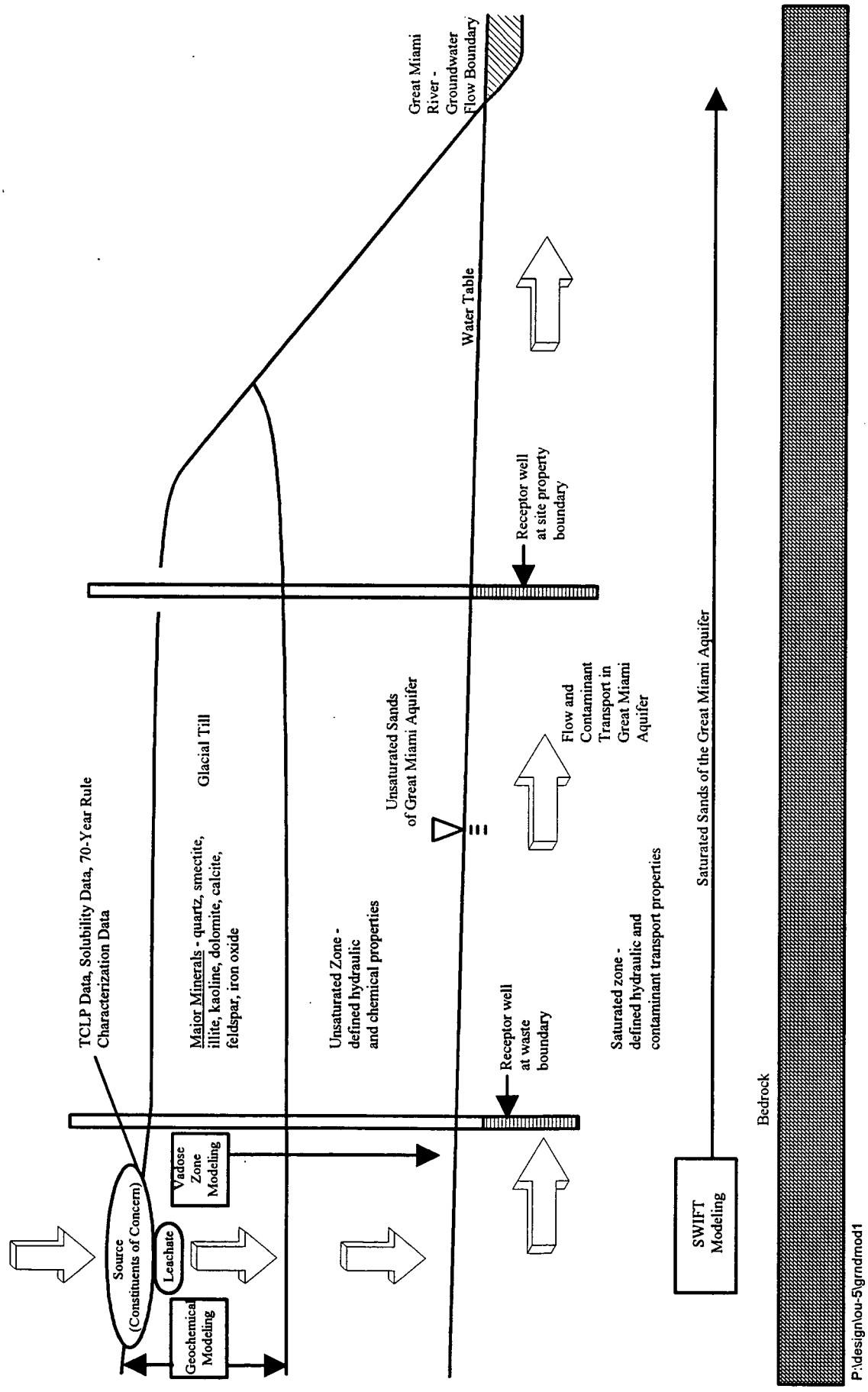

Figure 1-1 - Current Modeling Domain

Groundwater Fate and Transport Modeling Approach

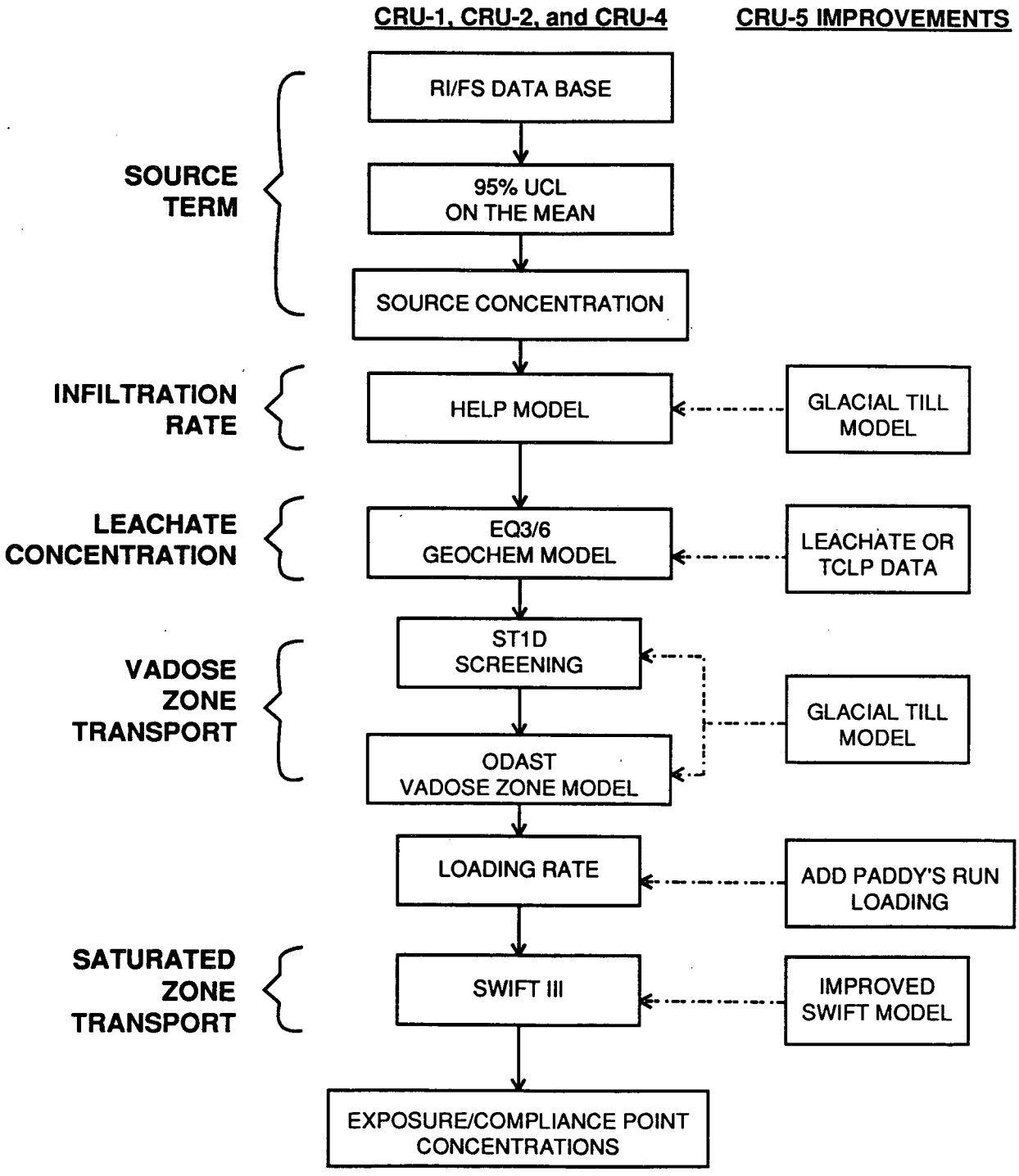

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Figure 1-2 - Groundwater Fate and Transport Modeling Approach

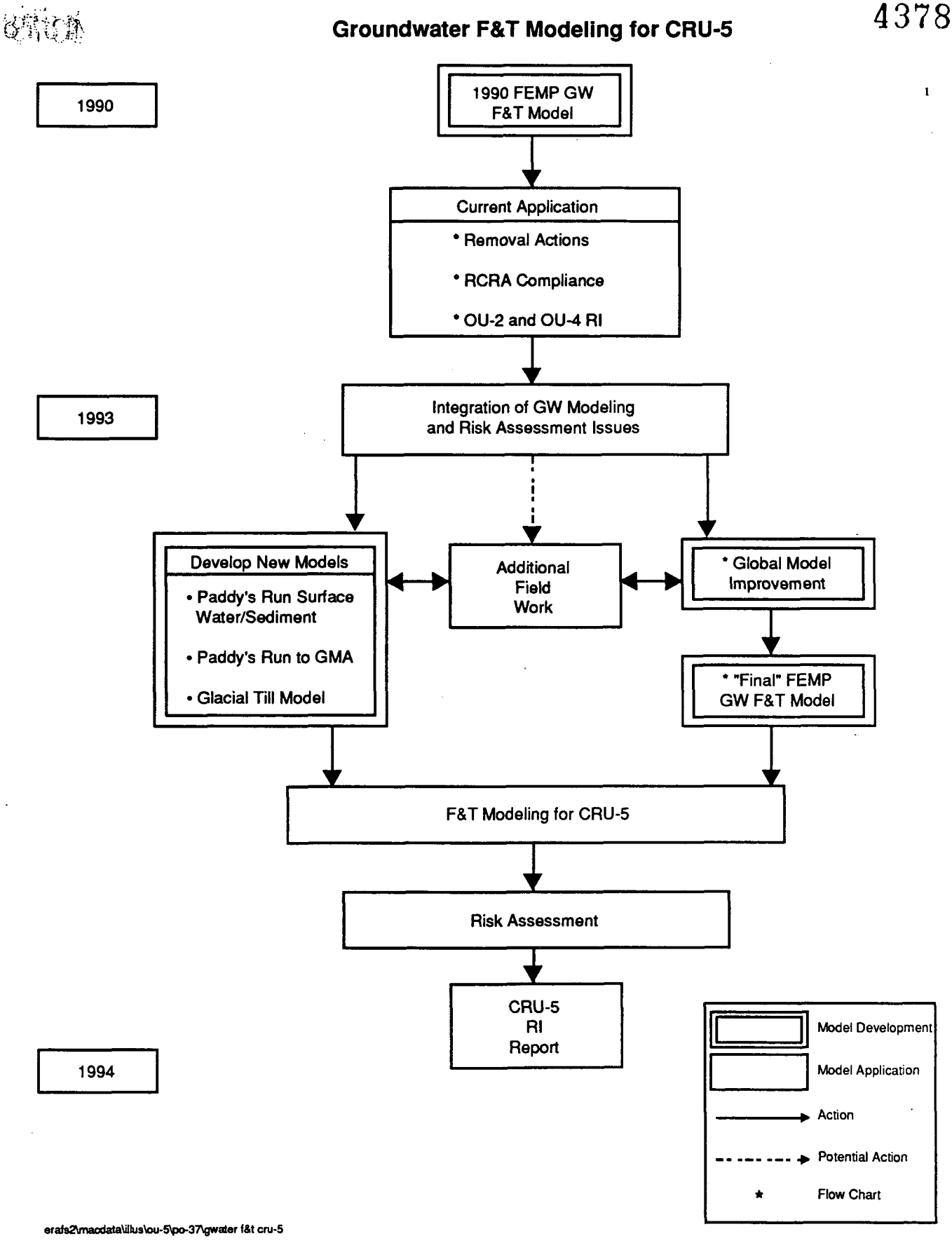

Figure 1-3 - Groundwater F&T Modeling for CRU5

1) The development of new models
2) Additional fieldwork
3) Global model improvement

With these new models, additional collected data, and the improved SWIFT model, the fate and transport modeling for the CRU5 risk assessment can be successfully completed.

The global model improvement program is being undertaken to refine the present SWIFT flow and transport model so that future applications will be accepted by review agencies. Figure 1-4 shows a flow chart of the overall model improvement program with the present report highlighted. This figure shows two parallel activities, preparing a stand-alone groundwater modeling report (DOE 1993b - extracted from the former Groundwater Report [DOE 1990a]) and performing an evaluation of the existing model culminating with a model improvement plan. After review by the US and Ohio EPAs, defined improvement activities will be implemented and a "final" groundwater model will be developed. The "final" model will be refined on a continuing basis by long-term improvement activities.

1.3 Model Application Objectives

Model application objectives are divided into short- and long-term objectives. Short-term applications of the groundwater model need to support characterization and baseline risk assessment studies. Long-term applications need to compare the effects of remediation scenarios for feasibility studies and support design efforts for final remediation.

1.4 Program Approach

The following concepts have governed the approach for designing a model improvement program:

1) Successful model applications need to consider accuracy. If the accuracy is known, appropriate steps can be taken to evaluate the resulting uncertainty. There is no perfect numerical groundwater model of any site. By necessity, groundwater models simplify the natural system. A model can only be as accurate as the data, assumptions, and governing equations on which it was developed. Refinement of groundwater models is a natural progression over the course of a site characterization and remediation project. As more data becomes available during site characterization and predicted results are compared to field results, an opportunity is available to refine and improve the accuracy of the model.

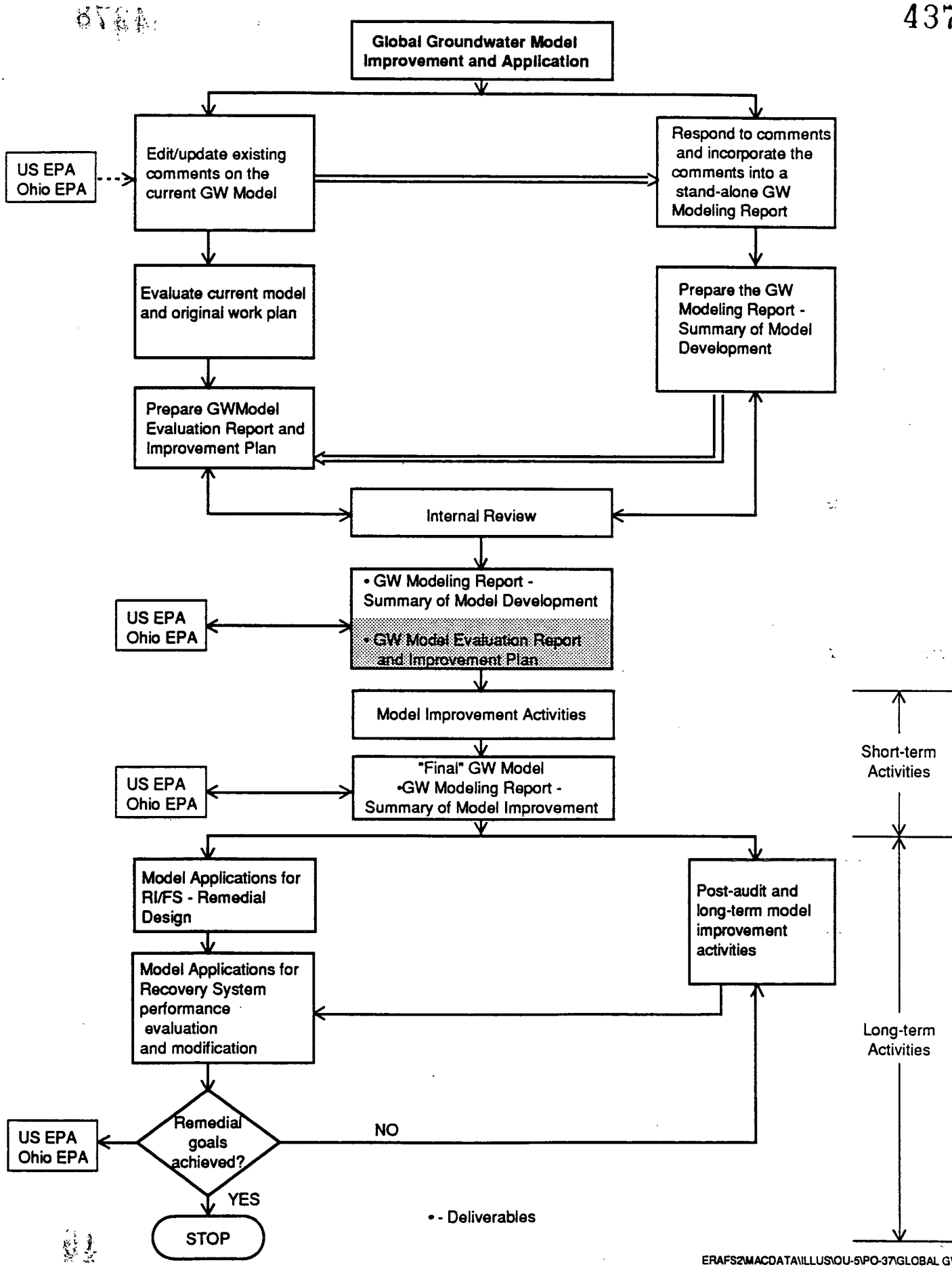

Figure 1-4 - Overall Model Improvement Program

2) A balance must exist between the ideal model and practical considerations. The present model is being used for various forms of analysis to support the remedial investigation. While the best possible model is desirable, a degree of practicality must govern improvement activities based on resource constraints and overall accuracy considerations. For example, if other sources of uncertainty in the risk assessment process far exceed the model uncertainty, then there is little value in further model refinement. The understanding of the uncertainty of predictions may in many instances be more important than reducing the uncertainty. With this understanding, the model can be applied in an appropriate manner and its limitations can be defined.

3) Proposed improvement activities need to build on the existing data and present model framework. Several years of analysis have lead to a reasonably sophisticated and refined model. Future improvement activities should focus on further refinement of the present model as necessary to meet the site remediation goals and regulatory criteria.

4) Short-term and long-term efforts need to be defined. Short-term efforts (between now and August 1993) are driven by the need to have an adequate model for the risk assessment process (especially the CRU5 risk assessment which has more sources and must assess more complicated pathways than the other operable units). The long-term activities (after August 1993) are extended verifications and post-audit activities to continue to check the accuracy of the model. The model must be ready to support the risk assessment for the CRU5 RI in August 1993.

5) There needs to be close communication with the US EPA and the Ohio EPA during the planning and implementation of improvement activities.

SECTION 2

SUMMARY OF FEMP GROUNDWATER MODELING

This section summarizes the groundwater model development program and model applications to date relying on previous reports (DOE 1990a, DOE 1990b, DOE 1991, DOE 1992a, DOE 1993a, and DOE 1993b). This information is not intended to be comprehensive, but rather to provide a convenient summary for the reader. For more detailed analysis, see these reports.

This section discusses the past progress in developing the present SWIFT flow and transport groundwater model for the FEMP. Figure 2-1 shows a timeline for major activities in the groundwater modeling program at the FEMP. This figure also shows data collection, model development, model improvement, and model application activities since 1986 including the proposed future activities.

The following subsections review:

1) FEMP hydrogeology
2) Selection and verification of the SWIFT groundwater and transport code
3) Construction and calibration of the present groundwater flow and transport model
4) Results of model applications to date
5) Comparison of the IT Work Plan to the Implemented Groundwater Modeling Program

2.1 FEMP Hydrogeology

The Great Miami Aquifer is a major buried valley aquifer underlying the FEMP site. The buried valley varies in width from about 1/2 mile to over 2 miles, having a U-shaped cross section with a broad, relatively flat bottom, and steep valley walls (Figure 2-2). Extensive deposits of sand and gravel fill this valley, ranging in thickness from 120 to 200 feet to only several feet along the valley walls. A clay interbed, 5 to 15 feet thick, occurs approximately 130 feet below the land surface and, where present, divides the aquifer into upper and lower sand and gravel units.

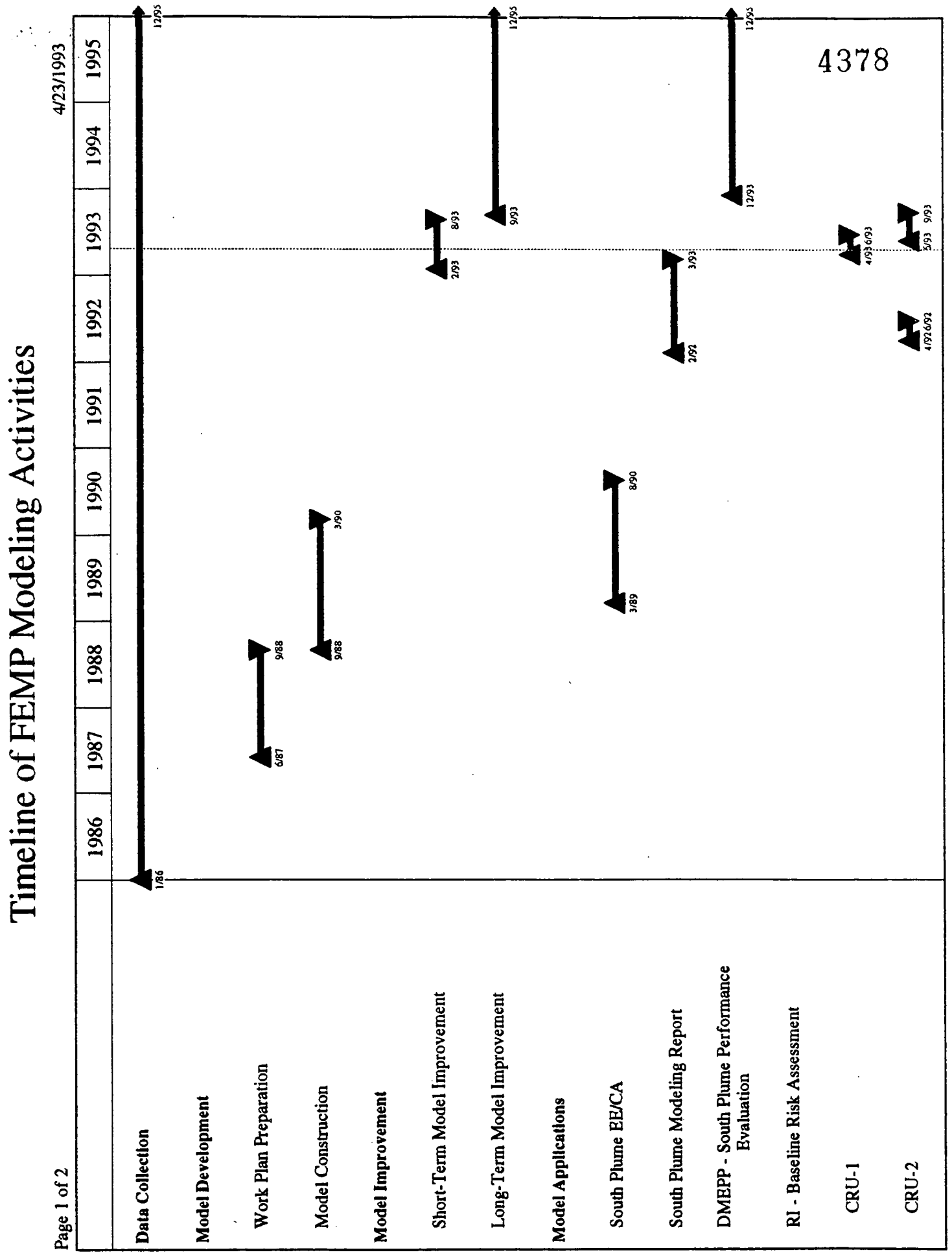

Figure 2-1 - Groundwater Modeling Program Elements Timeline (Page 1 of 2) 18

Timeline of FEMP Modeling Activities

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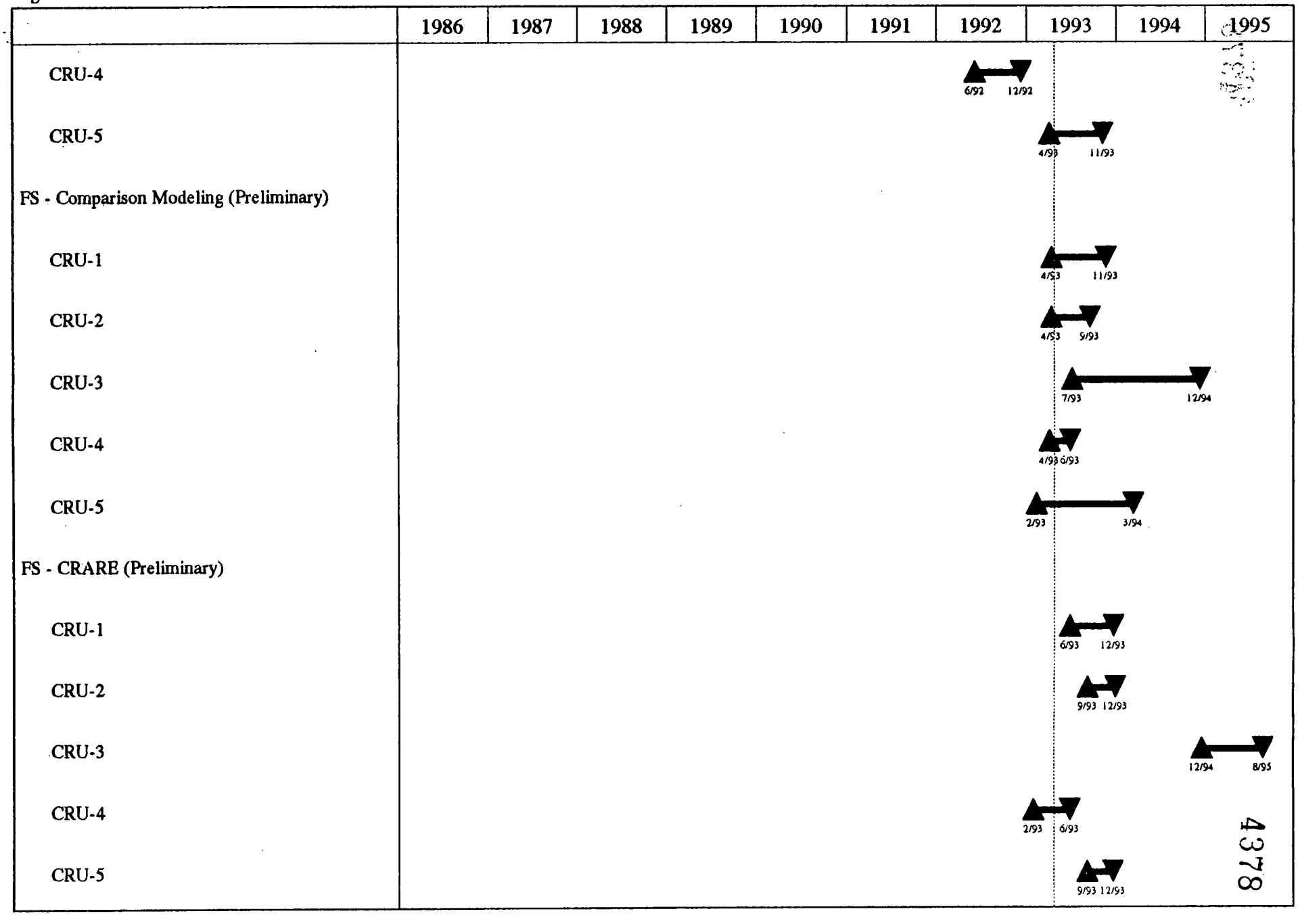
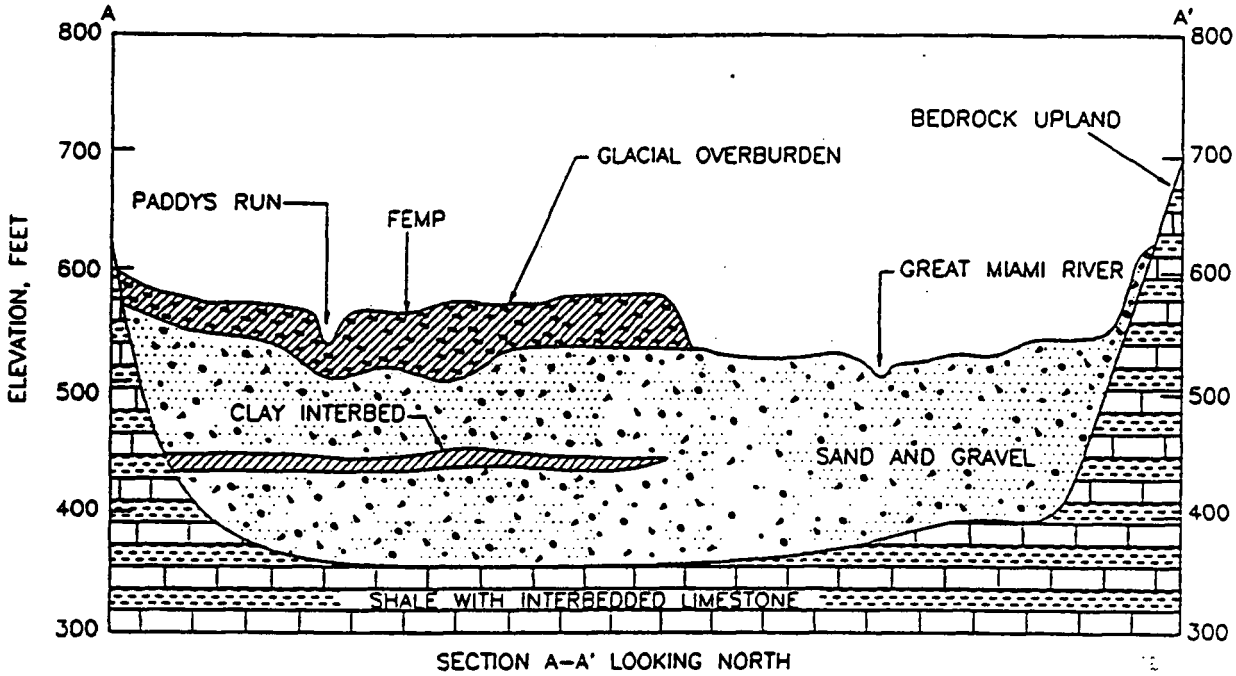


Figure 2-1 - Groundwater Modeling Program Elements Timeline (Page 2 of 2)

Figure 2-3 shows the generalized directions of groundwater flow in the Great Miami Aquifer. Groundwater enters the FEMP study area from three separate flow systems: the Dry Fork Section of the New Haven Trough to the west, the Shandon Tributary to the north, and the Ross Section of the New Haven Trough to the northeast. Groundwater exits the FEMP study area either by flowing east to the Great Miami River upstream from New Baltimore or by flowing south through the branch of the bedrock channel west of New Baltimore. In either case, the Great Miami River ultimately receives all the groundwater in the study area.

The Southwestern Ohio Water Company (SOWC) has large-volume pumping wells near the "Big Bend" meander of the Great Miami River east of the FEMP. These pumping wells produce a pronounced cone of depression that lowers the water table in the area surrounding the pumping wells. Groundwater elevation maps indicate that this cone of depression influences groundwater flow patterns beneath the FEMP. In particular, a groundwater flow divide is created such that groundwater underlying the northern portion of the FEMP flows east toward the SOWC wells and the Great Miami River. Groundwater from the southern and southwestern portion of the FEMP continues to flow along the natural gradient to the south-southwest through the buried valley. Near the southwest corner of the FEMP, a groundwater component from the west is also present. This causes the recharge from certain reaches of Paddy's Run to flow east-southeast until the regional southern component of flow is encountered.

Paddy's Run affects local groundwater flow along the western boundary and in the area south of the FEMP. Increases in flow in Paddy's Run lead to the formation of a groundwater mound typically centered on monitoring wells just southwest of the K-65 Silos and adjacent to Paddy's Run. During the dry months, Paddy's Run provides little recharge to the aquifer. In contrast, after heavy or sustained rainfall, large amounts of stream water infiltrate the aquifer from Paddy's Run and create a mound in the local water table. This groundwater mound changes the direction of flow patterns. For example, groundwater that normally flows to the east in the vicinity of Paddy's Run will be forced locally to flow to the west when this seasonal mounding occurs.

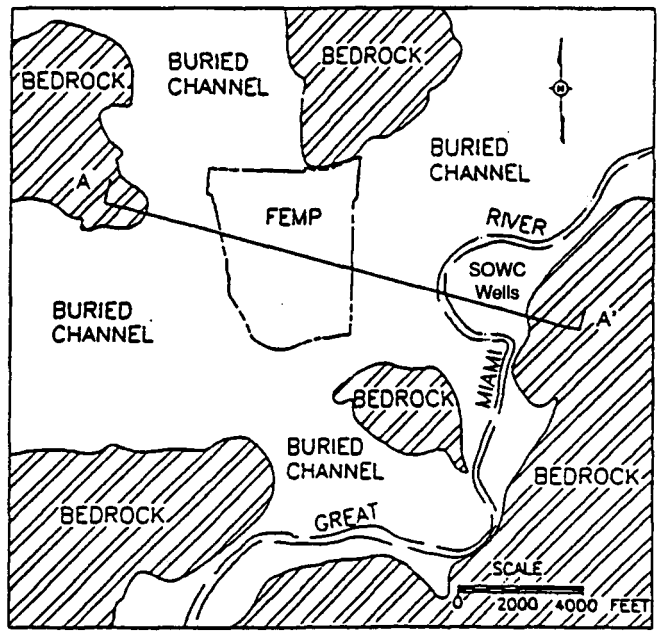


SECTION A–A' LOOKING NORTH

NOTES:

HORIZONTAL SCALE IS APPROXIMATELY 1" = 2500'

INFORMATION CONCERNING THE DEPTH AND ATTITUDE OF THE BEDROCK SHALE WAS OBTAINED FROM IT CORPORATION DRAWING 303317-8208.



LOCATION OF CROSS SECTION

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Figure 2-2 - Schematic Cross-Section of Buried Channel Aquifer

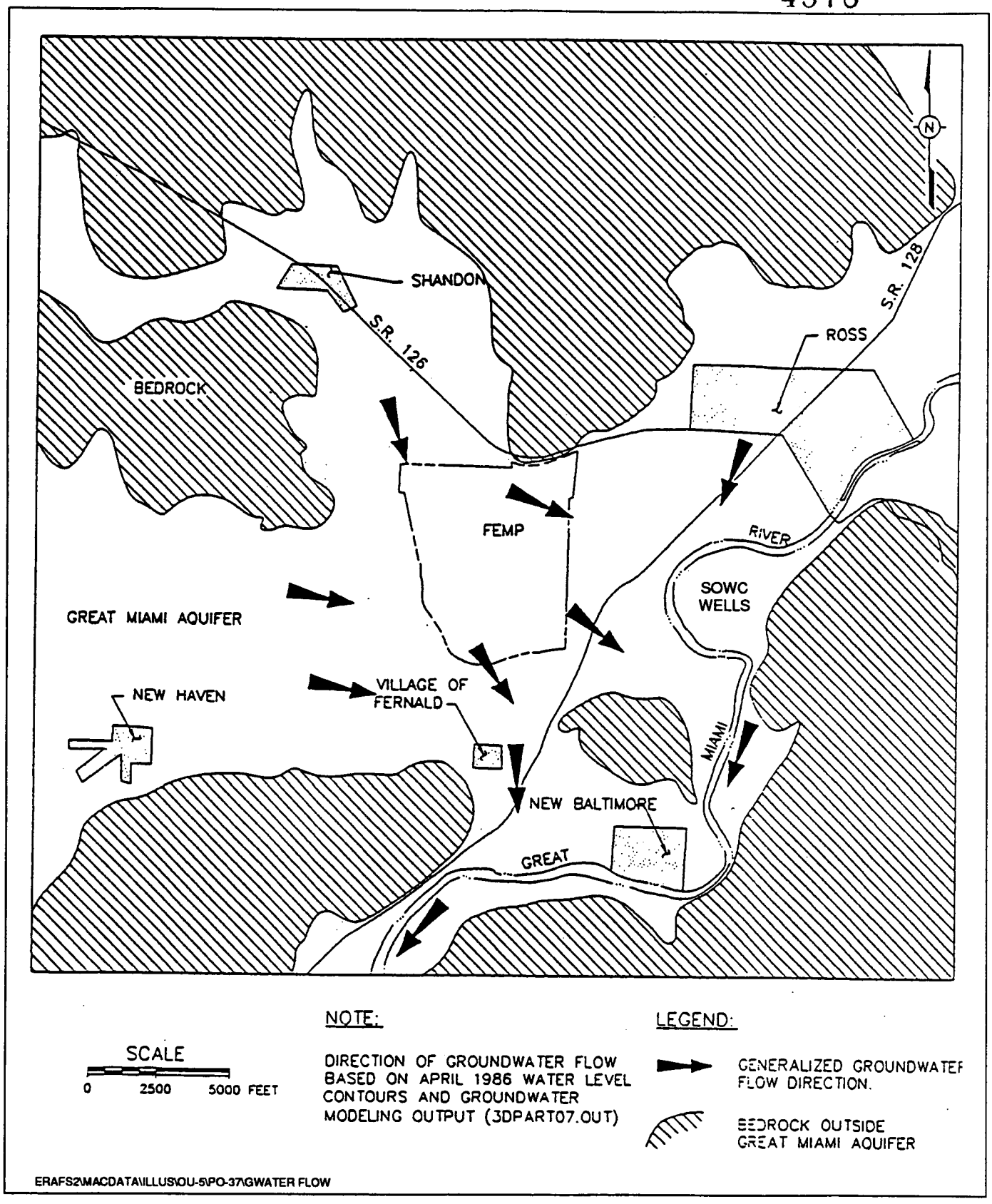

Figure 2-3 - Generalized Groundwater Flow in the Buried Channel Aquifer

2.2 Groundwater Flow and Transport Code Selection and Verification

The code selection, code verification, and summary of the development of the present groundwater flow and transport model are presented in three separate reports (IT 1988, IT 1990, DOE 1993b). The selection of the code was based on the following requirements:

1) Three-dimensional code capability
2) Contaminant transport capability
3) Adequate verification of the code
4) Code availability
5) Ability to model water table conditions
6) Ability to model decay chains
7) Ability to model adsorption and decay
8) Option to consider density and viscosity variations
9) Convenience of model application

The Sandia Waste Isolation Flow and Transport (SWIFT) code was selected as meeting these requirements. The selected computer program was originally SWIFT III Version 2.25 (UNIX based) and later it was updated to SWIFT/386 Version 2.52 (PC/DOS based).

To supplement earlier studies and to meet International Technology Corporation's (IT's) internal procedures, a comprehensive verification study of the SWIFT III code was completed and a report issued (IT 1990). This study compared the results of SWIFT III test simulations with MODFLOW (MacDonald and Harbaugh 1984) and GEOFLOW (IT 1986). This study was coordinated with a parallel study completed by GeoTrans. Tables 2-1 and 2-2 summarize the test problems used for flow and solute transport verification by both IT and GeoTrans during this process.

2.3 Groundwater Model Construction and Calibration

The construction and calibration of the present groundwater flow and transport model over the last 5 years are described in two documents (DOE 1993b and IT 1988). The construction and calibration of SWIFT have involved:

1) Construction of the present FEMP groundwater flow and transport model
2) Calibration of the present flow model
3) Calibration of the present solute transport model
4) Simulations of a uranium plume

2.3.1 Construction of the Present FEMP Groundwater Flow and Transport Model

The present groundwater flow and transport model uses the SWIFT/386 Veston 2.52 code. It is a three-dimensional, finite difference computer model. Steps in the development of the present model have included (DOE 1993b):

1) Construction and calibration of a **regional**, two-dimensional, steady-state, groundwater flow model

2) Construction and calibration of a **regional**, three-dimensional, steady-state, groundwater flow model

3) Application of two-dimensional analytical solute transport models to help strategize the numerical solute transport model

4) Construction of a **local**, two-dimensional, transient solute transport model

5) Construction and calibration of a **local**, three-dimensional, transient solute transport model with uranium concentration data from the monitoring wells

A regional flow model covering a defined area of 25,000 by 32,000 feet (Figure 2-4) included boundaries defined by regional flow patterns. The three-dimensional regional flow model consists of a 44 by 51 by 5 layer uneven grid with block sizes varying from 2,000 feet square to 250 feet square. Smaller mesh intervals were defined at locations where there was a large hydraulic gradient (for example at the SOWC water wells).

A local solute transport model was created within the regional grid to provide increased resolution within the site boundaries and areas of identified plumes. The local model, consisting of a 78 by 102 grid, covers an area of 9,750 by 12,750 feet, with constant model cells 125 feet on a side (Figure 2-5). The grid size resulted from the stability constraints imposed by using a uranium dispersivity of 100 feet. A literature review (DOE 1993b) determined this dispersivity. The grid was sized to accommodate dispersivities as low as 62.5 feet, or half the distance of the local area grid size of 125 feet. The interrelationship between the **local** and **regional** models was established by importing head values into the boundary cells (as a constant head boundary) of the local model predicted by the regional model. Thus, transient solute transport was superimposed on steady state flow model conditions.

Table 2-1 - SWIFT Code Groundwater Flow Verification

	GEOTRANS			IT		
Problem Type	**Analytical Solutions**	**Numerical Solutions**	**Field Comparison**	**Analytical Solutions**	**Numerical Solutions**	**Field Comparison**
Two Dimensional	1) Fully penetrating well, constant discharge, homogeneous isotropic confined aquifer, cartesian coordinates 2) Fully penetrating well, constant drawdown, homogeneous isotropic aquifer, confined radial coordinates 3) Fully penetrating well, horizontal anisotropic confined aquifer, cartesian coordinates 4) Fully penetrating well, leaky homogeneous isotropic confined aquifer, radial coordinates	Not documented in the available user manuals of verification reports	1) Hydraulic testing for thermal energy storage in an aquifer to compare: - pressure solutions - Anisotropic aquifer characteristics - Injection and observation well responses - Flow from aquitards - Effects of aquifer boundaries	GWF-1 1) Fully penetrating well, constant discharge, homogeneous isotropic confined aquifer, cartesian coordinates GWF-2 2) Fully penetrating well, constant discharge, anisotropic confined aquifer, cartesian coordinates GWF-3 3) Dupuit-Forchheimer steady state problem - to simulate flow from a free-water surface GWF-4 4) Boussinesq transient drawdown	GWF-5 1) Comparison of actual site data with GEOFLOW and MODFLOW codes for flow in an unconfined aquifer with irregular boundaries and steady-state flow	Not necessary
Three Dimensional	Not documented in the available user manuals or verification reports	Not documented in the available user manuals or verification reports	Not documented in the available user manuals or verification reports	Not necessary	GWF-6a, 6b, 6c, 6d 1) Comparison of SWIFT III results with results from MODFLOW and PTC codes	Calibration of site-specific model to field data

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Table 2-2 - SWIFT Code Solute Transport Verification

	GEOTRANS			IT		
Problem Type	**Analytical**	**Numerical**	**Field**	**Analytical**	**Numerical**	**Field**
One Dimensional	1) Transport with chain decay and equal retardation in an isotropic homogeneous aquifer, cartesian coordinates 2) Transport with chain decay and unequal retardation in an isotropic homogeneous aquifer, cartesian coordinates	Not documented in the available user manuals or verification reports	Not documented in the available user manuals or verification reports	ST-1 1) Transport with chain decay and equal retardation in an isotropic homogeneous aquifer, cartesian coordinates	Not necessary	Not necessary
Two Dimensional	Not documented in the available user manuals or verification reports	Not documented in the available user manuals or verification reports	1) Contaminant migration from a landfill to test code for: - solute convection and hydrodynamic dispersion - steady state velocity - time and space dependent contaminant source terms - aquifer influence functions	ST-2a, 2b 1) Transient transport in unidirectional flow field between two impervious boundaries Note: STRIP1B-FBC-G used for analytical solution	ST-2a, 2b 1) Transient transport in unidirectional flow field between two impervious boundaries Note: GEOFLOW used for numerical solution comparison	1) Calibration of site-specific model with field data
Three Dimensional	Not documented in the available user manuals or verification reports	Not documented in the available user manuals or verification reports	Not documented in the available user manuals or verification reports	Not necessary	ST-3a, 3b 1) 3-D solute transport for: - Anisotropic unconfined aquifer - flux boundary condition - Variable hydraulic conductivity - FMPC grid dimensions - numerical stability criteria	1) Calibration of site-specific model with field data

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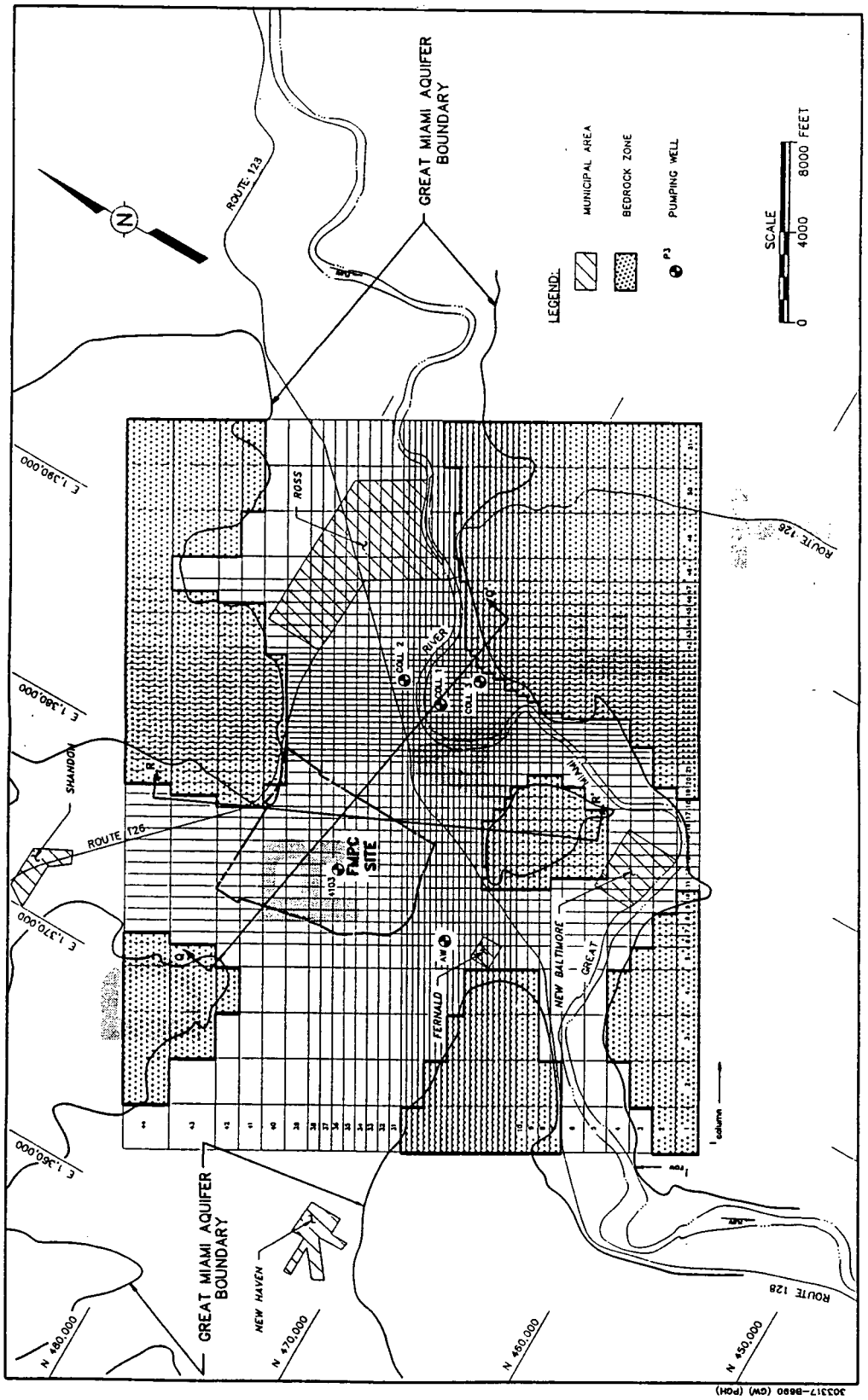

Figure 2-4 - SWIFT Flow Model Grid for RI/FS Model Area

The three-dimensional regional and local models contain five layers. The uppermost two layers represent the upper and lower parts of the upper buried valley aquifer that underlies the area. The middle layer represents a clay interbed that is present in the immediate vicinity of the FEMP site, and the lowermost two layers represent the upper and lower parts of the lower buried valley aquifer. Where the clay interbed is not present, the middle layer is assigned the same characteristics as the uppermost two layers. All of the layers extend laterally into bedrock at the edges of the buried valley.

Pumping wells are located in the area spanned by both the local and regional models. These include the SOWC wells (regional model only), FEMP production wells, and three industrial wells located south of the FEMP site. Pumping from each of these wells was assigned at historically determined rates to the proper cell and layer in the model.

2.3.2 Calibration of the Present Groundwater Flow Model

The calibration of the present groundwater flow model was performed by comparing hydraulic heads calculated by the model against heads measured in monitoring wells throughout the area (DOE 1993b). An initial flow calibration was performed using the **regional** flow model. A **local** flow recalibration (see DOE 1993b, Section 6.3.2) was performed for the modeling of local solute transport. Estimates of hydraulic conductivity and recharge were initially input to the model and then varied within a previously established range (IT 1988) to adjust model-computed heads to agree with observed monitoring well heads. The monitoring well heads used for calibration were measured in the Spring of 1986.

Groundwater flow conditions simulated by the model reproduced the observed flow conditions throughout the study area within the established criteria. Based on water levels from 55 wells, the arithmetic mean residual (observed head minus calculated head at the monitoring well) for the calibrated flow model was 0.21 feet. The mean of the absolute values of the residuals was 1.08 feet. The resulting potentiometric surface from the local model is shown in Figure 2-6.

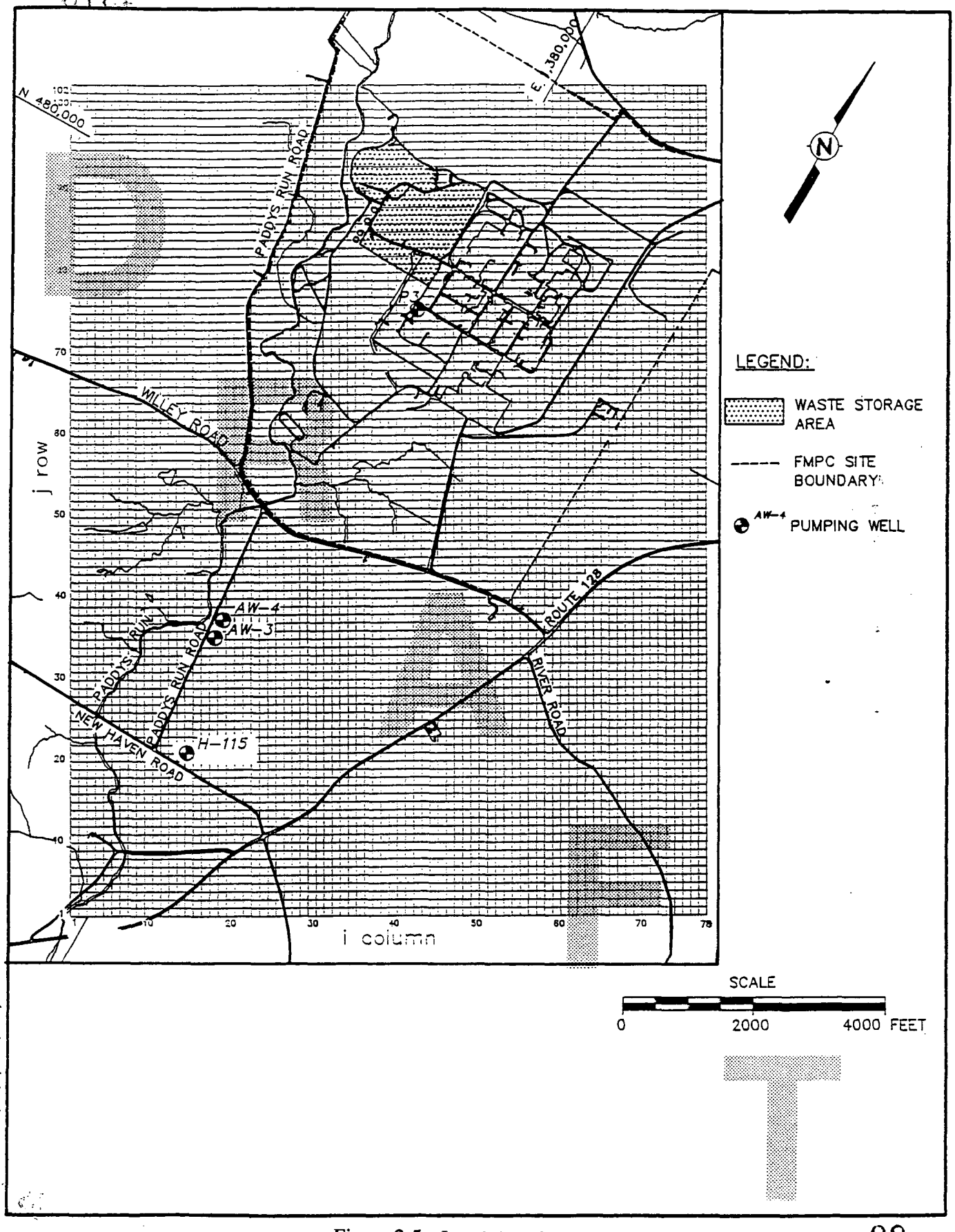

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Figure 2-5 - Local Area Model Grid

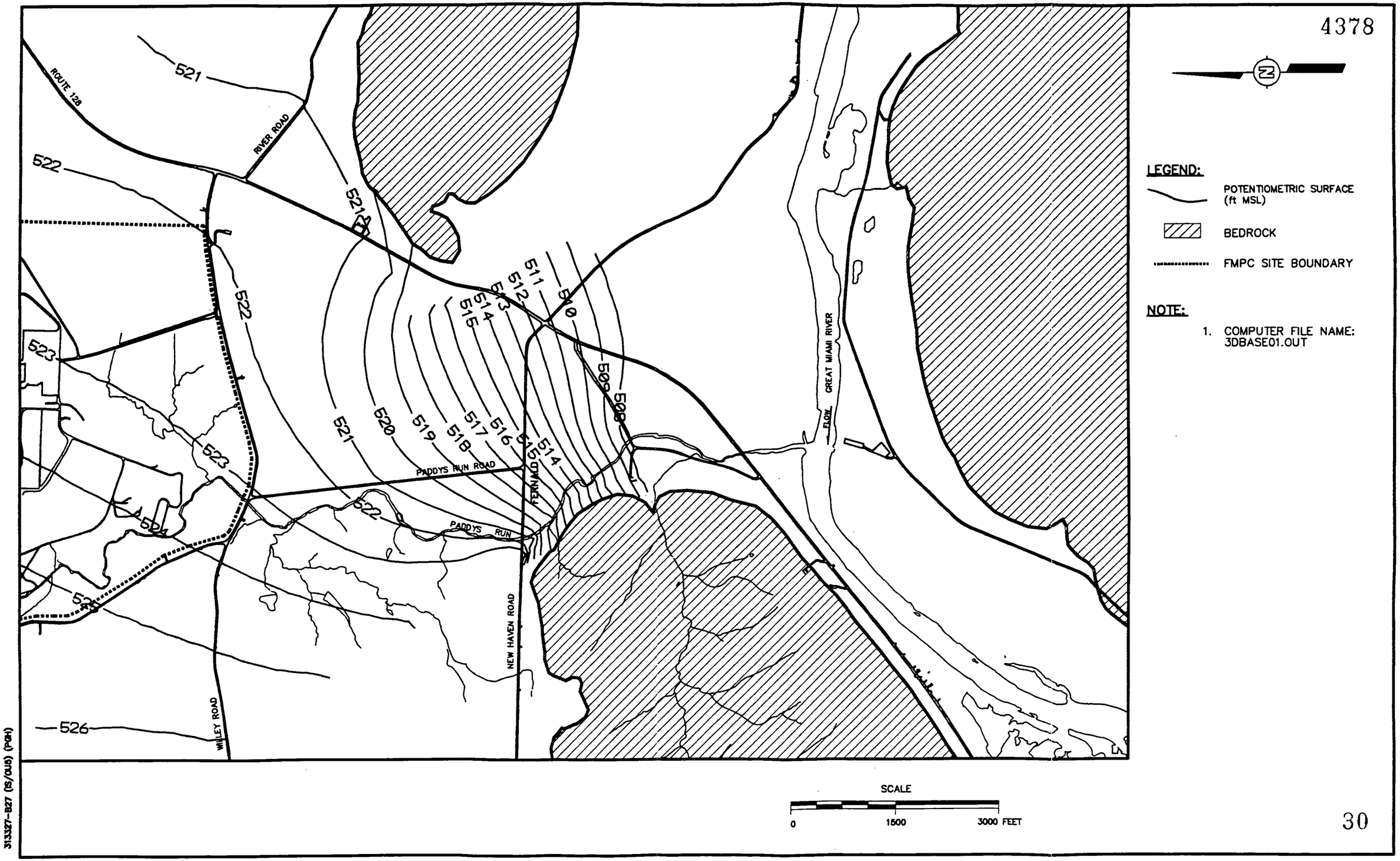

Figure 2-6 - Model Predicted Potentiometric Surface

2.3.3 Calibration of the Present Solute Transport Groundwater Model

The calibration of the present solute transport groundwater model (DOE 1993b) involved the following steps:

1) Designating appropriate cells as source cells where uranium may enter the groundwater system based on the current understanding of historic patterns of uranium release

2) Dividing the model time into source loading periods corresponding to historic records of intervals during which source loading was probably significantly different from other periods

3) Introducing reasonable initial estimates of uranium source loading, based on historical records, for each source cell

4) Establishing initial estimates of longitudinal and transverse dispersivity, as well as a distribution coefficient for uranium

5) Adjusting source loading, source loading periods, dispersivities, and the distribution coefficient until concentrations calculated by the model are close to concentrations measured in the field

The DOE (DOE 1993b) attempted calibrations with distribution coefficients corresponding to retardation factors of 1, 6, and 9. However, based on results of geochemical studies (DOE 1993b, Appendix A) and the goals of the solute transport calibrations, a retardation factor of 12 was selected as the most representative. Thus, the distribution coefficient was set at 0.022 cubic feet per pound, which corresponds to a retardation factor of 12. The constraint was to keep the dispersivities as close to 100 feet as possible and to keep the distribution coefficient as low as possible. The preference for a dispersivity of 100 feet was based on estimates by Anderson (Anderson 1984, 1989) and Borg et al. (Borg et al. 1976). Similarly, the geochemical investigation (DOE 1993b, Appendix A) found that the uranium occurs in complexes which have neutral or negative charges; such charges imply low retardation, hence the desire to keep the distribution coefficient low. The geochemical investigation included site-specific investigations using analytical data and geochemical speciation models.

Because the plume is narrow and has high concentration gradients away from the center, the concentration patterns could be matched by having either a sufficiently high retardation factor or a sufficiently low dispersivity. Calibration with a retardation factor of 12 yielded the preferred longitudinal dispersivity of 100 feet and transverse dispersivity of 10 feet. The model uses transverse dispersivity for vertical dispersivity, so the calibrated transverse dispersivity tends to be low.

The objective of the calibration was to produce a representative simulated plume. Statistical analyses that checked the calibration compared predictions against monitoring data from wells that yielded detectable

uranium in all samples. The calibration compared predicted concentrations against mean concentrations measured at the individual wells. Quarterly sampling involving multiple rounds provided the monitoring well data. Each well had a variable number of sampling rounds with most having four or five rounds. The majority of these wells used data from the 1988 and 1989 Resource Conservation and Recovery Act (RCRA) sampling rounds collected over a 2-year period. The calibration aimed at reducing the difference between the calculated uranium concentration and the measured mean concentration at each well. As many calculated concentrations as possible were brought within the 95 percent confidence interval of the mean (as determined at each target monitoring well).

With data collected up to April 1990, the calibration (DOE 1993b, Subsection 6.3.3.2) brought most of the calculated concentrations in Layer 1 into range (the 95-confidence interval). Only the concentration at Well 2061 and the concentrations at a few wells upgradient from known sources, upgradient of Paddy's Run, and south of the FEMP fell outside the range. Several concentrations at wells screened in lower layers also could not be brought into range.

2.3.4 Simulated Plume

The DOE (DOE 1993a) has used the present groundwater flow and transport model to simulate uranium concentrations for 1989. The calibrated solute transport model simulated a uranium plume centered approximately 500 feet south of the FEMP with a peak concentration above 400 μg/l in model layer 1 (Figure 2-7). The model shows that the majority of contamination is located within the upper half of the Great Miami Aquifer, with most of the uranium residing in the upper three model layers. The plume's 10 μg/l boundary extends from the FEMP's production area in the north to New Haven Road in the south and from just west of Paddy's Run to approximately 1,500 feet east of Paddy's Run Road.

2.4 Model Applications to Date

The present FEMP groundwater flow and transport model has been used to date to support several removal actions and RI/FS activities. These applications are summarized in the following subsections.

2.4.1 South Plume Removal Action

Because of the migration of a uranium plume off site, the DOE (DOE 1990a and DOE 1993a) initiated a removal action. This plume is termed the "South Plume" because the principal direction of expansion has been to the south.

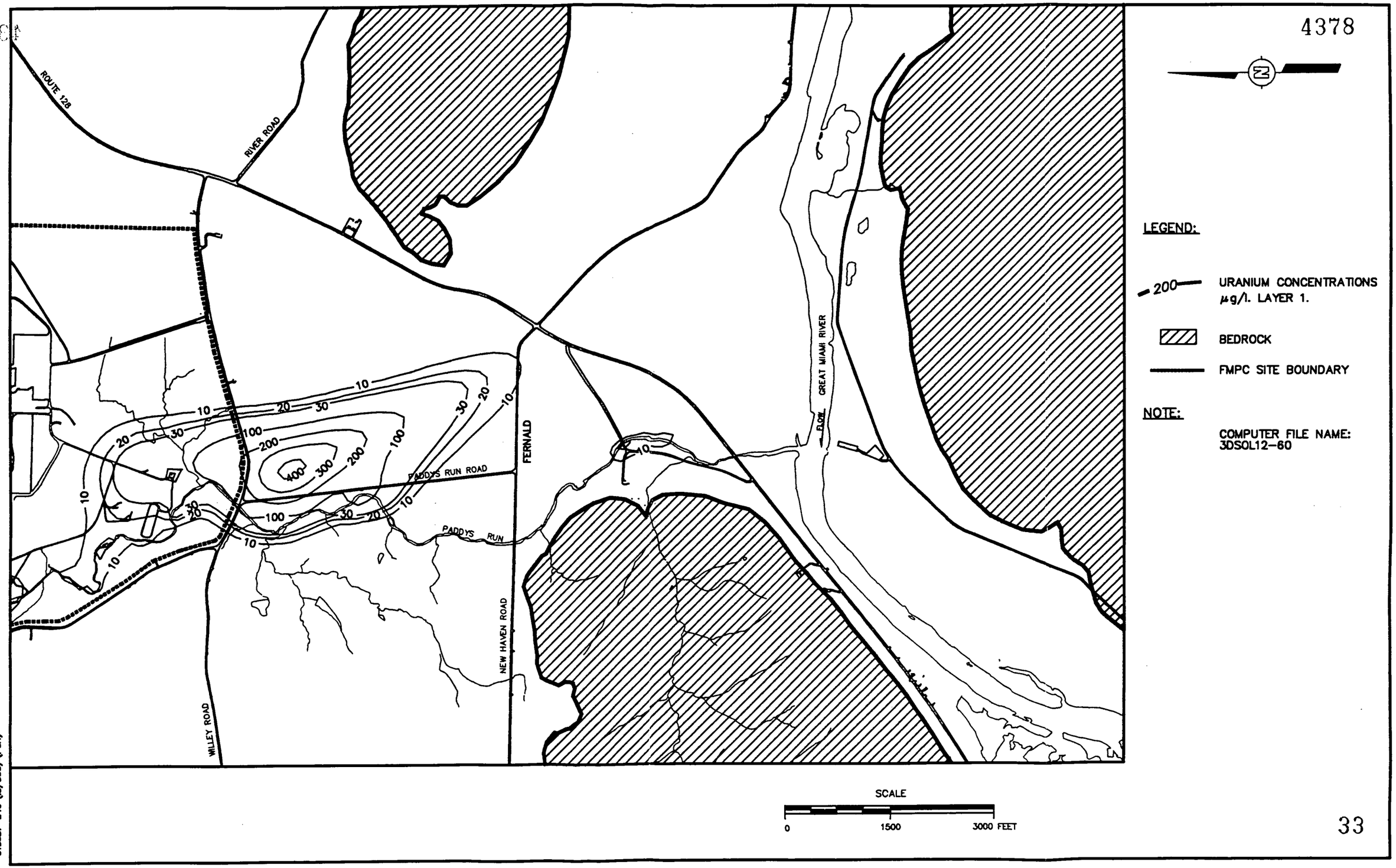

Figure 2-7 - Model Predicted Layer 1 Uranium Plume for 1989

South Plume EE/CA

The DOE (DOE 1990a) submitted the South Plume Engineering Evaluation/Cost Analysis (EE/CA) in May 1990. After the public comment process and resolution between the US EPA and the DOE, it was finalized in November 1990. A groundwater modeling investigation was undertaken in 1990 to determine number, placement, and pumping rates of interceptor wells for the South Plume EE/CA. The modeling work used an interim calibration of the solute transport model which used a retardation factor of 9 to simulate the uranium plume.

The South Plume EE/CA groundwater modeling tested several possible scenarios for dealing with uranium-contaminated groundwater. These included a no-action alternative, an alternative water supply alternative, and a pumping alternative with a goal of plume interception. The South Plume EE/CA selected an alternative which included groundwater pumping and discharge, an alternative water supply for two industrial users, installation of an interim advanced wastewater treatment system, and enhanced monitoring and institutional controls. The original location of recovery wells, based on groundwater modeling simulation (DOE 1990a), was along New Haven Road just west of its intersection with State Route 128.

South Plume Modeling Report

Subsequent to finalizing the EE/CA, information obtained from a separate RI performed by another site (the Paddy's Run Road Site [PRRS]), identified additional concerns in the South Plume area. The PRRS contaminants extended near the original location of the proposed recovery well field along New Haven Road. As a result of these conditions, it was necessary to relocate the well field to an area north of the PRRS. Additional groundwater modeling to support preliminary design efforts at the revised location was also identified as a task. This requirement formed the basis of the South Plume Modeling Report (DOE 1993a).

The South Plume Modeling Report was used to set the initial design parameters of the recovery wells at the revised locations and to establish an acceptable hydraulic conductivity range for use of the model through the use of sensitivity analysis.

Design, Monitoring, and Evaluation Program Plan

The Design, Monitoring, and Evaluation Program Plan (DMEPP) was developed pursuant to the requirements of the South Plume Removal Action - Part 2 and 3 Work Plan (WEMCO 1992a). This program plan defined a program of design confirmation, monitoring, and system evaluation activities associated with the South Plume groundwater recovery system. Because of the dependencies of the design and operation of the recovery system on the model, the DMEPP includes a pump test on one of the recovery wells. The results of this pump test will be used for model recalibration and refinement. The

DMEPP also includes a periodic performance evaluation on the model to evaluate the adequacy of the model and to make necessary changes to the model based on these evaluations on a continuing basis. Figure 2-8 shows a flow chart of the DMEPP activities.

2.4.2 RI/FS Fate and Transport Modeling

An important application of the present FEMP flow and transport groundwater model has been to support the risk assessment process in the RI/FS. The RI Report for each CRU contains a baseline risk assessment while the FS for each CRU contains risk assessments for each remedial alternative. In addition, an FS Comprehensive Response Action Risk Evaluation (CRARE) will be included in the FS report for each CRU. The CRARE will address the cumulative impacts of selected (or leading) operable unit remedial alternatives for the whole site. The CRARE will be originally developed for the first scheduled CRU FS with subsequent revisions for the remaining CRUs.

2.5 Comparison of IT Work Plan Requirements with Present Model

The Groundwater Flow/Solute Transport Modeling Work Plan (IT Work Plan) submitted by IT in June 1988 defines the program for the development of the present FEMP groundwater flow and solute transport models to support the ongoing, sitewide RI/FS for the FEMP site. The IT work plan consists of eight sections:

1) Introduction
2) Background
3) Model Code Verification
4) Model Data Base
5) Model Development
6) Model Application
7) Report Preparation
8) Schedule

The IT Work Plan defines the progressive development, calibration, and application of a flow and solute transport model. Several activities (such as preliminary model development, RI field sampling, code verification, geochemical study) are conducted in parallel and subsequently linked after completion. The overall model development process presented in this work plan is shown in Figure 2-9. This figure shows a multi-phase process to design, assess the accuracy, and to apply the flow and solute transport models consisting of the following steps:

1) Historical regional and site data, as well as modeling studies conducted by IT (IT 1987) and GeoTrans (GeoTrans 1985), were used to build a preliminary flow model.

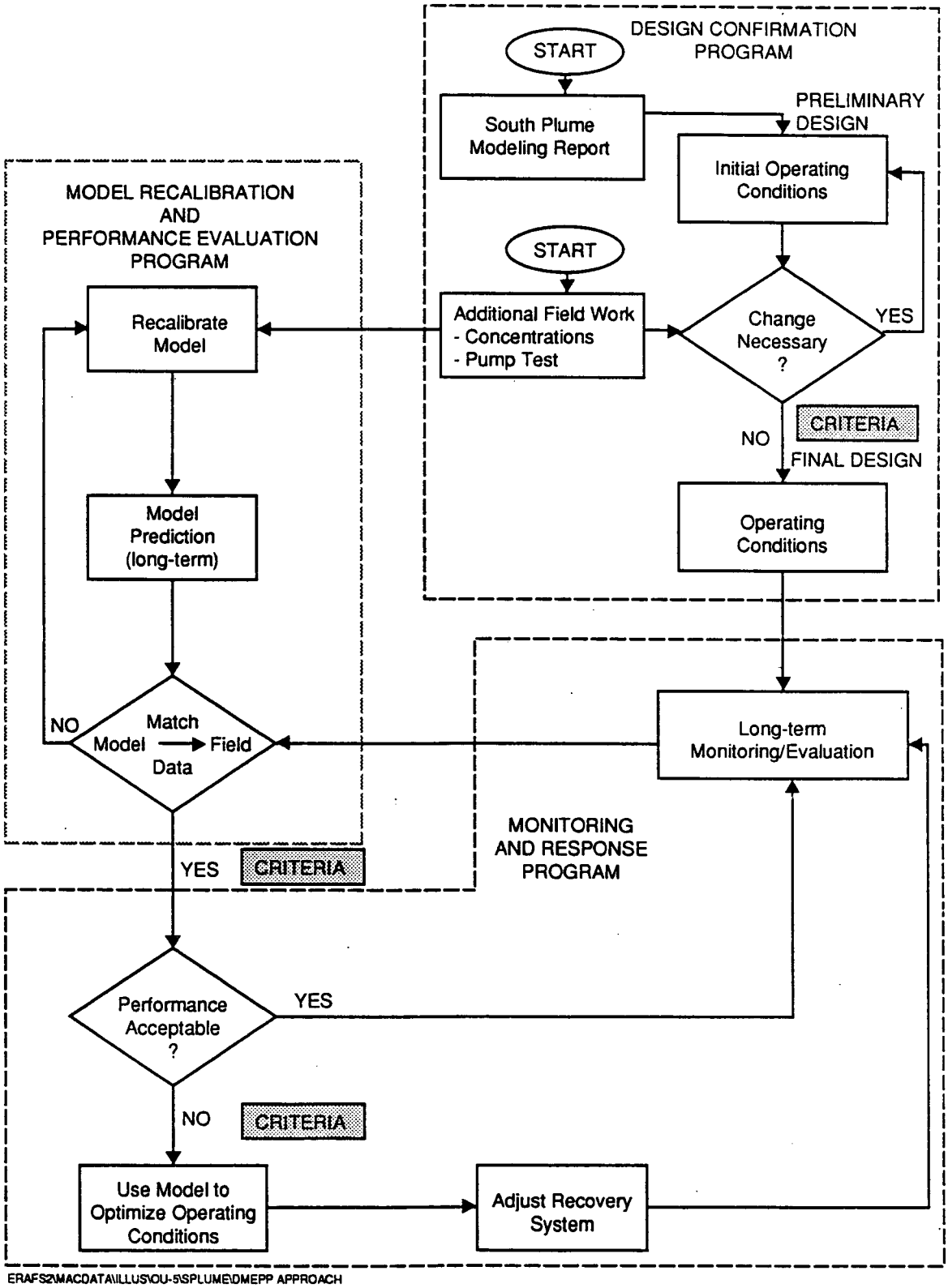

Figure 2-8 - Design, Monitoring, Evaluation Program Plan Flow Chart

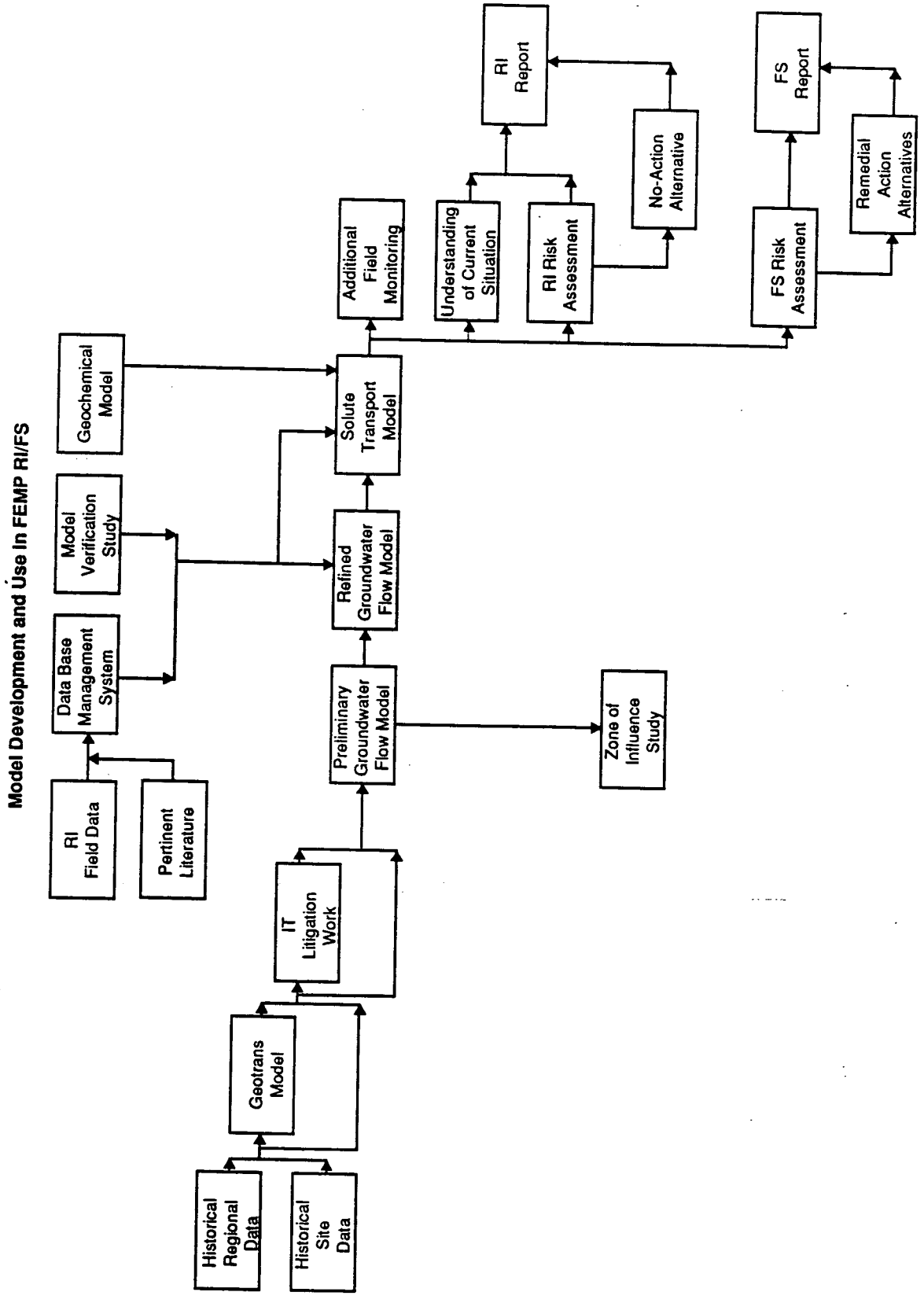

Figure 2-9 - Model Development and Use in FEMP RI/FS (Adapted from IT [IT 1988])

2) A refined flow model was created based on the preliminary model, additional RI and literature field data, and the model verification study.

3) A solute transport model was built using the same data sets and the results of a separate geochemical modeling effort.

4) The built models were used for defining additional field monitoring, preparing the RI Report (understanding current situation and performing the RI risk assessment), and the FS risk assessment.

Figure 2-10 shows the model development process, as defined in the IT Work Plan, in more detail. First, the two-dimensional flow model was to be built, refined, and calibrated. Next, the one-dimensional (analytical) and two-dimensional solute transport models were to be developed in parallel with the three-dimensional flow model. Finally, the three-dimensional numerical solute transport model was to be constructed and calibrated.

The following subsections summarize the major modeling program elements described in the IT Work Plan. Following these summaries, the proposed program is compared to the program that was actually implemented. Please refer to the original work plan (IT 1988) for a more detailed description of each of these elements.

2.5.1 Code Selection and Verification

IT selected SWIFT III to execute the numerical modeling during an earlier model code selection study. Four codes were found--SWIFT III, GEOFLOW, SWENT, and PTC--which met the criteria (see Subsection 2.2). SWIFT III was chosen from the four model codes based on the established selection criteria. At the time of model selection, no verification study of SWIFT III had been documented. A verification study was therefore proposed and implemented by IT (IT 1990). This verification involved creating site-relevant problem sets which could be solved by both SWIFT III and other numerical codes and analytical solutions. At the time of preparation of the IT Work Plan, only one- and two-dimensional comparisons had been accomplished. Additional verification simulations for the two-dimensional solute transport model and three-dimensional flow and transport model comparisons were described in the work plan. In addition, the IT Work Plan defined an approach, QA requirements, and a report format for the rest of the verification.

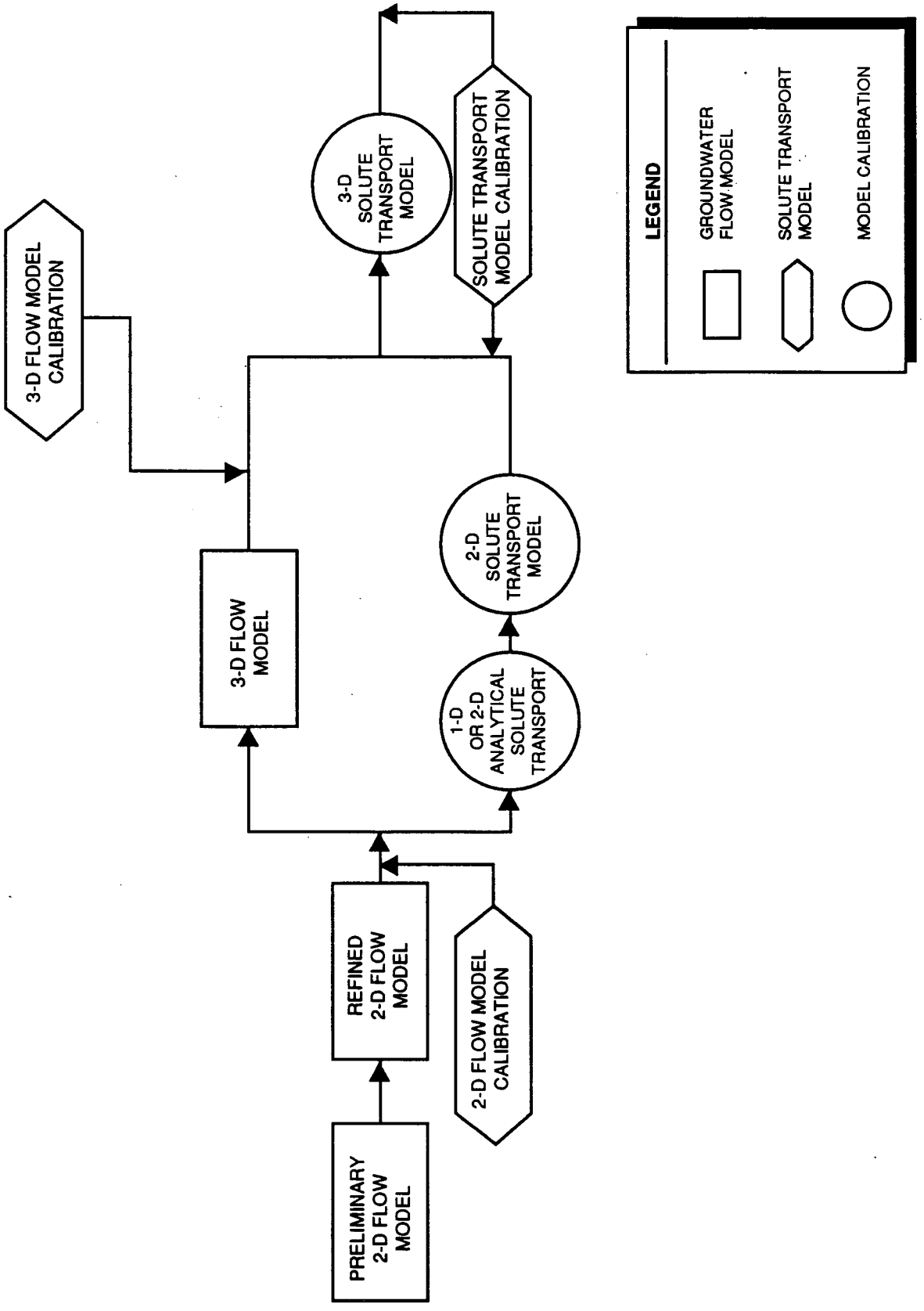

Figure 2-10 - Model Development of IT's Work Plan (June 1988)

2.5.2 Groundwater Flow Model

Table 2-3 lists the criteria in the IT Work Plan defined for judging the acceptability of a calibration run in the modeling effort. The absolute difference between computed and observed groundwater levels, as well as the standard deviation of the difference, were defined as measures of model performance. Two other tests of model performance were prescribed. The first was to evaluate the model results in the immediate vicinity of the major pumping wells. A second test of model performance was a consistency of flow rates and directions throughout the model area in comparison with observed and postulated conditions. A sensitivity analysis was also planned for the two-dimensional model. The two-dimensional sensitivity was to be carried out as a series of model runs, each representing a variation from the calibrated flow model resulting from a change in either a single parameter or a simplified combination of parameters.

The development of a three-dimensional model was prescribed which would account for the vertical gradients induced by pumping action, the vertical variability of important hydraulic properties or stratigraphy, and the effects of the partially penetrating wells that pump from depth. The same types of input data required by the two-dimensional model were also to be used by the three-dimensional model. According to the IT Work Plan, the calibration of the three-dimensional model is very similar to the two-dimensional calibration process; and only the hydraulic conductivity in the principal aquifer layers, the river leakage rate, and the pumping rate of the SOWC wells were to be varied.

2.5.3 Solute Transport Model

The IT Work Plan required the preparation of both one- and two-dimensional analytical models to evaluate the effects of flow rate, retardation, and dispersion on contaminant migration. Two representative chemical and radiological constituents are defined for the solute transport model. Only uranium and a soluble tracer were considered in this work plan.

The IT Work Plan required that the location and loading rates of each source be established in conjunction with an independent geochemical program (DOE 1989). The effective porosity and the longitudinal and transverse dispersivity were to be taken from published literature for similar hydrogeologic settings and aquifer material. However, each factor would be varied during the course of model calibration. The retardation factor would be initially established through a combination of field, laboratory, and geochemical modeling studies. The geochemical program would be used as a reference in estimation of the retardation factor.

The IT Work Plan also required that trend analysis be executed to establish a reasonable fit to observe uranium concentrations at critical receptor locations by adjusting source strengths, velocity vectors, retardation coefficients, and dispersivity within acceptable ranges of values.

Table 2-3 - Statistical Tests for Flow Model Calibration as Modified from DOE (DOE 1993b, Tables 5-2 and 5-6)

Statistical Measure	Predetermined Criteria	2-D Flow 1986 (2DFLOW)	3-D Flow 1986 (3DFLOW)
Mean of the Absolute Residuals (ft)	±0.5	0.083	0.326
Standard Deviation of Differences (ft)	≤ 2	1.080	1.083
Standard Deviation of Differences (ft)	≤ 3	0.20	1.365
Regression Coefficient Between Measured and Computed Values	1±0.05	1.02	0.937
Nearest Neighbor Autocorrelation Unit Normal Deviate	< 1.645	0.636	0.673

Two-Dimensional Solute Transport Model

According to the IT Work Plan, a two-dimensional SWIFT III solute transport model was to be based on the analytical modeling study. The initial steps in developing a two-dimensional solute transport model were the selection of an appropriate grid system and the assignment of meaningful boundary conditions. A smaller grid was to be established for the solute transport model to enhance computational efficiency. The numerical model would use the same input parameters as the analytical model. The main goal for the two-dimensional solute model was to obtain horizontal distribution patterns. Isoconcentration maps for uranium in groundwater would be developed based on the May 1988 sampling program to compare with model predictions.

Model calibration and sensitivity analysis were the two primary work objectives according to the IT Work Plan. The model calibration process would be initiated by the application of the two-dimensional solute transport model to predict the concentration pattern resulting from a hypothetical release of a unit mass of material from a given source. The predicted concentrations at key monitoring points would be compared to observed concentrations at the same locations to estimate the actual mass that would have had to be released to cause the observed condition. A range of model parameters would be used to establish a probable range of source conditions; and this range of source conditions would be compared to the actual mass of the release, as estimated from the geochemistry program, to evaluate the source-pathway-receptor relationship.

The two-dimensional sensitivity analysis would be limited to the key parameters, including the longitudinal and transverse dispersivities, the retardation factors, and the source strength leading to the use of the three-dimensional solute transport model.

Three-Dimensional Solute Transport Model

The IT Work Plan defined the vertical layers to be used in the three-dimensional solute transport model as identical to those used in the three-dimensional flow model. Boundary conditions along vertical boundaries would be the same as those used in the three-dimensional model with appropriate adjustments to account for the vertical layering. The source terms from the till would be assigned to the upper layer rather than distributed vertically. The three-dimensional solute transport model would be run as a transient case using steady state flow conditions, and the latter would be provided from the three-dimensional flow model.

According to the IT Work Plan, essentially the same input data as for the two-dimensional solute transport model would be used, including the best-fit parameter values established in the model calibration. Distinct parameter values would be assigned to vertically layered cells, and an additional parameter (vertical dispersivity) would be introduced to account for vertical dispersion. Literature values would be used as the initial values of the vertical dispersivity.

The IT Work Plan proposed that the calibration of the three-dimensional solute transport model would rely on the results of the two-dimensional model calibration. One additional criterion for acceptance would be the degree to which the model results reproduce observed vertical concentration profiles in addition to the horizontal concentration patterns. The vertical dispersivity and the geochemical properties of any interbeds would be the two principal fitting parameters.

The effect of parameter uncertainty would be the principal target of the sensitivity analyses. The interbed properties would be the focus of the sensitivity analysis using the three-dimensional solute transport model. A check of the influence of source term and the interaction between the river and the aquifer on the model results would also be made.

2.5.4 Model Application

The IT Work Plan defined RI/FS direct applications of both the groundwater flow and solute transport models. Two general types of applications are discussed, namely evaluation of the current situation and support of risk assessments.

Evaluation of Current Situation

The IT Work Plan states that the two- and three-dimensional flow models would be used to develop statistically based groundwater elevation contours for the vertical layers of interest over the model area. Several uses are described for the flow model, including:

1) Rate and direction of flow
2) Water balance at major pumping wells
3) Interaction with Great Miami River
4) Area of influence of production well

Due to the high dependence of the model results on the ambient hydrologic system and any induced forcing functions, the plan describes the testing of a range of input parameter values, including:

1) Varying pumping rate (SOWC wells, Albright-Wilson well, and FEMP production well)
2) Varying river elevation (low flow condition, mean annual flow condition, and flood condition)
3) Varying recharge (Paddy's Run only and entire model area)

The analytical solute transport modeling (Geotrans 1987), along with numerical solute transport modeling, would be used to study the rate of migration and dispersion of radionuclides and chemicals away from the various sources. Based on the model results, isoconcentration profiles for selected times would be developed for various depths being monitored at the FEMP (2000-,3000-,4000-Series) well elevations. Plots of concentration versus time at selected locations were to be produced.

Support to Risk Assessment

Model applications to support the risk assessment are defined in the IT Work Plan, including:

1) Evaluation of the significant pathways associated with past and current releases.

2) Augmentation of the existing data base by filling in the gaps between the single point observations.

3) Locations of maximum concentration, possibly resulting from the integration of the contributions from multiple sources, as well as the approximate extent of any contaminant plume.

4) The groundwater flow and solute transport model will be used to predict whether concentrations in groundwater at critical receptors will increase and whether other receptors will be impacted to a significant extent.

5) Evaluation of the technical feasibility of remedial actions.

6) Full application of the solute transport model and prediction of the future conditions with various remedial action alternatives.

2.5.5 Comparison of IT Work Plan to the Implemented Groundwater Modeling Program

The modeling program has generally followed and fulfilled what was proposed in the IT Work Plan. Model code selection and verification and model development were performed. The model development proceeded in a similar manner as described in the work plan with the establishment of both two-dimensional and three-dimensional flow models. Development of analytical and numerical solute transport models were performed for two- and three-dimensional cases. Model calibration was performed for flow and solute transport models. Sensitivity analyses for flow models were completed and documented. However, sensitivity analysis for the solute transport model was presented for only the three-dimensional model.

For model application, site characterization was performed based on the calibrated groundwater flow and solute transport models. Key issues proposed in the IT Work Plan for flow model application were explored, including:

1) The evaluation of the rate and direction of the groundwater flow
2) Water balance at major pumping wells
3) Interaction with Great Miami river

4) Area of influence around the recovery well
5) Characterization of the current site flow field

Also, the pumping rate of the wells existing in the study area, the river elevation, and the recharge from Paddy's Run were varied to test the dependence of the model results on the ambient hydrologic system and any induced forcing functions. The solute transport model was also used to study the rate of migration and dispersion of radionuclides and chemicals away from the various sources. Analytical solutions, including ST1D and ODAST, were used to study contaminant movement in the vadose zones.

The solute transport model has been applied to date in many instances to evaluate the significant pathways associated with past and current releases in the support of risk assessment. Risk assessment activities are an ongoing focus of the program. The existing data were augmented to fill in the gaps between the single point observations. Model applications, such as defining the locations of maximum concentration resulting from multiple sources, as well as the approximate extent of any contaminant plume, are ongoing.

SECTION 3

REGULATORY MODELING CRITERIA

This section provides a summary of applicable federal and state regulations and guidance concerning the use of groundwater flow and contaminant transport models at the FEMP. This summary is based upon a more complete review of the regulations and guidance of the US EPA, the Ohio EPA, the DOE, and the United States Nuclear Regulatory Commission (NRC) which is presented in Appendix A. Appendix A has reviewed the federal and state laws, regulations, and guidance that apply to groundwater flow and transport modeling. Because each agency has focused on its own unique challenges, the review shows that no one agency has developed a comprehensive set of criteria.

Only the CERCLA and RCRA requirements are directly applicable to the FEMP remediation. The DOE and NRC regulations and guidance predominantly apply to siting and development of low level disposal facilities, not remediation. However, a discussion of these requirements is provided because they could constitute CERCLA Applicable or Relevant and Appropriate Requirements (ARARs) or To Be Considered (TBCs) for a particular FEMP project. Unless or until they are invoked for a project, they are not legally binding on the FEMP remediation program.

The modeling evaluation approach outlined in Section 4 will follow the criteria defined in this section.

3.1 Summary of US EPA Modeling Criteria

The current US EPA modeling guidance gives few details on model design requirements or quality assurance activities regarding model and data development, documentation, and maintenance. The US EPA guidance focuses mainly on model selection criteria. Despite incomplete guidance, the US EPA suggests the application of groundwater and transport modeling to analyze alternatives and to assess risk for CERCLA. As part of RCRA programs, the disposal facility design process may require modeling to show no effect on a drinking water source. The RCRA constituent of concern clause also suggests the need for geochemical modeling when naturally occurring or alternate sources are involved. Such modeling could help determine the source of a constituent and the potential for an exposure and health risk. The SDWA outlines criteria that consider the Time of Travel (TOT) of contaminants to a public water supply and attenuation of contaminants during transport. Given the need to assess risk, the rules ultimately require some assessment of uncertainty and overall model accuracy with regards to travel time and other performance measures.

3.2 Summary of Ohio EPA Modeling Criteria

The Ohio EPA has developed regulations and guidance to protect the state's interest in the CERCLA, RCRA, and SDWA processes. These regulations and guidance outline the presentation and demonstration of data accuracy, groundwater modeling, compliance with specific performance objectives, and risk assessment reports. The Ohio EPA emphasizes the need to show that one has enough data to evaluate alternatives and risk assessments. The Ohio EPA requires that calculations document, justify, and use inputs that yield the fastest possible TOT. The Ohio EPA defines the need for a well defined paper trail to support the calculations that assess the TOT and other performance objectives. Finally, the Ohio EPA suggests three main applications of groundwater modeling: to integrate and interpret site data as part of a Groundwater Quality Assurance Plan (GWQAP), to evaluate alternatives and assess risk for a RI/FS, and to assess compliance with performance objectives related to PWS wells.

3.3 Summary of DOE Modeling Criteria

DOE Order 5820.2A covers the management of all radioactive wastes and requires performance assessments as part of the low level waste (LLW) disposal facility design process. This Order indicates that models will be used to conduct the performance assessments. The Order also states that monitoring should be used to validate or modify the models used in performance assessments.

3.4 Summary of NRC Modeling Criteria

While not directly applicable to the FEMP, the NRC regulations and guidance supplement areas not discussed by the US EPA including more detailed requirements for model uncertainty analysis and modeling quality assurance. While these regulations and guidance do not apply to the FEMP as a matter of law, DOE Order 5820.2A implicitly draws upon much of the philosophy and direction of the NRC.

SECTION 4

EVALUATION OF THE PRESENT FEMP FLOW AND TRANSPORT GROUNDWATER MODEL

This section compares the present FEMP flow and solute transport groundwater models with the modeling criteria defined in Sections 2 and 3 and to US and Ohio EPA comments to define needed model improvement activities. This section first presents a summary of regulatory comments on the groundwater model to establish US EPA and Ohio EPA's concerns. The present FEMP groundwater flow and transport model is then evaluated in terms of the following elements of the modeling process (see Figure 4-1):

1) Model Design
2) Model Comparisons with Field Data
3) Model Uncertainty Analysis
4) Model Application

Figure 4-1 further categorizes these elements into subelements.

4.1 Regulatory Comments

Comments were received from the US EPA and the Ohio EPA on the CRU2 RI Report (DOE 1992b), the CRU5 Initial Screening of Alternatives Report (DOE 1992c), and the South Plume Removal Action Groundwater Modeling Report (DOE 1993a). The discussion below summarizes the comments on each report in terms of the above four elements of the design process.

4.1.1 CRU2 Remedial Investigation (RI) Report

Appendix B presents US and Ohio EPA comments related to the groundwater model on the CRU2 Remedial Investigation Report. The US and Ohio EPA comments on this report focus heavily on model design issues with some comments on model comparisons with field data, model uncertainty analysis, and model application. The comments on model design deal mainly with model construction issues such as mesh design, definition of source terms and boundary conditions, and use of correct model inputs. In particular, the Ohio EPA is concerned with the limited vertical discretization in the groundwater model and its averaging effect on leachate concentrations in the aquifer. The Ohio EPA also has noted that these mesh issues may also interact with the loading rates and how they are defined.

The US EPA has concerns about how geochemical processes may attenuate the transport of long-lived radionuclides. The US EPA also expresses concerns about the simulation of all the CRU2 waste areas

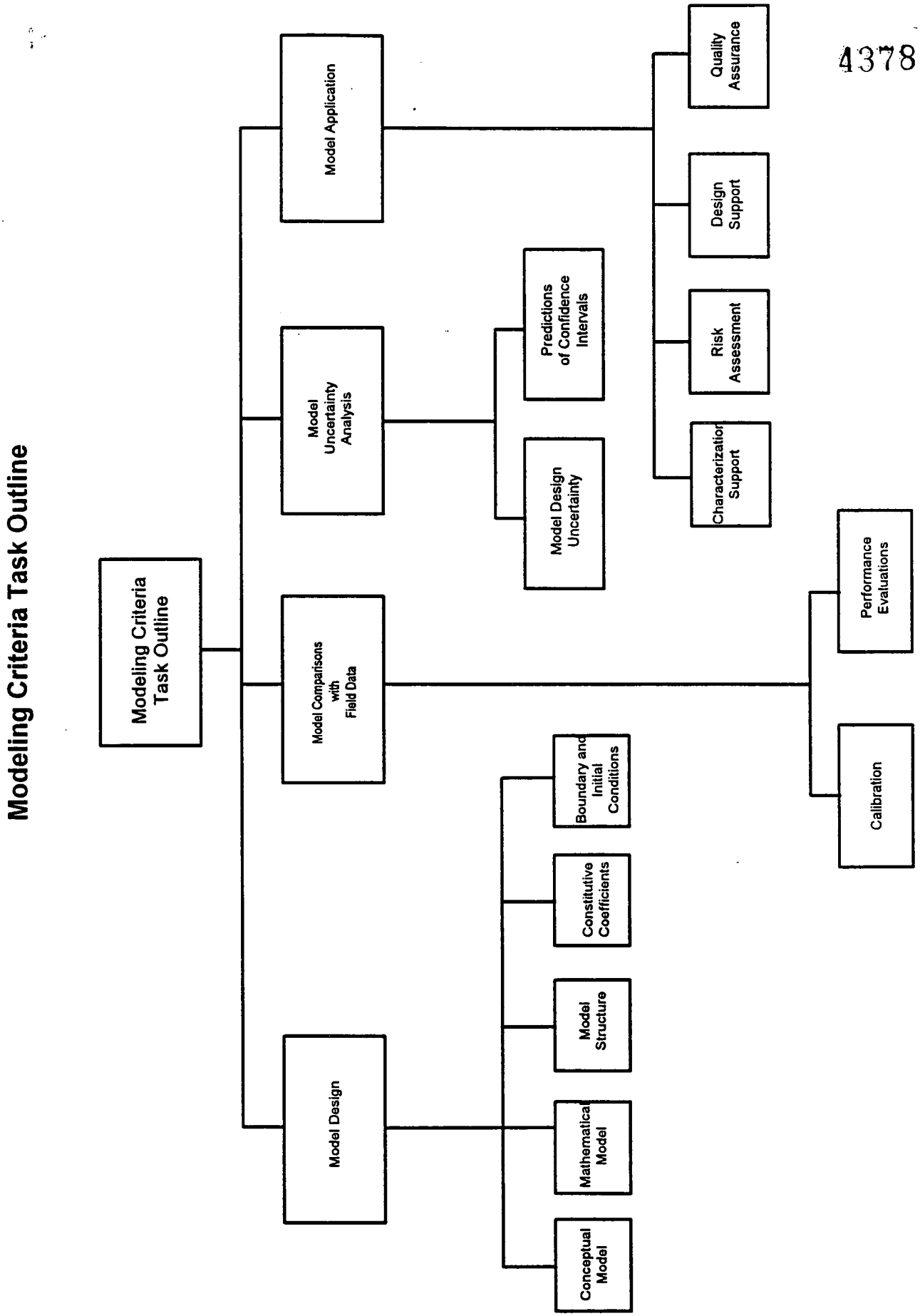

Figure 4-1 - Modeling Criteria Task Outline

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together as source terms. The Ohio EPA wants the DOE to discuss how it varied the calibration parameters, what determined an acceptable calibration, and what statistics it used for the local model in contrast to the regional model. The Ohio EPA requested that the statistical measures performed for the regional model also be developed for the local model.

The Ohio EPA also has a number of comments on issues related to model application. Their comments focus primarily on presentation concerns. The Ohio EPA wants to see specific figures that show uranium concentrations at different depths and contours for particular uranium isotopes. They also want figures to show groundwater flow directions at the time of different sampling events. Finally, the Ohio EPA wants the DOE to summarize the mass of nuclides in the unsaturated and saturated zone, both in the sorbed and dissolved fraction, and how much has actually decayed.

4.1.2 CRU5 Initial Screening of Alternatives Report

Appendix C presents two Ohio EPA's comments on the CRU5 Initial Screening of Alternatives Report. The Ohio EPA notes that it has not approved the FEMP site groundwater model, and consequently, conclusions are invalid and output from this model should not be used. The Ohio EPA states that the site model fails to predict the existing South Plume concentrations and/or flow conditions. However, Ohio EPA notes that DOE has outlined a plan to correct the identified problems with the model.

4.1.3 South Plume Removal Action Report

Appendix D gives the complete set of comments from and responses to the US and Ohio EPA on the South Plume Removal Action report. These comments deal directly with issues related to model design, comparison of predictions with field data, model uncertainty analysis, and model application.

Model design comments show concern for overly constrained representations of the hydraulic conductivity domain. Specifically, one comment discusses the lack of site-specific hydraulic conductivity data used in the model. The comments question the use of regional data instead of site specific data and its effect on how accurately the model predicts contaminant concentrations. Other comments note that this lack of data and uncertainty in the model has implications for the design of recovery well locations. One comment suggests that there is a need for contingency wells in case the deficiencies in model input data incorrectly predicts system performance.

Several Ohio EPA comments and one US EPA comment deal with issues involving comparisons of predictions with field data and model uncertainty. The US and the Ohio EPA are concerned about misplaced confidence that the model can accurately predict the effect of well pumping on chemical migration. Similarly, the US and Ohio EPAs believe that the DOE has overstated accuracy of particle tracking analysis. Comments also indicate that the DOE has misplaced confidence in the simulated plume near Paddy's Run where large residuals exist in uranium measurements. These comments show concern

for the effect of the assumed recharge distribution on predicted heads in layer 1. Given these limitations of the current model, these comments state that model results cannot replace good data. These comments also question the validity of averaging well concentrations over time for calibration of the model.

Several Ohio EPA comments and one US EPA comment deal with model application and presentation related issues. These comments show regulatory concern about difficulty in inspecting the simulated effects of currently proposed well field through comparison of predicted present plume and the 70-year predicted plume. These comments also suggest that a lack of detail on the predicted hydraulic head map restricts the interpretation of the simulated capture zone. These comments state the need for a no action (baseline) scenario map within the report to show the effects of various pumping scenarios on the PRRS plumes. The US EPA also cites a lack of sufficient documentation concerning calibration of the groundwater flow model.

4.1.4 Summary of Regulatory Comments

Overall, these comments show that the Ohio and US EPAs have many concerns about the accuracy and appropriate use of the site groundwater model. These comments have stated a need for additional vertical layers to conservatively estimate aquifer concentrations of contaminants. These comments suggest that site-specific data is needed to reduce the uncertainty of the flow and transport model. Comments also express concern about the calibration of the model. These comments suggest the need for better planning of the model applications and better presentation of results. Finally, concerns are expressed about misplaced confidence in the use of the model and the validity of using a model with recognized deficiencies.

4.2 Evaluation of Model Design

Model design includes definition of the conceptual model; formulation of the mathematical model; creation of a model structure; derivation of constitutive coefficients (hydraulic conductivity, storage coefficient, retardation, dispersivity, etc.); and definition of boundary and initial conditions (Figure 4-1). To define the conceptual model, sampling activities identify flow and transport processes, structural heterogeneities, and geochemical processes. The formulation of the mathematical model involves basically the selection of the governing equations and the computer code based on the conceptual model. To construct the model, one must simplify the site structure and associated hydrogeologic parameters. An analyst must develop constitutive coefficients, such as hydraulic conductivity, specific storage, and porosity; boundary conditions, such as aquifer geometry and piezometric (total) head, contaminant concentration, and mass flux along or across the aquifer boundary; and initial conditions, such as head and concentration distribution at a particular point in time. These inputs depend not only on how the true values from the real world are collected by the analyst, but also on the amount of aggregation or

averaging performed in the model formulation (e.g., the size of the grid elements) and the model structure.

The next five subsections evaluate the model in terms of the categories presented in Figure 4-1.

4.2.1 Conceptual Model

Data collected from several investigations have been used to develop a conceptual model for the Great Miami Aquifer system (see Section 2.1). The Draft Groundwater Report (DOE 1990) reviewed the literature of previous studies on the geology and hydrogeology of the area. The Sitewide Characterization Report (DOE 1992a) and the Groundwater Modeling Report Summary of Model Development (DOE 1993b) describe the present conceptual model of the Great Miami Aquifer system.

The current conceptual model represents a reasonable hypothesis of the natural system. Hundreds of borings and seismic geophysical analysis have defined the overall structure of the aquifer system. The defined sources and sinks correspond reasonably well with the collected data and other analogous hydrogeologic settings. Field data from borings, well logs, and water level data have been used to establish potential flow paths and direction. The current conceptual model apparently contains a coarse, yet reasonable, representation of heterogeneities, such as layering, at the site.

A recognized weakness is present. To date, only steady state flow parameters have been used to define boundary conditions for the local flow field. With transient effects apparent in Paddy's Run, the Great Miami River, surface recharge, and constant head boundaries, consideration of possible transient effects needs to be made. For long time scale applications (such as those that are used in risk assessments) the steady state flow assumption is valid. However, other smaller scale applications of the model may need to consider transient effects.

4.2.2 Mathematical Model

The definition of the conceptual model has played a key role in the selection and formulation of the mathematical model for the present FEMP flow and solute transport model (see Subsection 2.2). The SWIFT code (three-dimensional groundwater flow and solute transport) was selected to model flow and solute transport based upon established criteria (IT 1988). IT and others (DOE 1990) have completed verifications of the SWIFT code. These verifications have shown that SWIFT results compare well with analytical codes and other numeric codes.

While there are some inaccuracies associated with the mathematical aspects of any code, these inaccuracies represent only a small fraction of the uncertainty associated with the overall modeling effort (e.g., from the conceptual model interpretation, parameter estimation, and model aggregation). No additional code verification effort is necessary. However, procedural type code verifications are

necessary when the code version changes or the computer platform changes. These activities are described under Subsection 4.4.

4.2.3 Model Structure

Model Grid

The present solute transport grid (78 by 102) extends over the production areas, Paddy's Run, and the South Plume area; however the eastern grid boundary is very near the eastern site boundary. The domain of the solute transport model grid needs to be expanded to the east because flowpaths from the northern portion of the site are directed toward the east and because certain risk assessment simulations show constituents leaving the model grid in this direction. Therefore, it is likely that simulated pumping will occur at the eastern edge of the site near the present grid boundary. Introduction of recovery wells in the eastern part of the grid would invalidate the currently assumed constant head boundary conditions. Theoretical receptors may exist to the east. Therefore, the SWIFT grid should be extended eastward to reduce boundary interference effects and to predict long-term transport more accurately.

Vertical Discretization

Presently, the model has five vertical layers covering approximately 170 feet of saturated aquifer. Two effects may be the result of this coarse layering. First, maximum concentrations determined in the risk assessment process may be underestimated by the relatively large block size. Two, the calibrated solute transport model has over predicted contamination at depth. A lack of vertical discretization in the numerical model may cause much of the over-prediction of uranium in the lower layers. Oversimplification of hydrologic structure both in the vertical variation of hydraulic conductivity and by a lack of numerical vertical discretization probably contribute significantly to the over prediction. The model averages concentrations over the entire block: therefore as the model steps through time, contaminant transport quickly takes place from layer 1 to layer 2. Correction of this problem may require the use of more vertical layers or blocks in the SWIFT code. The addition of layers needs to be tempered by resulting long run times. Layers may also be better matched to screen intervals of the 2000, 3000, and 4000 series wells.

4.2.4 Constitutive Coefficients

The values and origin of constitutive coefficients are described in another report (DOE 1993b, Table 4-1). Values of these parameters are derived from earlier studies performed in the region and from the literature. In general, these values provide reasonable estimates of parameter values in the model.

Certain key aquifer parameters need to be refined with site specific data. Hydraulic conductivity and storativity need to be directly measured at the FEMP site through a large-scale pump test. The design

confirmation program of the DMEPP (see Section 2) has required this pump test (DOE 1993c). A seven level observation well and a large number of 2000 and 3000 series wells will be monitored during the pump test to define horizontal hydraulic conductivity and to obtain a qualitative idea of vertical flow parameters. Slug tests at the multi-level observation well will provide some relative basis for assessing the vertical distribution of horizontal hydraulic conductivity.

4.2.5 Boundary and Initial Conditions

The FEMP regional flow model has constant head boundaries within the aquifer and at the Great Miami River, no flow boundaries at bedrock interfaces, and constant flux boundaries for recharge at the surface and at production wells (DOE 1993b). Constant head boundaries were based on historical water elevations from wells in the vicinity of the boundary. River elevations were based on a HEC2 model run of the Great Miami River. Locations of bedrock boundaries were based on well logs, seismic analysis, and stratigraphic correlations. Pumping rates were set with information from well owners while recharge rates were based on various studies. Recharge rate and constant head boundaries were altered during calibration (DOE 1993b).

Constant head values were imported from the appropriate cells of the solved regional flow model to set boundary conditions for the solute transport (local) grid. Uranium source terms were defined to some degree with historical data (DOE 1993b, Table 4-2); however, final loading rates and time periods were set based upon the calibration process. Initial aquifer uranium concentrations were set at zero.

In general, the boundary conditions are appropriate for the system being modeled. The most uncertain parameter in the model development is the source term. Source loading history is an extremely difficult parameter to estimate due to the uncertainty of site history, sampling uncertainties, and transport unknowns. While the basis of these source terms was established to some degree on the conceptual model and site history, a large uncertainty remains in the source locations, loading strengths, and time distribution of loading strengths. Source locations, loading periods, and loading strengths were all varied substantially during the calibration process. Source term calculations need to be improved for the vadose zone, Paddy's Run, and to account for biotic transport (see Figures 1-2 and 1-3).

Efforts are underway to build a till model, a Paddy's Run model, and a biotic transport model to define source terms to and from SWIFT. The DOE plans a series of field sampling and experimental activities that should help develop a model of the till overburden (i.e., the unsaturated flow portion of the conceptual model). Since waste management activities have been conducted on the till overburden, this activity should also help define existing source loading terms to the aquifer. Data generated by these field sampling and till model building activities should be used to define flow and transport processes that move constituents from the surface down to the Great Miami Aquifer. The Paddy's Run model will better define the source term strength within Paddy's Run and transport from Paddy's Run to the aquifer. The biotic transport model will provide source terms for various scenarios for each CRU and the entire

site. The biotic transport model will pay particular attention to the up-take into plants and consequently to animals to help quantify the health risk to humans. These modeling efforts should also define possible ranges in the source term parameter that would serve as inputs to the uncertainty and sensitivity analyses.

4.3 Evaluation of Model Comparisons with Field Data

This section discusses the comparison of predicted model outputs with field data. Two types of activities perform this comparison: model calibrations and performance evaluations (i.e., extended verifications or "validations" - Figure 4-1). The matching of model output against historical field data is called calibration. Calibration is defined as the process of adjusting model parameters (material properties, boundary conditions, and initial conditions) until the model confirms the analyst's understanding of the system. In contrast, performance evaluations calibrated output with independent field data. The sections below describe the criteria and needs for future comparisons with field data and related sensitivity analyses.

4.3.1 Calibration

Flow Model Calibration

The present FEMP flow model is calibrated to 1986 water elevation data. Since that time, additional data has been collected at existing wells and new wells have been installed (and water elevations measured). The flow model should be recalibrated based on the latest available data including the South Plume pump test.

As part of this calibration effort, the flow model calibration criteria needs to be updated. Checks on the calibration include both quantitative and qualitative comparisons. Quantitative comparisons include comparison of model predictions with field measurements both in time and space and by interpreting the mass balances. While previous work plans have emphasized similar statistical tests (IT 1988, Table 5.3) to evaluate calibration results, such tests must be based on some idea of site-specific parameter variation (NRC 1990, p. 231). Consequently, the calibration criteria must be reviewed and updated to reflect current conditions. Criteria needs to built on statistical, geostatistical, and sensitivity analysis results.

Solute Transport Model Calibration

The present solute transport model is calibrated using data up to April 1990. Target values for wells were set by averaging multiple samples collected over several years. Two calibrations were performed; the first calibration set the uranium retardation factor to 9 and used a simple outlier test. The second calibration set the uranium retardation factor equal to 12 and used a confidence interval method.

Dispersivities were held reasonably constant during the calibration. Source terms (time and loading rates) were varied until a reasonable match with the data sets was obtained (DOE 1993b).

The solute transport model needs to be recalibrated for the following reasons:

1) Similar to the flow model, additional data has been collected at monitoring wells that were in existence during the original calibration (see DOE 1993b). In addition, new monitoring wells have been installed and sampled. These data show the southern extent of the south plume to be farther north than was believed during the original calibration. The calibration needs to be updated to reflect these latest data.

2) The original calibration using an estimated retardation factor of 9 resulted in a reasonable match to the monitoring data (except for the South Plume southern extent as described above) with most of the contamination at the higher model layers. Based on the results of a geochemical study (DOE 1993b, Appendix A), the retardation factor was revised upward to 12 to fall within the studies range (approximately 11 to 40). The calibration using the retardation equal to 12 resulted in more uranium simulated at depth (which does not match monitoring data) and a much larger historical mass loading to the aquifer. The geochemical study miscalculated the retardation factor by using a grain density instead of a bulk density in the retardation equation. In fact, geochemical studies indicate a range of retardation factors from approximately 8 to 33, indicating that the original R=9 calibration was within range. Further calibration efforts need to consider these factors.

As part of this calibration effort, the solute transport model calibration criteria need to be updated in a similar manner as the flow model criteria. In some instances, the method used in the original calibration of simply maximizing the number of wells within the confidence interval lead to erroneous results. In addition, calibration criteria need to consider total mass of uranium in the aquifer. The calibration criteria must be reviewed and updated to reflect current conditions. Criteria needs to build on statistical, geostatistical, and sensitivity analysis results.

4.3.2 Model Performance Evaluation

A performance evaluation (extended verification) simply repeats the calibration process and uses the criteria described above with one essential difference: the performance evaluation takes the calibrated model and compares model predictions with an independent set of field measurements. These independent field measurements should involve multiple conditions that have true uniqueness. Unique conditions include high and low recharge, conditions before and after pumping or installation of a cutoff wall or cap, flood stages for major surface waters such as the Great Miami River, or the installation of drains.

A single performance evaluation was performed on the two-dimensional flow model (DOE 1993b). Using a 1988 water elevation data set under a drought condition, a reasonable match of a model simulation was made varying only factors related to this drought condition (constant head boundaries, recharge, and river stage). This performance evaluation supports the validity of the two-dimensional flow model.

Performance evaluations of the three-dimensional flow and solute transport models need to be performed. The South Plume recovery system will provide stressed conditions to perform some of these evaluations. The DMEPP (DOE 1993c) has defined a requirement for annual comparisons of model predictions to field data. Other appropriate site situations should also be used for these performance assessments of the model.

4.4 Evaluation of Model Uncertainty Analysis

Traditional methods of model accuracy assessment compare predictions to historical field measurements and evaluate goodness-of-fit after the fact. Calibrations and model performance evaluations generally constitute these traditional methods (see Section 4.3). Although important indicators of model performance, such methods do not truly measure prediction errors. For example, one cannot easily distinguish between a good comparison based on an artificially manipulated and an over parameterized model from one based on an accurate description of the dominant transport processes. Rather than just focusing on measurement errors (e.g., differences with historical field measurements), model accuracy assessment needs to consider error from natural heterogeneity and structural differences between the model and the real world.

Uncertainty analysis activities are needed to better understand the potential range of model output. If the potential range of model output is quantified, the model can be used appropriately. Figure 4-1 divides uncertainty analysis into two steps. The first step is to estimate the spread or variance in model inputs. The second step consists of estimating confidence intervals of the key performance measures based on the anticipated application of the model (for example, groundwater travel time and the maximum concentration in the aquifer for the risk assessment process). Sensitivity analyses should estimate the change in outputs resulting from changes in specific inputs, that is, the sensitivity partial derivatives.

Although model sensitivity analysis has been performed as part of the model development and during certain applications (for example, DOE 1993 a and b), no more formal or extensive uncertainty analysis has been conducted to date.

4.4.1 Model Design Uncertainty

The two steps of model uncertainty analysis are described below:

Uncertainty in the Conceptual Model

While the conceptual model is reasonable, uncertainties exist in interpretations and selection of input parameters. Flow and transport processes, the effect of heterogeneity, and geochemistry can be possible interpretations of the conceptual model. The derivation of parameters for the conceptual model (DOE 1993b, Figure 2-1) shows variation in the selected values. General uncertainties that should feed into the uncertainty analysis simulations include:

1) Certain waste characteristics and source and recharge/infiltration terms that interact with the Great Miami aquifer

2) Certain variations in hydraulic conductivity and dispersivity across the site

3) Certain interpretations of how uranium distribution coefficients and associated retardation coefficients vary across the site

Uncertainty in the Mathematical Model

Uncertainty in the mathematical model relates to how well the governing equation models a given process and how well it structures the domain of the site. The mathematical uncertainties can be characterized through parallel calculations with different numerical codes or analytical solutions. Previously, the DOE (DOE 1990) has shown that SWIFT has been extensively verified and compared with other codes. These verifications have shown that SWIFT results compare well with analytical and other numerical codes. The DOE (DOE 1990) also has partially addressed the question of structure when it used relatively simpler models to develop a general understanding of model conditions at the FEMP. Specifically, they checked the sensitivity of results to one- and two-dimensional models and thereby helped generate initial estimates of input parameters for calibrating the more complex three-dimensional models. They also investigated indirectly the uncertainty in boundary conditions through sensitivity analyses with their two-dimensional codes.

Uncertainty in Model Structure

Uncertainty in model structure includes the effects of varying block size and the assumptions inherent in building the mathematical model from the conceptual model. Mesh and block size impact model results because of the effect of averaging parameters in the finite difference method. The original mesh size was selected based upon several factors, for example, degree of resolution, total domain that needed to be covered, run times, and numerical dispersion.

Mesh size has been and will be altered to support particular applications requiring more detailed results. For example, mesh was refined in the South Plume area to a 62.5-foot by 62.5-foot grid to support the recovery system evaluation process. Any such mesh refinement activities need to perform sensitivity runs to understand the impact of grid size reduction.

Uncertainty in Constitutive Coefficients

Estimates of model inputs and their variance or uncertainty are needed to define overall uncertainty. Values for various model inputs have been estimated during the construction of the SWIFT site model. The derivation of constitutive coefficients (DOE 1993b, Figure 4-1) shows variation in most of these parameter values. These input values have been estimated from field data and from literature values. Key constitutive coefficients that account for the majority of flow and transport variation include hydraulic conductivities, dispersion coefficients, and retardation factors. Data sets that estimate these parameters should be reviewed and evaluated. Geostatistical approaches like kriging should estimate not only the inputs but their variance. Geostatistical techniques should include ones such as ordinary kriging with linear regression and cokriging with two or three attributes (Zimmermann et al. 1991).

Uncertainty in Boundary and Initial Conditions

Finally, estimates of the uncertainty and response derivatives for boundary and initial conditions including source terms are needed. Flow and transport process identification has relied on historically derived source loading schedules and spatial locations. Data has been collected from a large number of monitoring wells over several years during the course of remedial investigations at the FEMP. Additional data has been collected since the derivation of the model parameters in 1989 and 1990. A large uncertainty exists in the magnitude and time phasing of the source loading, as well as in terms of location of application throughout the site.

Uranium and other important constituent concentrations need to be defined in terms of spatial and time-phased distribution as source terms. These data sets need to be further analyzed with statistical and geostatistical techniques to better understand time and spatial distribution of data sets. Geostatistics should first be used to estimate the spatial variation and related uncertainty (i.e., variance) of water levels and uranium concentrations. These geostatistical studies may identify additional locations for data collection to optimize the model calibration effort.

4.4.2 Predictions of Confidence Intervals

Uncertainty analysis simulations predict confidence intervals for performance measures such as groundwater travel time and maximum concentration in the aquifer. The process of determining the uncertainty of output performance measures should be phased and designed to meet the needs of the model user. Initially uncertainty analyses should start out as simplified propagation of uncertainty bands

using sensitivity analysis to vary key aquifer parameters within conservatively established ranges. If the risk assessment effort can accept the output distribution bands, then the uncertainty analysis effort should stop. If the risk assessment effort needs a narrower band of uncertainty, then further efforts need to be planned and conducted. These efforts may include collection of additional data to reduce input uncertainty, recalculation of input and output uncertainties and sensitivities, change to a more sophisticated methodology for calculating uncertainty of performance measures, model redesign (e.g., the grid), or recalibration. If the output distribution proves acceptable, then the risk assessment effort can use the model's output of confidence intervals for various performance measures. Otherwise, this process continues iteratively until the risk assessment effort accepts a probabilistic output distribution from the groundwater modeling effort. If the uncertainty analysis expands to include a substantial number of simulations, then it may be necessary to use simpler models to define uncertainty of performance measures. Output from these simpler models will need to be correlated with SWIFT output.

Sensitivity Analysis

Sensitivity analysis varies input parameter values in order to understand the effect on selected output parameters. Sensitivity analysis not only supports the uncertainty analysis process described in this section, but also may support the comparison with field data process for calibration (Section 4.3), and support specific applications (Section 4.5).

Sensitivity analysis has been performed as part of the model building effort (DOE 1993b). For the two-dimensional flow model, the recharge, hydraulic conductivity, and river leakage factor were varied in sensitivity runs for different aquifer zones. For the three-dimensional flow model, sensitivity analysis was performed on hydraulic conductivity layers 4 and 5, river bed leakage factors, recharge rates at certain locations, and the north boundary condition. For the solute transport model with the retardation equal to 9, sensitivity analysis was performed on dispersity ratio (longitudinal versus transverse) and hydraulic conductivity of the clay interbed. In all cases, the output parameter was the calibration criteria, specifically, the mean residual, and the mean absolute residual.

Sensitivity analysis has also been included in model applications. For example, the design of the South Plume recovery system (DOE 1993a) varied hydraulic conductivity and assessed this impact on the effectiveness of recovery well capture. With this analysis, a range of hydraulic conductivity at which simulated capture met the objectives was determined and the system designers obtained important information on the uncertainty inherent in the model application.

For the uncertainty analysis, the first phase should be sensitivity analysis on the key transport parameters, namely horizontal hydraulic conductivity, dispersivity, and retardation. Variation of these parameters over defined ranges should account for the majority of the uncertainty on the maximum concentration in the aquifer and the time of travel, the risk assessment performance measures. The ranges of these

parameters should be established based upon analysis of available data attempting to identify realistic but conservative ranges.

4.5 Evaluation of Model Applications

The model has been and will be used at the FEMP for many applications. The three primary categories of these applications are characterization, risk assessments and design support studies (Figure 4-1). In addition, applications must follow a quality assurance program to guarantee the quality of the modeling process and supporting documentation. These applications are summarized in the following subsections.

4.5.1 Characterization Support Applications

Model applications that support characterization efforts include:

Investigation Support

Investigation support may estimate groundwater flow and transport to help locate monitoring wells or to support other investigatory activities. Particle tracking simulations define potential flow paths and help delineate subsequent monitoring well locations.

Miscellaneous Assessments

The model may be used to assess unique situations, for example, the capture zone analysis of an existing well. No applications of this type have been performed with the present model.

4.5.2 Risk Assessment Applications

Several types of risk assessment applications are performed with the model, including:

Baseline

The baseline risk assessment, conducted as part of the RI, determines the impact of leachate generated from waste areas (without remediation) on the aquifer. The RI/FS has scheduled baseline risk assessments for each CRU. To date baseline risk assessments have been performed for CRU1, CRU2, and CRU4. These assessments have used a fate and transport modeling process that includes source term development at each waste area, transport through the vadose zone, and transport through the aquifer (see Section 1). The performance measures in the aquifer include maximum concentration and travel time to the boundary.

Alternatives Evaluation

As part of the FS, the risk based impact of different remediation alternatives on the aquifer are compared with the model. Feasibility studies will be prepared for each CRU. Feasibility studies are presently in different stages of development for the different CRUs.

Comprehensive Response Action Risk Evaluation

The CRARE assesses the cumulative impact of residual levels of contamination after remediation for all operable units. CRAREs will be prepared as part of each CRU feasibility study. The CRARE will use the leading remedial alternatives for each CRU to determine residual concentrations and the presence of engineered units. Each successive CRARE will become more refined as feasibility studies for the different CRUs are completed. These assessments use a fate and transport modeling process that includes source term development at identified zones of remedial contamination and engineered units, transport of leachate through the vadose zone, and mixing and transport through the aquifer (see Section 1).

Performance Assessment

As part of the design process, the risk based impact of any designed facilities will be determined. This process accompanies Title II and Title III design. Releases from the facility and the failure of the facility will be modeled to determine the impact of such occurrences on groundwater. No performance assessments have been performed to date.

4.5.3 Design Support Applications

Model applications that support design efforts include:

Optimization of Selected Alternative

A modeling study may be performed for specific situations where modeling compares engineering design options for a selected alternative. An ongoing study at CRU1 is an example of this type of study. This study compares several options for remediating the waste pits and evaluates the impact of these various alternatives on groundwater.

Groundwater Recovery Design

An important use of the model is the support of design of groundwater remediation systems. Design of these systems will take place in stages, including conceptual, preliminary, and final design. To date the model was used to design the South Plume Groundwater Recovery System and to help size the Advanced Wastewater Treatment (AWWT) System. The model was used to screen options for the pumping rate

and location in the original South Plume EE/CA (DOE 1989). The model was used to select the final location, to investigate pumping options, to evaluate well capture, and to explore the sensitivity of hydraulic conductivity variation on well capture (DOE 1993a). In sizing the AWWT System, the model set preliminary locations of recovery wells on the east border of the site to create a hydraulic barrier for eastward migrating contamination.

4.5.4 Model Quality Assurance

Each organization that performs modeling needs a quality assurance program and appropriate procedures. Because multiple organizations currently use models, a method of quality assurance across all organizations is needed. The next sections divide the quality assurance process into seven categories:

1) Code Development and Documentation
2) Configuration Control
3) Model Maintenance
4) Model Application Plan
5) Presentation of Results
6) Technical and Peer Reviews
7) Post-Audit Assessments

Code Development and Documentation

The SWIFT code has been developed and documented according to the quality assurance requirements of NUREG-0856 (Reeves et al. 1986a, 1986b, and 1986c) and Ward et al. (1984). IT (1990) performed verification of the code for situations specific to the FEMP site model. Internal procedures for code verification on particular computer platforms are needed for each organization performing modeling.

Configuration Control

Appropriate quality assurance procedures are needed to enter and maintain data in the model data base (configuration control). Data should be evaluated for its intended use and appropriateness. Data should be collected under control of a quality assurance program. The data base should use specific procedures to maintain data quality. Procedures should control data collection and management to ensure consistent compliance with planned steps for collection and management. A data management procedure should be written and appropriate personnel trained in its use. This procedure should assure identification, storage, maintenance, traceability, legibility, and retrievability of key data from the model data base. Finally, the procedure should detail the steps required to change or add to the data in the model data base.

The FEMP presently has a quality assurance program for collecting and managing data that meets these requirements (WEMCO 1992b).

Model Maintenance

Model maintenance procedures are needed to assure the reliability, retrievability, traceability, and storage of models. The word "model" in this context includes both computer codes and associated data inputs. Written procedures should track code and data input changes and describe how to test modified codes and data inputs. Basically, the procedures should apply to all quality assurance procedures used in model development and documentation and require accurate record keeping and reporting of changes. For results presented in final reports, the procedures should require saving of key input and output files for inspection and possible re-use. The paper trail should also include reports and files related to the improvement and testing of the model. The procedures should require updated instructions for using the code and preparing input data files. Improper documentation could prevent a code from being adequately reviewed and could propagate errors in code use. Documentation should start at the beginning of a new software development or improvement project.

Presently, contractors to the DOE have been performing the modeling. These contractors should have procedures covering model maintenance. If multiple organizations perform the modeling, additional steps are needed to assure that the different organizations are using the same model.

Model Application Plan

The model application plan is the first step in assuring quality in a model application. The application plan should address the certain specific issues and be subject to technical review. For each type of application (e.g., risk assessment, alternative evaluation, and design support), the plan should address the performance measures required by the particular application. Each of these types of analyses should have different goals and objectives and therefore the focus of each plan should accordingly change. It should not be necessary to write a plan for each analysis if a group of analyses fall under the "same type of analysis."

Presentation of Results

Because of the variety of analyses which should be performed, the analyst should document each step of the modeling process in a final report. The report should document the completion of the work conducted in accordance with the model application plan. The report should outline application objectives, provide background on model development and calibration, show the results of simulations, discuss model limitations and uncertainties, and summarize conclusions. Figures and tables should summarize significant results. Appendices can show detailed output and supporting documentation.

Technical and Peer Reviews

Each organization should conduct its own review of the modeling efforts. For example, NRC (NRC 1991b, p. 6.1.5.1-3 through 4) describes the reviews they should conduct for modeling results. Qualified (internal and/or external) personnel independent of original work should perform fully traceable and documented reviews. Technical reviews should interpret and judge documents, material, or data that involve accepted practices and standard techniques. Peer reviews should interpret and judge documents, material, or data that go beyond existing techniques or represent the state of the art.

Post-Audit Assessments

Post-audit assessments provide a vehicle to compare model predictions with field data over long periods of time. The model that results from the calibration and performance evaluation should predict flow and transport conditions at smaller intervals of time. Collection of new field data at these same time intervals should determine and help interpret the discrepancies with the previous predictions. The post audit should be conducted after several of the prediction intervals have passed to ensure significant changes had time to occur. The evaluation of the results of the post audit are similar to the methods used for the calibration and performance evaluation.

No model post-audit program presently exists at the FEMP. Post-audit assessments need to supplement the performance evaluations described above. The first audits should be performed 5 years after calibration. Subsequent audits will need to be performed.

SECTION 5

SHORT-TERM MODEL IMPROVEMENT PLAN

This section presents the short-term program of tasks necessary to improve the FEMP groundwater model. The objective of the short-term program is to create a model that is capable of supporting the CRU5 risk assessment by September 1993. These short-term tasks have been selected based on the discussion presented in Section 4.

The short-term model improvement activities will focus on model structure changes; geostatistical analysis; geochemical parameter review; a recalibration and performance evaluation program; sensitivity and uncertainty analysis; capture zone applications; and establishment of report content and format for the RI fate and transport modeling presentation. These short-term modeling activities have been organized into the following four categories:

1) Model Design
2) Model Comparisons with Field Data
3) Model Uncertainty Analysis
4) Model Applications

These tasks are defined in more detail in the following subsections.

5.1 Model Design

5.1.1 Extend Transport Model Area

The solute transport model will be extended to the east for the following reasons:

1) To prevent model boundaries from interfering with calculated heads and concentrations when simulated pumping takes place on the eastern part of the site.

2) To establish locations of receptors on the grid (i.e., presently simulations predict that transport of contaminants leave the computer grid just east of the site).

3) To use more realistic boundary conditions on the solute transport grid, namely the SOWC wells and the Great Miami River. This will improve the flexibility of the flow portion of the solute transport grid.

Presently, the solute grid is 78 by 102 in the XY plane. To expand the grid to the Great Miami River will require a 78 by 145 grid using the same grid size.

5.1.2 Increase Vertical Resolution of Transport Model

An additional layer may be added to the solute transport model grid following vertical mixing zone calculations and initial review of solute transport calibration. If determined necessary, this layer will be added to the upper part of the model (i.e., model layer 1) where the majority of the contaminants are located. This additional layer will provide a more conservative estimate of the immediate impact by the source terms on the aquifer and a higher resolution for the vertical contaminant concentration profile.

It is estimated that, if fully implemented, these horizontal and vertical grid expansions will add approximately 30,000 blocks and execution times will be increased by approximately 75 percent.

5.1.3 Develop Glacial Till Model

A more sophisticated model of the glacial till will be developed to improve the definition of sources that migrate through the glacial till as well as to support other characterization and remediation efforts of the till. This modeling effort is already underway and is due to be completed in August 1993. Output from this model will define the source terms to the SWIFT aquifer model. Incorporating this output into the SWIFT model should be reasonably routine since linkage between these models and the SWIFT model has been considered during this model building effort.

5.1.4 Develop Paddy's Run Model

A independent and smaller scale model of Paddy's Run will also be developed to improve the definition of source terms that migrate from Paddy's Run to the aquifer. The Paddy's Run model will calculate the runoff contributions from the waste units to Paddy's Run and define the stream bed interactions between specific contaminants and the basal sediments. This model will provide source terms for understanding flow and transport relationships between surface and subsurface contaminant concentrations. This modeling effort is already underway and is due to be completed in May 1993. Output from this model will help define the source terms to the SWIFT aquifer model.

5.1.5 Develop Biotic Transport Model

A biotic transport model will also be created to improve the definition of contaminant transport through biological pathways. While output from this model will not directly define source terms in the SWIFT aquifer model, it will support the overall delineation of fate and transport of contaminants through the different media and support the risk assessment effort.

5.2 Comparisons with Field Data

5.2.1 Review and Update Calibration Criteria

Calibration criteria will be updated and/or developed to define quantitative and qualitative criteria for the calibration effort. Quantitative criteria includes the definition of both target locations and statistical parameters (and acceptable ranges of these parameters) for calibration of the flow and transport models. In addition, qualitative comparisons between monitoring data and model predictions will be required. Qualitative criteria include evaluation of correspondence among model simulations and the physical structures of the hydrogeological system. Qualitative features include, but are not limited to, the pattern of heads and concentrations.

Both steady state and transient flow calibration criteria will be developed since the flow model will be calibrated with the South Plume pump test results. Recent water elevation data measured prior to the pump test will be analyzed to select an appropriate time series of data to represent steady state conditions and for developing target head values. It is expected that quantitative criteria for the flow model will include measures of mean residual, maximum residual, variance of residual, and spatial correlation of residuals. Also, criteria for water mass balances will be defined.

For the solute transport model, criteria will be established for matching model results to target concentrations. Previous solute transport (uranium) calibrations used a limited, pre-1990 data base for developing calibration criteria. Uranium concentrations were statistically analyzed to define a sample mean and a 95 percent confidence interval of the population mean. Calibration attempted to minimize residuals and maximize the number of model results within the target confidence intervals. Due to the small number of data (less than four) in many wells, the 95 percent confidence intervals were much larger than the ranges of measured concentrations and thus meaningless in many wells.

Since additional data became available, the latest and all existing data will be compiled and evaluated to redefine the solute transport calibration criteria. Both data range and 95 percent confidence interval of mean for each monitoring well will be considered as the target range. An attempt will be made to balance two primary calibration targets: (1) concentrations at particular blocks representing location of measured data, and (2) total mass of contaminant in the aquifer. To assist in this effort, necessary statistical analysis of existing uranium concentration data will be performed.

5.2.2 Recalibrate/Validate Flow Model

The flow portion of the model will be calibrated first to a steady state condition measured before the South Plume pump test. The calibration criteria will be a "steady state" set of heads and acceptable ranges. Constant head boundary conditions may also be redefined based on this data set in the extended

model area. Other types of boundary conditions (e.g., constant flux condition) will also be considered based on available data. Results from the pump test, defining hydraulic conductivity and possibly hydrogeological boundaries, will be incorporated as initial values for hydraulic parameters in the model at the beginning of the steady state flow calibration effort.

Transient calibration, which matches the model simulated and measured drawdown vs. time data measured during the pump test for the pumping well and observation wells, will be performed following the first successful steady state flow calibration. Since the transient calibration will need to adjust some hydraulic parameters that can also affect the steady state model results, the transient and steady state flow calibrations will become an iterative process.

The overall flow calibration is complete when the calibration criteria are met and the analyst is satisfied for both the steady and transient cases. An approach of keeping the model simple without over complicating the zonation of parameters will be followed during the calibration.

During the calibration, residual error will be determined and statistical parameters will be calculated and compared to the established criteria. Graphs will show these residuals on two-dimensional planar contours, on cross sections, as a variation in time along with predicted and measured state variables, and on sample scattergrams that compare predicted versus measured data along a line of agreement (line of zero residuals). Water balances will be performed to obtain results within the established criteria. Finally, the model results will also be evaluated against the qualitative criteria defined.

A transient flow model prediction will be performed, after the overall flow calibration is done, by simulating the step-drawdown portion of the pump test. The only model parameter that will be changed in the calibrated flow model for this simulation is the pumping rate. Therefore, this simulation can be used as the validation of the calibrated flow model and to further characterize the accuracy of the calibrated flow model.

5.2.3 Review Geochemical Parameters and Existing Solute Transport Calibrations

The derivation of the distribution factor (Kd) for uranium will be assessed to select the most appropriate Kd for the solute transport model. Available data related to Kd will be compiled and reviewed. These data will be statistically analyzed to determine common statistical parameters and, if appropriate, geostatistical parameters. Results of all the existing solute transport calibration runs (specially the two final calibrations with retardation factor = 9 and 12) will be reevaluated by using the updated calibration criteria. A range of acceptable Kd will then be determined based on the review of geochemical data and the existing calibration runs. If necessary, as determined by the data, multiple zones may be created for Kd in the updated solute transport model.

5.2.4 Recalibrate Solute Transport Model

After the flow model is successfully recalibrated, the flow model's impacts on the solute transport model will first be evaluated with all the current transport parameters remaining unchanged. This evaluation will be performed for all the accepted solute transport calibration runs from the review described in Subsection 5.2.3. If none of these existing sets of transport parameters (i.e., Kd, dispersivity, and source loadings) remain acceptable according to the updated criteria, the solute transport model will need to be recalibrated. In a similar manner, as the flow model, residuals will be calculated and analyzed during the calibration. Mass balances will be calculated based on uranium predicted to be present in the aquifer (both dissolved and adsorbed states) versus the required source loading.

Based on experiences in development of the current model, the ranges of acceptable solute transport parameters along with the recommended representative value of each parameter will be determined instead of just a single set of transport parameters.

After the information (i.e., retardation factor and dispersivities) learned through the history matching during the calibration has been incorporated into the solute transport model, historical source loading terms will be decoupled from the model in most of the future model applications including the sensitivity analyses. Results from the glacial till model and Paddy's Run model will be inserted as future source terms. Also, the monitoring data will be contoured and directly inserted as initial concentrations in the model applications. By decoupling the historical source term and directly using the monitoring data as the initial conditions after the calibration, the model application becomes more modular and flexible.

5.3 Uncertainty Analysis

5.3.1 Perform Geostatistical Analysis

Geostatisical analysis will be conducted to understand and correlate the spatial distribution of key data sets. These data sets include the water elevation data and the uranium analytical data from the 2000, 3000, and 4000 series monitoring wells. Calculations will include the sample semivariogram, and kriging and cokriging estimators along with their estimation variance. This analysis will be used to help determine calibration criteria and to identify areas of the site where lower confidence exists in the analyzed data sets.

5.3.2 Perform Sensitivity Analysis on Kh, Kd, and Dispersivity

Sensitivity analysis will be performed on horizontal hydraulic conductivity (Kh), distribution coefficient (Kd), and dispersivity (α) in order to understand the effect of variation of these parameters on the maximum concentration and transport of a normalized plume. For this study, a theoretical source will

be applied to a SWIFT model cell and ranges for these three parameters will be established based upon previous data, the literature and the South Plume Pump Test. The initial run will be a baseline case using the model calibrated values of these parameters. Sensitivity runs will vary Kh, Kd, and α over the defined ranges to assess theoretical differences in maximum concentrations and travel time (the risk assessment performance parameters). Results will show the theoretical uncertainty bands on these performance measures. Output from sensitivity runs will be evaluated to determine the impact on the flow calibration criteria and the impact on solute transport in both the horizontal and vertical planes. Results of the uncertainty analyses will be used to define safety factors for clean-up goals and remedial designs.

5.4 Model Applications

5.4.1 Perform Capture Analysis on Existing Wells

The model will be used to analyze the capture zone of drinking water wells with significant pumping rates that may potentially be impacted by plumes from the site. Two wells have been identified for this analysis; the South Ohio Water Company wells located east of the FEMP on the east side of the Great Miami River and Knollman's well located south of the FEMP just south of Willey Road.

Pumping rates will be determined by available records. Capture zone analysis will consist of three steps:

1) Hydraulic impact will be assessed by contouring drawdown at both baseline (non pumping) and pumping conditions.

2) Capture zones will be defined by seeding many particles in a small diameter circle around the well and running the particle tracker in reverse.

3) Forward tracking will be conducted to confirm the results of the reverse tracking. A plane of particles will be defined at some distance upgradient from the well. The particle tracker will be run to determine if any particles breakthrough from these locations.

Figures will show predicted drawdowns, reverse and forward capture results in both the X-Y and the Y-Z planes.

5.4.2 Establish Report Content

As part of the quality assurance effort, the content of modeling application reports will be formally established so that there is a complete and consistent coverage of the important modeling elements in the documentation. This format will define the necessary contents, the general format, and the degree of

detail. Some differences in format will be defined for different applications of the model. For example, a risk assessment application report will require different sections and analysis than a feasibility study or a design report. Once report content is established, subsequent reporting efforts will follow this format.

5.4.3 Define Post Audit Program

As part of the quality assurance effort, a post audit program will be formally established containing the following elements. This post audit program will define a program that will periodically assess the ability of the model to make time dependent predictions over a long time period. Requirements will be established for the timing and content of the post audits. It is expected that the first post audit will be conducted after a minimum of 5 years after model calibration. Simulations from the model will predict flow and transport conditions at defined intervals of time. These predictions will be compared with field data collected at these same time intervals. The evaluation of the results of the post audit will use the same methodology as the calibration.

5.5 Schedule of Activities

Subsection 1.2 describes the overall model improvement program. As shown on Figure 1-4, the Groundwater Modeling Report - Summary of Model Development (DOE 1993b) and this present report are prepared in parallel and submitted to the Ohio and US EPAs at the same time. After completion of the short term activities, the long term activities will commence and continue through the completion of the project.

Figure 5-1 summarizes the schedule of activities starting April 1993, for the short-term model improvement effort. Figure 5-1 also breaks down activities into model design, comparisons with field data, model uncertainty analyses, and model application. These activities have already started and will end with a summary report in August 1993. Letter reports will be prepared at the end of each task.

Schedule of Short-Term Model Improvement Activities

4/27/1993

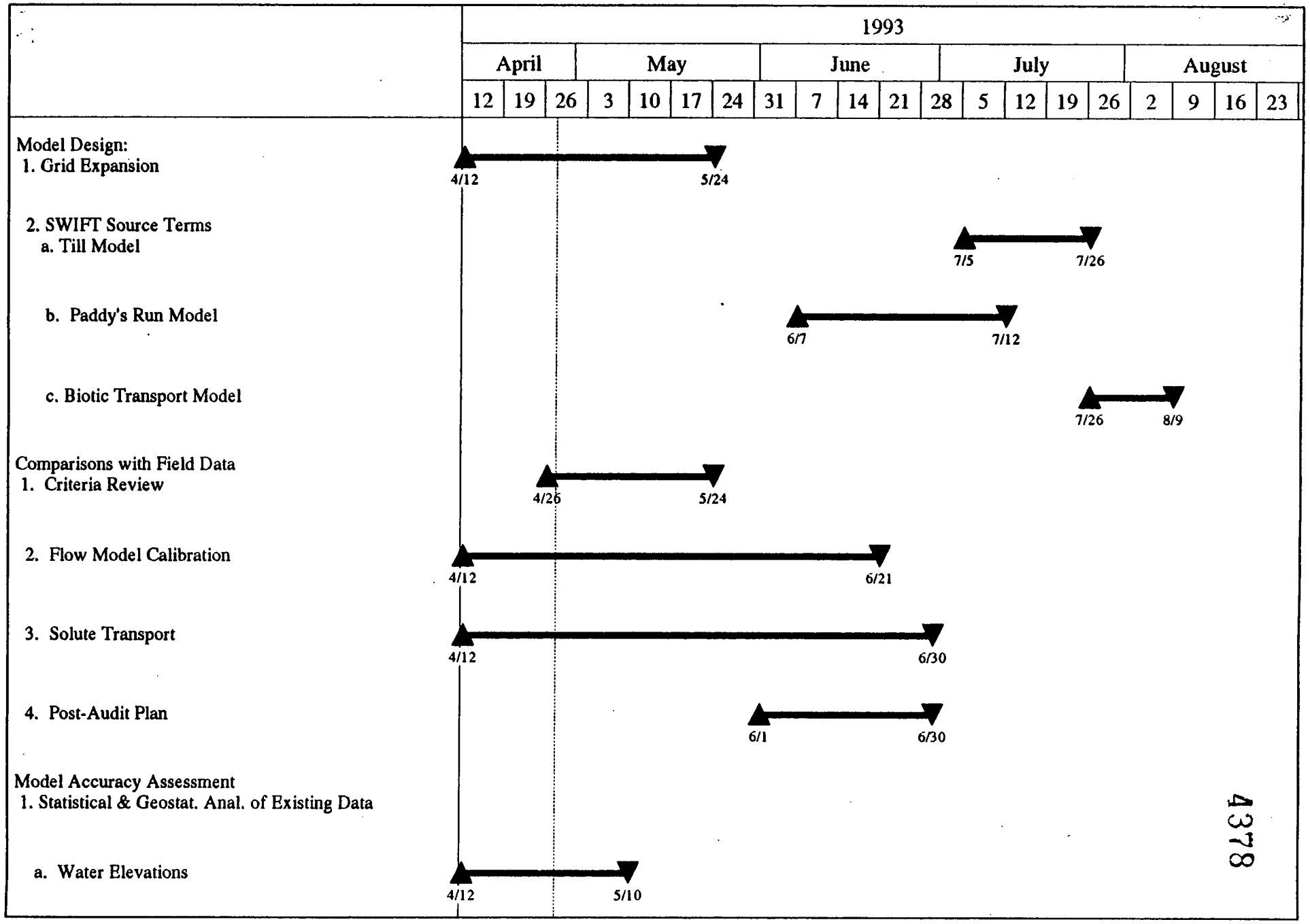

Figure 5-1 - Schedule of Short-Term Model Improvement Activities (Page 1 of 2)

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Schedule of Short-Term Model Improvement Activities

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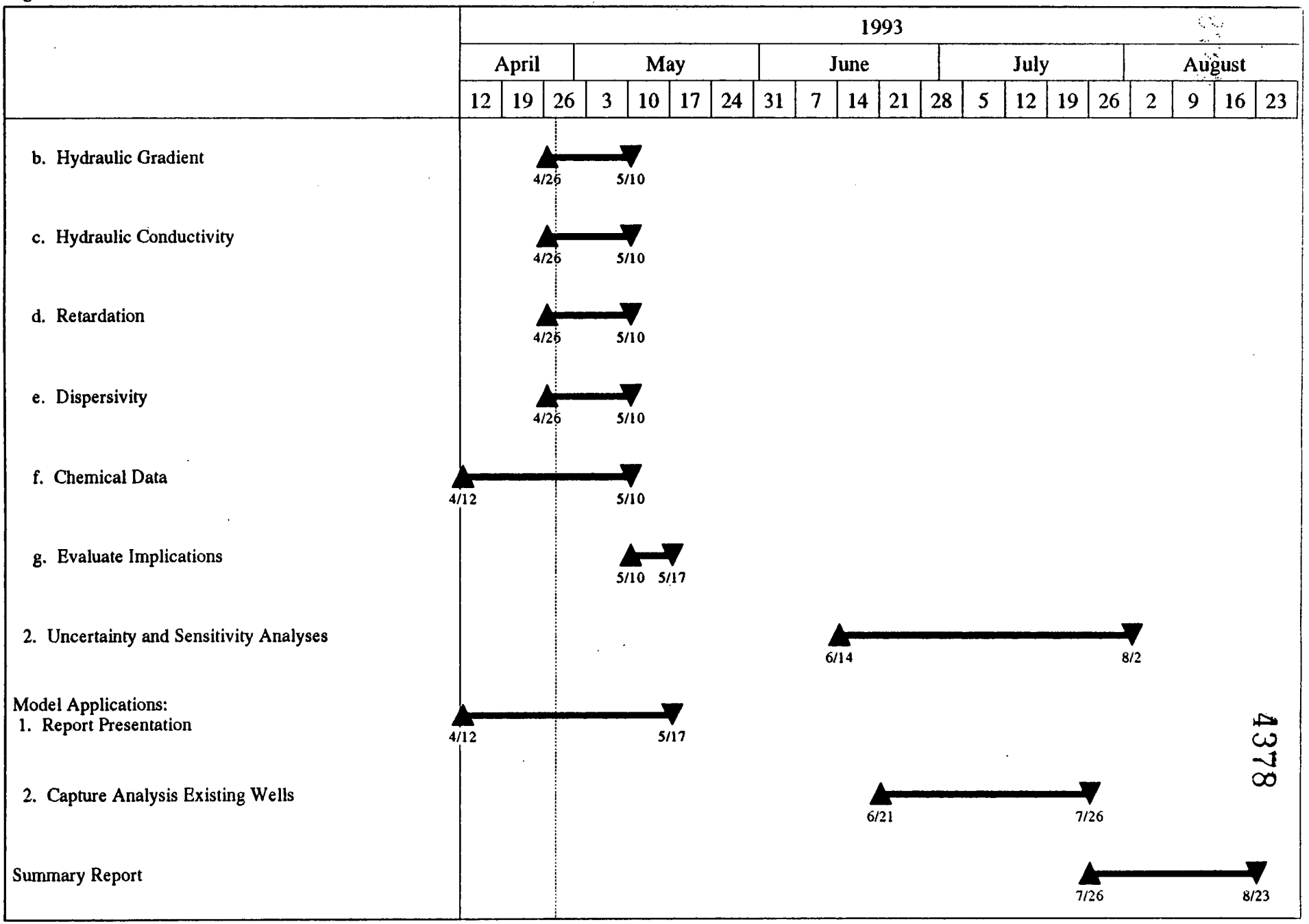

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Figure 5-1 - Schedule of Short-Term Model Improvement Activities (Page 2 of 2)

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SECTION 6

LONG-TERM MODEL IMPROVEMENT PLAN

The long-term model improvement activities will focus on refinement of the "improved" model. The refinement activities include performance evaluations (i.e., extended verification or "validation") of the model, an incorporation of refined output parameters from the other supporting models, and a post-audit program. The model, improved with the short-term activities, will be used for the various applications at the FEMP. The long-term model improvement activities will continue the review and integration of existing data into the assessment of model uncertainty for fate and transport applications. Based on the needs of the model users, more sophisticated determination of uncertainty measures may be conducted. The following sections discuss these activities.

6.1 Performance Evaluation

Periodic performance evaluations will be performed during the long-term improvement program. The performance evaluation helps show that the model can predict groundwater flow conditions under a set of hydrogeologic stresses that differ from those of the original calibration. Using a data set that is independent from the data used to calibrate the original model, the performance evaluation repeats the calibration process using the established criteria defined in the short-term program. These independent field measurements should involve multiple conditions that are truly unique. Unique conditions include high and low recharge, conditions before and after pumping or installation of a cutoff wall or cap, or flood stages for major surface waters such as the Ohio and Great Miami rivers. These different hydrologic conditions significantly "stress" the calibrated model and serve as appropriate unique conditions. The performance evaluation will test whether one calibration with one set of flow and transport rates and hydraulic conductivities and other data can predict the state variables under another set of system stresses. Based upon the results of the performance evaluation, a decision will be made as to whether the model accurately reproduces these different conditions and whether recalibration is necessary. If it is, the model will be recalibrated in accordance with the description in Subsection 5.2.

There is no guarantee of anomalous conditions in the next couple of years. Therefore, a convenient set of conditions for the first performance evaluation is the South Plume recovery system pumping. The South Plume recovery system water level monitoring data will be used as a different set of conditions (i.e., pumping of the South Plume) for the performance evaluation. Since the recovery system start-up is scheduled for August 1993, data from the first 6 months of operation will be available in early 1994. Other aquifer monitoring data collected during this period will also be incorporated into this analysis.

Other verification exercises will be tied to anomalous conditions. It is expected that one additional performance evaluation will be performed within the next 5 years.

6.2 Post Audits

Post-audit assessments will be conducted at intervals of several years after completion of the modeling studies. These audits will be started after a minimum of 5 years and will be conducted every 5 years. The short-term effort of model improvement (see Subsection 5.4.3) has defined a task to define the details of the post-audit program. The long-term program will comply with this post-audit plan.

6.3 Source Terms Refinement

Results of the Till, Paddy's Run, and Biotic Transport Model may also be refined over time with additional data collection or performance evaluations. Therefore, these models and their output terms may potentially be changed. If this occurs, the SWIFT aquifer model will also need to be updated with these revised source terms. Future source terms will also change based on the latest definition of leading alternatives for remediation of the different CRUs.

6.4 Model Uncertainty Analysis

The need for further uncertainty analysis will be established by the model users on an application-by-application basis. In formulating plans for a particular application, the performance measures and the degree of understanding of the uncertainty of these performance measures will be established. Then the specific application will include supporting simulations to assess model accuracy regarding the identified performance measures.

The long-term effort will reduce model design uncertainty by narrowing the input parameter distributions. New data from the hydraulic conductivity distribution studies and the representative geochemical analysis will be available to help refine input distributions. Also, routine monitoring data and possibly other supporting data (treatability studies or engineering studies) collected since the previous uncertainty analysis will also be available.

The long-term model improvement effort will use either a simple confidence band or a more sophisticated stochastic technique to perform probabilistic predictions as required by the risk assessment activity. The selection of approach will depend on the need for a narrower uncertainty band than was defined in the short-term uncertainty analysis. The simple band approach will be more conservative by using simple minimum and maximum values of input parameters translating to higher output uncertainty. If confidence intervals of additional performance measures are defined by the risk assessment group, then these performance measures will also be addressed.

6.5 Quality Assurance

The quality assurance and procedural type requirements defined in Subsection 4.5 will be followed over the course of the long-term program. In particular, quality assurance procedures will track changes to the baseline groundwater model as improvements occur and control the use of the model. The project and the organizations performing modeling will comply with these requirements.

6.6 Schedule of Activities

Figure 6-1 summarizes the schedule of activities for the long-term model improvement effort. These activities will start in September 1993 and continue through the end of the project.

Schedule of Long-Term Model Improvement Activities

4/27/1993

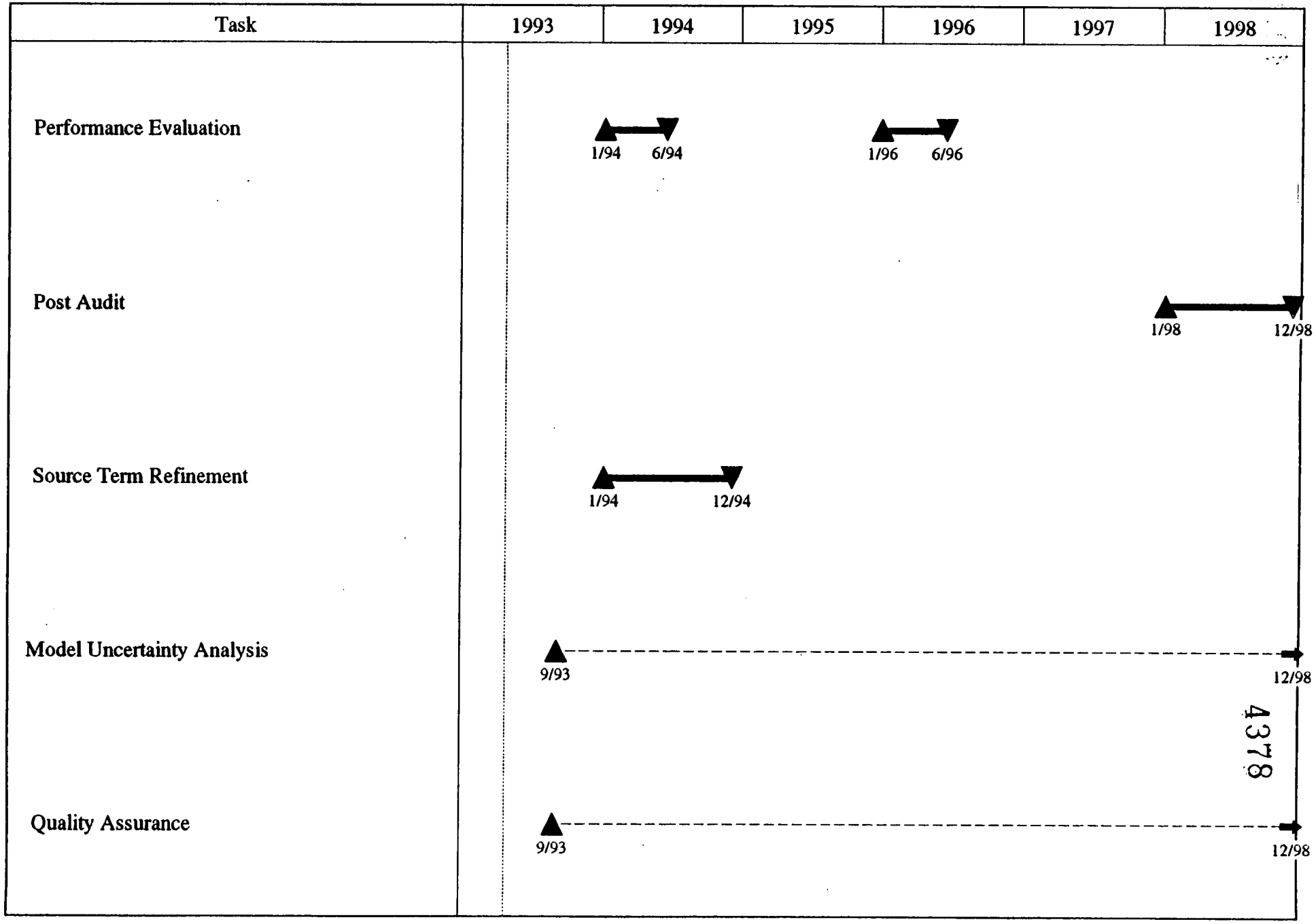

Figure 6-1 - Schedule of Long-Term Model Improvement Activities

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SECTION 7

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APPENDIX A

REVIEW OF REGULATORY CRITERIA

APPENDIX A

REGULATORY MODELING CRITERIA

This section reviews Federal and State regulations and guidance concerning the use of groundwater flow and contaminant transport models to develop criteria for model improvement and application. This section reviews the regulations and guidance of the US EPA, the Ohio EPA, the DOE, and the United States Nuclear Regulatory Commission (NRC). This section discusses the regulatory modeling criteria following a format that breaks the modeling process into model design, model uncertainty analyses, model comparisons with field data, and model application.

Only the CERCLA and RCRA requirements are directly applicable to the FEMP remediation. The non-CERCLA regulations and guidance predominantly apply to siting and development of low-level waste disposal facilities, not remediation. However, they could constitute CERCLA Applicable and Relevant and Appropriate Requirements (ARARs) or To Be Considered (TBCs) for a particular FEMP remedial project. Unless or until they are invoked, they are not legally binding on the FEMP remediation program.

1.0 MODEL DESIGN

Model design defines the conceptual model, formulates the mathematical model, and simplifies the site structure, constitutive parameters, and boundary/initial conditions for model use. This section identifies model design criteria as derived from a review of Federal and State laws, regulations, and guidance.

1.1 United States Environmental Protection Agency Regulations and Guidance

US EPA regulations and guidance that affect model design come from Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (Superfund), Resource and Conservation and Recovery Act (RCRA), and the Safe Drinking Water Act (SDWA).

CERCLA

Because of the large number of available models, CERCLA provides guidance for model selection (US EPA 1988b). This 1988 guidance represents a significant advance in the US EPA modeling program because it defines the model selection process.

RCRA

RCRA provides limited model design guidance through its regulations on the design of a groundwater monitoring system for hazardous waste storage, treatment, or disposal (TSD) facilities (40 CFR Sections 264.97, 264.98, 264.99) and clean up of contaminated conditions at active facilities in any area where there was historic disposal of either hazardous or solid wastes (40 CFR Section 264.100). RCRA encourages the use of assumptions that over-predict releases and concentrations "where time and/or resources are limited" (US EPA 1986, p. 150). The US EPA gives preference to numerical models over analytical models (US EPA 1986, p. 158). The US EPA's RCRA guidance lists publicly available models (US EPA 1986, p. 158).

SDWA

The 1986 Amendments to the SDWA contain provisions for the Wellhead Protection (WHP) Program. The WHP Program assists states in protecting areas surrounding wells against contaminants that may have adverse effects on human health (SDWA, Section 1428[a]). Wellhead protection could be an issue at the FEMP because of the proximity of the Southeast Ohio Water Company Wells. The US EPA Administrator has issued technical guidance (US EPA 1987b) that states may use to determine the extent of such areas of protection in accordance with Section 1428(e). The provisions affect model design through the interrelationships among various wellhead delineation criteria and physical processes (Figure A-1). The SDWA Amendments in Subsection 1428(e) define wellhead protection areas (WHPAs) as "the surface and subsurface area surrounding a water well or well field, supplying a public water system, through which contaminants are reasonably likely to move toward and reach such water well or well field." It is not clear whether the site has been designated a WHPA by the State or not.

The US EPA (US EPA 1987b) established guidelines for the delineation of WHPAs, and developed delineation criteria, criteria thresholds, and delineation methods. Delineation criteria represent conceptual standards that form the technical basis for WHPA delineations. The US EPA (US EPA 1987b) identified five criterion: (1) distance, (2) drawdown, (3) time of travel, (4) flow boundaries, and (5) assimilative capacity. Figure A-1 relates WHPA delineation criteria and physical processes. Note that the distance criterion often represents an arbitrary policy decision, past experience, or non-technical considerations. Hence, this criteria does not relate directly to flow and transport modeling. In contrast, the last four criteria relate to various aspects of flow and transport modeling as indicated by Figure A-1. The drawdown criterion relates to the "cone of depression" or "area of influence concept." The time of travel criterion deals with the maximum time for a groundwater contaminant to reach a well. The flow boundary criterion applies mainly to small aquifer systems where the total travel time to the boundaries is small or zone of influence caused by pumping rapidly reaches a boundary. Assimilative capacity deals with how the saturated and unsaturated zones attenuate contaminants.

Figure A-1
Relationship Between WHPA Delineation Criteria and Physical Processes

PHYSICAL PROCESS \ CRITERIA	DISTANCE	DRAWDOWN	TIME OF TRAVEL	FLOW BOUNDARIES	ASSIMILATIVE CAPACITY
ADVECTION		●	●	●	
HYDRODYNAMIC DISPERSION (Mechanical dispersion and molecular diffusion)			●		●
SOLID-SOLUTE INTERACTION (Adsorption, chemical reactions)			●		●

ERAFS2\MACDATA\ILLUS\OU-5\WHPA RELATION

1.2 Ohio Environmental Protection Agency Regulations and Guidance

The Ohio EPA's Division of Ground Water (DGW) established procedures to review hydrogeologic portions of RI/FS Work Plans and Reports for the Division of Emergency and Remedial Response (Ohio EPA 1990b). With regard to model design, the guidance on solid waste disposal facility siting criteria states that all calculations should use inputs that yield the fastest possible time of travel (TOT) given the range of hydraulic conductivities (EPA 1991a).

1.3 United States Department of Energy Orders

The DOE low-level waste disposal order (DOE 1988a, Chapter 3) recommends review of NRC low-level waste disposal standards that pertain to model design. The requirement to use monitoring measurements (DOE 1988a, Chapter 3, Paragraph 3b) can serve as the rationale to have modeling guide the sampling program so that it can provide data for model design. These criteria will be discussed in the next subsection.

1.4 United States Nuclear Regulatory Commission Regulations and Guidance

Through its regulations, the NRC has also provided guidance to define the issues surrounding process and parameter identification, model selection, estimates of model inputs, assessment of model accuracy, model application, and evaluation of model results in relation to low level waste disposal licensing. Guidance includes requirements that the disposal site shall be capable of being characterized, modeled, analyzed, and monitored (NRC 1988a). This includes various standard review plans (SRPs).

The SRPs that guide NRC staff in their license application evaluations provide additional criteria for groundwater and solute transport modeling. These SRPs (e.g., NRC 1983, 1988a, 1988b, 1988c, 1991a, 1991b, and 1991c) and other guidance show that NRC staff look for specific technical evidence in their evaluation of the defensibility, suitability, and appropriateness of groundwater flow and transport models. Criteria that apply to model design include:

1) Describes completely the contaminant transport pathways between the engineered disposal unit and the site boundary and existing or known future groundwater user locations (NRC 1991b, p. 6.1.5.1-4)

2) Estimates and justifies the physical and chemical input parameters used in the transport models to calculate radionuclide concentrations (NRC 1991b, p. 6.1.5.1-4)

3) Describes the data and justifies the manipulation of any data used in the analyses (NRC 1991b, p. 6.1.5.2-3)

2.0 MODEL UNCERTAINTY ANALYSIS

This section identifies model uncertainty analysis criteria as derived from a review of Federal and State laws, regulations, and guidance. Model uncertainty analysis is the calculation of uncertainty or confidence intervals of model output, specifically for certain performance measures.

2.1 United States Environmental Protection Agency Regulations and Guidance

CERCLA

The US EPA (US EPA 1992) has issued final guidelines for exposure assessment under CERCLA. These guidelines describe the role of uncertainty analysis in assessing model outputs. The guidelines also discuss how uncertainty results from parameter uncertainty, sensitivity of inputs to outputs, and propagation of these uncertainties and sensitivities through a given model. These guidelines describe both qualitative and quantitative techniques to evaluate model uncertainty relating to the risk assessment. Quantitative methods include sensitivity analysis, analytical uncertainty propagation, probabilistic uncertainty analysis or classical statistical methods. These guidelines further state that the degree of uncertainty analysis is dependent on the requirements of the assessment.

RCRA

The US EPA (US EPA 1986, p. 158) recommends uncertainty analyses for RCRA TSD permitting through sensitivity analyses: "The sensitivity of the model output both to the measured and assumed input parameters should be determined and incorporated into any discussion of model results."

SDWA

The model uncertainty analysis with respect to SDWA criteria in the WHPA context depends on the uncertainty in meeting the criteria thresholds discussed in Table A-1. Criteria thresholds represent limits above or below which the selected criteria will cease to provide the desired protection. A state's choice of a criterion usually combines technical and administrative considerations. The US EPA (US EPA 1987b, Section 3.2) gives examples of such criteria.

2.2 Ohio Environmental Protection Agency Regulations and Guidance

The Ohio EPA addresses model uncertainty analysis only indirectly from the viewpoint of model design in its "Review of Work Plans and Reports Generated During the Remedial Investigation and Feasibility Process" (Ohio EPA 1990b, pp. 4-6). Part II.A.3 of Ohio EPA (Ohio EPA 1990b) shows that the agency will review whether the sampling program will generate enough data to develop and evaluate the alternatives fully.

2.3 United States Department of Energy Orders

The DOE (DOE 1988a, Chapter 3) only implies the need for uncertainty analyses because these DOE orders require performance objectives and performance assessments involving flow and transport modeling. The dose requirements (DOE 1988a, Paragraph 3a) implicitly require that the performance assessments use uncertainty and sensitivity analyses to develop confidence intervals for the groundwater travel time, maximum concentration in the aquifer, and cumulative release to the accessible environment.

2.4 United States Nuclear Regulatory Commission Regulations and Guidance

Performance standards for low-level waste disposal facilities are described in 40 CFR 191 and 10 CFR 61. To be licensed, a disposal facility must meet certain requirements. For example, 10 CFR Part 61 requires that one can model the site.

Various SRPs (e.g., NRC 1983, 1988a, 1988b, 1991a, 1991b, and 1991c) and other guidance show that NRC staff look for specific technical evidence in their evaluation of the uncertainty of the groundwater and transport models. Specifically, NRC staff want evidence that gives the calculated radionuclide concentrations and groundwater travel time at appropriate distances down gradient from the site, including associated uncertainties in the methods and data (NRC 1991a, 6.1.5.1, p. 6-7).

3.0 MODEL COMPARISONS TO FIELD DATA

Federal and State regulations give some guidance regarding the comparison of predicted model outputs with historical field data. Three types of activities perform this comparison: (1) model calibrations, (2) performance evaluation (i.e., extended verification or "validation"), and (3) post audit assessments. Calibration matches predicted against historical field data. Performance evaluation uses the calibrated model to predict new results and compares them with independent data measured over a longer period and at different times. Post audits compare model predictions with field data collected several years after completion of model study.

3.1 United States Environmental Protection Agency Regulations and Guidance

US EPA (US EPA 1986, p. 158) gives brief guidance on how to use field data in the calibration of the groundwater model. Van der Heijde and Park (van der Heijde and Park 1987) discuss the use of data in performance evaluations. These field data should represent a totally independent set of field measurements (as opposed to those used in the calibrated model) that involve multiple conditions at uniquely different hydrogeologic stresses.

Van der Heide (van der Heide 1987) gives guidance on quality assurance programs for collected data that would be used in model comparisons.

3.2 United States Department of Energy Orders

For low-level waste facility siting, the DOE (DOE 1988b, Chapter 3) states that: "(3) where practical, monitoring measurements to evaluate actual and prospective performance should be made at locations as required, within and outside each facility and disposal site. Monitoring should also be used to validate or modify the models used in performance assessments."

3.3 United States Nuclear Regulatory Commission Regulations and Guidance

For low-level waste facility siting, NUREG-0856 (NRC 1983) and the NRC (NRC 1991b, p. 6.1.5.1-4) require comparisons with field data or data from well design experiments to demonstrate that the model correctly accounts for major processes and can accurately represent the geohydrologic system.

4.0 MODEL APPLICATION

Model application involves the use of the model to make predictions to support investigatory or design efforts. Quality assurance is also included in this section because adequate execution of related technical and scientific tasks requires reproducible and defensible modeling results. The following subsections review the guidance for model application and related model quality assurance as given by Federal and State regulations.

4.1 United States Environmental Protection Agency Regulations and Guidance

The US EPA (US EPA 1986, p. 156) sees uses of modeling, although with recognized limitations. For example, it says "modeling results should not be unduly relied upon in guiding the placement of monitoring wells or in designing corrective actions." In contrast, the US EPA's RCRA alternative concentration limit guidance (US EPA 1987a, p.4-6) states that "[a]lthough not required for an ACL demonstration, mathematical simulation models of groundwater flow and contaminant transport can be extremely useful tools for the applicant..."

The Superfund program allows modeling to predict concentrations in groundwater for an assessment of risks at the site (US EPA 1986a, 1988a) and to predict the concentration for an assessment of the residual risk after implementation of the preferred remedial action (US EPA 1988a).

The US EPA (US EPA 1992, Section 3.5.3.3) gives some brief guidance on the use of quality assurance in modeling activities. Specifically, US EPA (US EPA 1992, Section 3.5.3.3) deals with obtaining, installing, and using a model. Van der Heijde (Heijde 1987) has also outlined several elements of a model quality assurance program.

4.2 Ohio Environmental Protection Agency Regulations and Guidance

The DGW addresses model application through its guidance and policy entitled "Groundwater Guidance on Solid Waste Siting Criteria: Minimum Distance from a Public Water Supply Well, Ohio EPA (Ohio EPA 1991a)." The Ohio EPA (Ohio EPA 1991a, pp. 1-2) places restrictions on the siting of a sanitary landfill facility (SLF). An SLF cannot lie "...within the surface or subsurface areas surrounding a public water supply well through which contaminants may move toward and may reach the public water supply within a period of five years." This rule protects public water supply (PWS) wells by mandating a 5-year water TOT. This TOT provides time to assess and remedy possible releases of leachate at an SLF. The Ohio EPA (Ohio EPA 1991a) explains how to show compliance with this rule and what criteria may exempt a facility from this rule.

All four of the following final guidance and policy documents issued by the DGW deal indirectly with various model application and documentation and review aspects of model quality assurance:

1) Review of Groundwater Quality Assessment Plans

2) Guidance on Solid Waste Siting Criteria: Minimum Distance from a Public Water Supply Well, Ohio EPA (Ohio EPA 1991a)

3) Significant Zone of Saturation, Ohio EPA (Ohio EPA 1991b)

4) Procedures for DGW Review and Comment on Sanitary Landfill Facility Permit-to-Install Applications, Ohio EPA (Ohio EPA 1991c)

The Ohio EPA (1990a) establishes policy and procedures for DGW review of groundwater quality assessment plans (GWQAP) submitted for hazardous waste land disposal and other similar types of facilities. In terms of model application, these requirements suggest specific uses of groundwater and transport modeling that would help integrate and interpret site specific data. Furthermore, modeling would also help define additional data needs that ultimately will be used to evaluate alternatives.

4.3 United States Department of Energy Orders

The DOE (DOE 1988a, Chapter 3) deals primarily with model application and only indirectly with model quality assurance by reference of various NRC regulations which are discussed below. Specifically, DOE 5820.2A, Chapter 3, outlines performance objectives and performance assessment requirements for the management of low-level waste (LLW). It states or recommends that the DOE:

1) Must analyze Federal and State regulatory requirements to determine application to each LLW management facility.

2) Review standards imposed by NRC with a caution that these usually do not directly apply to DOE operations.

3) Should consult NRC and US EPA regulations to determine "what, if any, application they have to the management of LLW at DOE facilities." However, the DOE (DOE 1988a, Table 2) remains unclear as to what type of DOE LLW facility is not regulated by 40 CFR 190 and 191.

4) Must analyze the regulations on a case-by-case basis for each facility.

5) Must assess performance as part of design process and use a "systematic analysis of potential risks posed by waste management systems to the public and the environment, and a comparison of those risks to established performance objectives (DOE 5820.2A, Attachment 2, p. 3).

4.4 United States Nuclear Regulatory Commission Regulations and Guidance

Regulation 10 CFR 61 stipulates key standards for model applications that evaluate facility performance. These regulations contain reference to limits on:

1) Cumulative releases of radioactivity to the accessible environment

2) Radionuclide concentrations in special sources of groundwater

3) Groundwater travel time requirements from the disturbed zone to the accessible environment

NRC guidance requires various model application and model quality assurance efforts. NRC (NRC 1983, 1991c) has comprehensive guidance to define a process for reviewing model applications. These efforts include the use of a quality assurance program to ensure adequate quality in the developed and maintained computer codes and data generated for and by these codes including a catalog of changes and the most updated version of the codes in use (NRC 1991c, p. 1). The NRC requires a description of the contaminant transport models used in the analysis, including modeling procedures and complete documentation of the codes as required in NUREG-0856 (NRC 1983; 1991b, p. 6.1.5.1-4). Also, the guidance requires that evidence exists that justifies, documents, verifies, and calibrates any equations or program codes used in the analyses (NRC 1991a, p. 2-9). Also, NRC guidance requires evidence of peer review and management approval to ensure a systematic record of reviews for most geotechnical data, flow and transport calculations analyses (NRC 1988b; 1991c). The NRC guidance considers the maintenance of a quality assurance program on both the computer codes and the data that goes into these computer codes.

NRC (NRC 1991a, p. 9-5, 3rd paragraph) guidance suggests that measures include those that ensure verification of accuracy of data input to computer codes. NRC (NRC 1991c, p.3-4) suggests that these data should be defined, controlled, and verified. In addition, the intended use of these data should be documented as part of the planning process. This model data base should help the NRC evaluate the "defensibility, suitability, and basic conservatism " of the modeling results (NRC 1991b, p. 6.1.5.1-3). A model data base should be developed that follows these suggestions. Model inputs should consist of raw site data, performance assessment data, and engineering design data. Site data should include regional and site data from current activities and past site studies. NRC (NRC 1988c, Table 1) lists tests and procedures necessary to evaluate or document approximately 70 important parameters for licensing a low-level radioactive waste disposal site.

APPENDIX B

US EPA AND OHIO EPA COMMENTS ON CRU2 REMEDIAL INVESTIGATION REPORT

307. Commenting Organization: U.S. EPA Commentor: Gene Jablonowski
Section #: 5.3.3.1 Pg. #: 5-13 Line #: 9 Code: C
Original Comment # 24
Comment: It should be clearly stated how attenuation, the loss of contaminants from the plume, could be a factor that would affect radionuclides with relatively long half-lives (> 1000 years) or low mobility.

Response: **Agreed.**

Action: **More discussion will be provided in the revised (Phase II) RI concerning the attenuation of radionuclides with relatively long half-life (> 1,000 years) or low mobility.**

308. Commenting Organization: U.S. EPA Commentor: Gene Jablonowski
Section #: 5.4.7 Pg. #: 5-61 Line #: 20 Code: C
Original Comment # 25
Comment: This section should not only summarize the contaminant transport information for the individual waste areas, but also the cumulative contaminant transport effects, if they exist, of all the OU 2 waste areas combined.

Response: **See Comment/Response No. 304.**

Action: **See action to Comment/Response No. 304.**

304. Commenting Organization: U.S. EPA Commentor: Gene Jablonowski
Section #: 5.3.1 Pg. #: 5-9 Line #: 4 Code: M
Original Comment # 21
Comment: In calculating the resuspension rates and the highest on-site and off-site airborne particulate concentrations for each of waste areas, calculations should have been performed to determine areas on-site and off-site that are maximally affected by the cumulative effects of all the waste areas.

Response: **Agreed.**

Action: **Issues regarding appropriate modeling protocol and procedures used in the draft RI air transport analysis are unresolved. In the event that the modeling effort requires revision, Section 5.3.1 will be revised to include the cumulative effects of all the waste areas.**

247. Commenting Organization: U.S. EPA Commentor: Saric
Section #: Appendix B Pg. #: B-52 Line #: 37, 38 Code:
Original Specific Comment #221
Comment: The text states that conceptual models were used to simulate ground-water flow. This statement appears to be inaccurate because only one model was used to simulate ground-water flow at the site. DOE should check and correct this statement, if necessary.

Response: **Comment noted.**

Action: **The text will be checked and corrected, if necessary.**

250. Commenting Organization: U.S. EPA Commentor: Saric
Section #: Appendix B Pg. #: B-82 Line #: 23 Code:
Original Specific Comment #224
Comment: The text should define the term "normalized concentration."

Response: **Agreed.**

Action: **Normalized concentration will be defined in the revised text.**

251. Commenting Organization: U.S. EPA Commentor: Saric
Section #: Appendix B Pg. #: B-97 Line #: 10 Code:
Original Specific Comment #225
Comment: DOE should provide examples of the constituents referred to in the statement "peak concentrations of some constituents . . . can be expected to be quite low." The range of the expected low concentrations should also be provided.

Response: **Agreed.**

Action: **A list of constituents and ranges of concentrations will be provided.**

252. Commenting Organization: U.S. EPA Commentor: Saric
Section #: Appendix B Pg. #: B-157 Line #: 18 Code:
Original Specific Comment #226
Comment: The phrase "of the contaminant plume" should be revised to read "of the concentrations in the contaminant plume."

Response: **Agreed.**

Action: **The text will be corrected.**

331. Commenting Organization: OEPA Commentor:
Section #: Pg. #: Line #: Code:
Original Comment # 4
Comment: The RI report fails to determine whether any of the waste units are contributing to groundwater contamination presently. Significant groundwater contamination does occur near a number of the waste units. The resolution of the waste units as groundwater contamination sources can not be put off until the OU5 RI, since the OU2 ROD should be complete before the issuance of the that RI.

Response: **Agreed.**

Action: **See action to Comment/Response No. 22.**

2. <u>Specific Cmment - #1-119</u>
(Commentor: Ohio EPA and GeoTrans)

353. Commenting Organization: OEPA Commentor:
Section #: Pg. #: P4-29 Line #: 21-27 Code:
Original Comment # 22
Comment: DOE has not included figures illustrating ground water flow based upon the quarterly Phase II RI Report sampling events. Additionally, the text does not include a technical discussion of ground water flow gradients or directions. As a result, it is impossible to evaluate MW 2052's adequacy as an upgradient monitoring well.

Response: **Agreed. The same comment was received from the US EPA.**

Action: **The revised (Phase II) RI Report will contain an expanded discussion of the hydrostratigraphic features.**

386. Commenting Organization: OEPA Commentor:
Section #: Pg. #:5-21 Line #:31-36 Code:
Original Comment # 55
Comment: Ohio EPA has identified many problems with the SWIFT II model as it has been used by DOE. DOE is currently taking action to fix some of these problems. As such, it is not suitable for use for the OU2 RI fate and transport modeling. Once the model input is corrected, then it can be used for this process.

Response: **A global groundwater model improvement task based on USEPA and OEPA comments is currently underway. However, the problems associated with the current groundwater model may not be critical to the type of model applications in the OU 2 RI report.**

Action: **Necessary justifications of the type of model applications in OU 2 RI using the current model and the needs of model sensitivity analyses will be determined for the revised (Phase II) RI Report.**

428. Commenting Organization: OEPA Commentor: GeoTrans
Section #: 5.4.1.3 Pg. #: Line #: Code: C
Original Comment # 97
Comment: Is it possible that vertical mixing is only on the order of a few feet or less thus questioning the vertical discretization used in the groundwater transport model. If the size of the grid blocks is significantly greater than the vertical mixing of the plume, the model will result in geometric mixing and underprediction of the level of the concentration. In other words, by applying relatively coarse vertical grids, the model will undercalculate the concentration level. Has this been sufficiently explored? In the regional model this was less of an issue as the scale of the transport plume was greater.

Response: **The corrected contaminant loading terms from ODAST and the measured vertical contaminant concentration profiles will be used to study the selection of the size of the vertical mixing zone. It is expected that the vertical resolution of the current groundwater model is sufficient to support the risk assessment.**

Action: **The size of the vertical mixing zone will be discussed in the revised (Phase II) RI Report text.**

429. Commenting Organization: OEPA Commentor: GeoTrans
Section #: 5.4.1.3 Pg. #: 5-26 Line #: 31 Code: E
Original Comment # 98
Comment: What uranium is presented in the contour plot? Is it U-238 or all isotopes added together. This should be more clear both in the text and the figures. Also what model layer is this? It appears to be the topmost layer.

Response: **Comment noted.**

Action: **The text of the revised (Phase II) RI Report will be clarified with regard to presentation of the results.**

445. Commenting Organization: OEPA Commentor: GeoTrans
Section #: B.3.7.2 Pg. #: Line #: Code: M
Original Comment # 114
Comment: It would very useful to provide summary tables or plots of the mass in place. It is difficult to understand just how much of the material actually leaches, how much is in the vadose zone (sorbed and dissolved) and how much is within the groundwater flow system (sorbed and dissolved) and how much actually decayed. A semi-log plot might be useful here.

Response: **Comment noted.**

Action: **A discussion of mass balance of the contaminant in the model simulations will be presented in the revised (Phase II) RI Report.**

446. Commenting Organization: OEPA Commentor: GeoTrans
Section #: B.3.7.2 Pg. #: Line #: Code: M
Original Comment # 115
Comment: There should be some discussion or displays of the concentration level at different depths. It is difficult to understand and accept the areal contours without some indication of the vertical mixing. A vertical plot would be extremely useful.

Response: **Comment noted.**

Action: **Representative vertical profile of contaminant concentrations will be provided in the revised (Phase II) RI Report.**

448. Commenting Organization: OEPA Commentor: GeoTrans
Section #: B.3.7.1 Pg. #: B-104 Line #: 19 Code: M
Original Comment # 117
Comment: How were the parameters varied? What determined acceptable recalibration? What were the final values? How did these vary from the regional model? What is the importance of these changes? Does this say something regarding the calibration efforts of the regional model? It seems that the local model was recalibrated with

greater emphasis on matching the local monitor wells. Why not provide the statistics as was provided in the regional model calibration?

Response: **Comment noted.**

Action: **The development of the regional and local groundwater model will be described in detail in the Groundwater Modeling Report to be submitted in April, 1993.**

449. Commenting Organization: OEPA Commentor: GeoTrans
Section #: B.3.7.1 Pg. #: B-104 Line #: 9-30 Code: M
Original Comment # 118
Comment: There is no discussion of the perimeter boundary conditions. It must be assumed that the calibrated heads from the regional model were interpolated to for Dirichlet (prescribed heads value) boundary conditions. This should be more clearly stated as this has definite implications regarding the limitations of mesh refinement. For example, the local area model must be used with caution in modeling any additional sources/sinks at wells. Furthermore, the model can not be easily used to simulate transient groundwater flow.

Response: **See Comment/Response No. 448.**

Action: **See action to Comment/Response No. 448.**

450. Commenting Organization: OEPA Commentor: GeoTrans
Section #: B.3.7.2 Pg. #: B-105 Line #: 33-35 Code: M
Original Comment #119
Comment: How were the loading rates defined? Was the interpolation performed using the log of the concentration? Was there a check on the preservation of, i.e. the area under the curves? Could the approximation of the "spikes" to a uniform value for a specified period of time result in an additional numerical mixing and loss of artificial reduction in the calculated peak concentration?

Response: **Comment noted.**

Action: **The revised (Phase II) RI Report will clarify the use of the ODAST model and the source term determination process.**

APPENDIX C

OHIO EPA COMMENTS ON CRU5 INITIAL SCREENING OF ALTERNATIVES REPORT

Commenting Organization: Ohio EPA Commentor:

Section: Page: 6-2 Lines: 1, 2, and 3 Comment Code:

Comment No. 27

Comment: This is representative of the SWIFT III model, which was not approved by the Ohio EPA (see comment 18 above). Figure 6-1 is not representative of the existing south plume contaminant concentrations and/or flow conditions. Please correct.

Response: Figures 6-1 and 6-2 are representations of the studies done for placement of the South Plume EE/CA (now South Plume Removal Action) well fields. They are not necessarily required to support the ISA text and will be deleted. However, they cannot be replaced with maps displaying more recent data as this would not be representative of the data used to perform the initial study.

Action: Figures 6-1 and 6-2 and any references in the text to these figures will be deleted from the ISA report.

Commenting Organization: Ohio EPA Cementer:

Section: Page: 3-88 Line: 16 Comment Code:

Comment No. 18

Comment: SWIFT III model output data has not yet been approved by the Ohio EPA.

Response: A report is in preparation describing the SWIFT III groundwater model and its application results which will be provided to the agencies for approval in late spring. Additionally, a model improvement effort is underway to address agency concerns regarding SWIFT III and its application at the FEMP. This approach is consistent with that present US EPA representatives at the January 7, 1993 TIE meeting.

Action: The SWIFT III groundwater model reference and associated text and figures will be deleted from the ISA.

February 26, 1993 Response from Graham E. Mitchell, Ohio EPA

The DOE's responses to Ohio EPA comments on the CRU5 ISA Report were acceptable, with the exception of the comment listed below:

1) Page 13 original comment 27 - Conclusions based upon data obtained through the groundwater modeling process are invalid. If accurate site-specific data nullifies the conclusions of the South Plume EE/Ca, then the conclusions should be revisited and revised accordingly. This is not a criticism of the model but on the process and assumptions. At the groundwater meeting held in Cincinnati on January 7, numerous problems with the groundwater modeling process were discussed and the DOE outlined a plan to correct these problems and produce a model calibrated to actual field data.

APPENDIX D

THE US EPA AND THE OHIO EPA COMMENTS ON THE SOUTH PLUME REMOVAL ACTION GROUNDWATER MODELING REPORT

Department of Energy
Fernald Environmental Management Project
P.O. Box 398705
Cincinnati, Ohio 45239-8705
(513) 738-6357

SEP 1 5 1992
DOE-2694-92

Mr. James A. Saric, Remedial Project Director
U.S. Environmental Protection Agency
Region V - 5HR-12
230 South Dearborn Street
Chicago, Illinois 60604

Mr. Graham E. Mitchell, Project Manager
Ohio Environmental Protection Agency
40 South Main Street
Dayton, Ohio 45402

Dear Mr. Saric and Mr. Mitchell:

TRANSMITTAL OF RESPONSES TO UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (U.S. EPA) AND OHIO ENVIRONMENTAL PROTECTION AGENCY (OHIO EPA) COMMENTS ON THE SOUTH PLUME REMOVAL ACTION GROUNDWATER MODELING REPORT

References: 1) Letter, J. A. Saric to J. R. Craig, "Approval of the South Plume Removal Action Groundwater Modeling Report," dated June 5, 1992

2) Letter, G. E. Mitchell to J. R. Craig, "South Plume Removal Action Groundwater Modeling Report," dated May 20, 1992

This letter transmits the Department of Energy's responses to U.S. EPA comments (Reference 1) and Ohio EPA comments (Reference 2) on the South Plume Removal Action Groundwater Modeling Report. The responses are provided as Enclosures 1 and 2.

If you or your staff have any questions, please contact me FTS 513-738-6159 or C. J. Fermaintt at FTS 513-738-6157.

Sincerely,

Jack R. Craig
Fernald Remedial Action
Project Manager

FN:Fermaintt

Enclosure: As Stated

Recycled and Recyclable

cc w/enc.:

J. J. Fiore, EM-42, TREV II
S. Frush, EM-424, TREV II
K. A. Hayes, EM-424, TREV II
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R. Bowser, WEMCO
J. P. Hopper, WEMCO
L. Kahill, Radian
AR Coordinator, WEMCO

RESPONSE TO U.S. EPA COMMENTS ON THE U.S. DEPARTMENT OF ENERGY'S SOUTH PLUME REMOVAL ACTION GROUNDWATER MODELING REPORT, APRIL 1992

Comment 1: The modeling report probably overstates the accuracy of particle tracking analysis. For example, page 4-4 of the modeling report states that the revised location of the groundwater extraction wells will deflect the organic contaminant plume by less than 1 foot and the inorganic plume by a maximum of 20 feet. The U.S. Department of Energy (DOE) Ground Water Report (dated December 1991) described particle tracing as a function of the three dimensional groundwater flow model. The smallest cells used in the south plume area of interest (rows 10 through 19 and columns 5 through 10) are 250 feet by 500 feet. Unless the model code is capable of tracking particles within individual cells the accuracy is overstated. In addition, it is also unclear if the model code account for other factors which reduce the accuracy of particle tracking, such as dispersion and diffusion. Additional information could be provided to support the conclusions of the particle tracking analysis.

Response: See DOE response to OEPA Comment #1.

Action: As stated in response Comment #1 made by the Ohio EPA.

Comment 2: The Ground Water Report generally lacks sufficient documentation concerning calibration of the ground-water flow model. The three dimensional ground-water flow model was calibrated to 1986 ground-water elevation data. The ground-water flow model was not calibrated to 1988 data as was the two dimensional ground-water flow model. Both models should be calibrated to 1988 data to confirm that the ground-water model accurately represents drought conditions.

Additional calibration checks should be conducted with the most complete data set available such as 1991 or 1992 ground-water elevation data. Additional calibration of the three dimensional ground-water flow model is required because layer 1 of the model has only one observation point and layer 2 has no observation points in the area of interest in the south plume (rows 10 through 19 and columns 5 through 10). In addition, layer 2 of the ground-water flow model has only two observations points south of Fernald Environmental Management Project (FEMP) property. Because further remedial actions will be required in the south plume (as well as other areas of FEMP), an additional post-calibration verification audit should be completed.

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It is not possible to make a point-by-point check on the model's calibration because the Ground Water Report presents only the residuals between modeled and observed measurements. DOE should provide a table which presents both the observed (water level elevation and uranium concentration) and the modeled measurements.

Response: See DOE response to OEPA Comment #5..

Action: As stated in DOE response to OEPA Comment #5.

Comment 3: A review of the calibration of the contaminant transport model was not conducted; however, as with the ground-water flow model, the most complete data set should be used to calibrate the model or at least perform a post-calibration verification audit.

Response:

Action: As stated in DOE response to OEPA Comment #5.

Comment 4: To provide a check on the accuracy of the model to predict future remedial actions, the ground-water flow model should be run to simulate the effect that pumping from the south plume extraction wells will have on the water table. Ground-water elevation data for specific monitoring points should be modeled so that the model predictions can be verified by future field observations.

Response: DOE concurs with U.S. EPA comment. The predicted effect that pumping from the south plume extraction wells will have on the water table is reported in the South Plume Removal Action Groundwater Modeling Report (Figure 14). Once the wells are actually pumping, field observations will be used to verify the predictions which were made using the model.

The recently submitted South Plume Removal Action - Design, Monitoring, and Evaluation Program Plan (DMEPP), defines a program of model validation using pump test and initial operation of the well field, and routine monitoring to verify model predictions.

Action: As stated in the response.

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General Comments

Comment 1: The conclusions reached in the above-mentioned report seem to place too much credibility on the ability of the model to accurately predict the effects of well placement variation on the chemical migration. The current model lacks the required level of calibration to accurately differentiate between the alternate well schemes. For example, on page 5-1, line 8, the model is not accurate enough to reliably state that the currently proposed well field will deflect the inorganics plume by less than 20 feet. The position of the plumes is simply not that well known.

Response: DOE agrees that predictive results obtained from the FEMP local flow/transport model are limited. This limitation is due, in part, to the need for further calibration work. The FEMP transport model is not satisfactorily calibrated south of Willey Road. Until additional site specific data is obtained for the model domain pertaining to the SP, until the model mesh is further refined, until the northern PRRS plume boundaries are better delineated, and until additional calibration work has been conducted, predictions made using the FEMP local uranium transport model will remain questionable.

The SP recovery well field locations are not based on the FEMP local uranium transport model. Instead they are based on the FEMP local flow model, field based uranium contour plots, and particle tracking. Because of these inherent uncertainties, the recovery system has been designed in a conservative manner with excess pumping capacity, excess force main capacity, and additional stubs for future well connections. A periodic evaluation program will determine if the system is achieving its objectives and changes will be made based on the results of this evaluation (see DMEPP for further explanation).

Groundwater modeling was performed for the South Plume (SP) Removal Action (simulated flow vectors, linear velocities, and uranium concentration values) in an area where well control was sparse and where time predictions were queried. Recovery wells are being designed in a line normal to the axis of the plume. These recovery wells are best viewed as barrier wells with a significant capability of arresting uranium buildup at the proposed recovery location. They are based on the FEMP local flow model. Particle tracking (STLINE) was imposed on the local flow regime as estimated by SWIFT III governing flow equations under steady state conditions. Particle tracking results have been compared and integrated with field characterization data south of Willey Rd.

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The extent of the uranium plume in the South Plume Area is best determined using field-based uranium contour plots. South of Willey Rd, well control (for modeling purposes) is believed to be satisfactory along the eastern frontage of Paddys Run Rd. Predicted water levels near Paddys Run appear to be adequately calibrated. In the case of transport though, only three wells have been calibrated for uranium in wells south of Willey Road. Risk assessment time plots generated from FEMP local flow/transport modeling, over time intervals of 5, 10, 20, ... years at best postulate a southeasterly component and a moderate uranium concentration gradient on the western edge of the SP.

Because of the limited well calibrations for extrapolating uranium transport and the conservative approach to stress advective transport of uranium, particle tracking (STLINE) was emphasized in the SP well recovery field design. Particles seeded in the uppermost model layer suggest that the proposed configuration of SP recovery wells will have the least impact on the PRRS plumes. The cell size of the mesh south of Willey Rd. preclude accurately predicting particle deflections of the order of 20 ft. The particle tracking is initially constrained by the output flow vector and velocity from a SWIFT III cell. That output is generated from 125 ft cells. This mesh cell size of the SP improved the numerical stability in solving the governing flow equations but is too coarse to be employed in other routines to predict particle deflections of 20 ft.

Action: The modeling report will be revised to stress the use of the FEMP regional flow and FEMP local flow/solute model as an optimization tool rather than an accurate predictor of deflections in the PRRS plumes. Text will also be revised to emphasize the accuracy of the model predictions being made using the various groundwater model codes.

Additional site specific data will be obtained from the South Plume area during a planned pump test and the installation of additional monitoring wells under Parts 2 and 3 of the South Plume Removal Action. Work is proceeding (Part 5 of the South Plume Removal Action) to further delineate plume boundaries in the South Plume Area. Further calibration work is also planned (see response to OEPA comment #5).

Comment 2: The discussion on model sensitivity on page 4-7, lines 25-35 clearly indicates that the model is overly constrained in its ability to represent the groundwater flow system. The model does not include the local hydraulic variability on the scale of tens and hundreds of

feet, thus is not the referenced sensitivity analysis (i.e, variation of hydraulic conductivity and recharge) are not provided in the report.

Response: Flow parameters imported from the FEMP regional flow model to the FEMP local flow model might be off-scale in some areas of the model domain if localized hydraulic variability in those areas is high. Site specific hydraulic data to support modeled input parameters is sparse south of Willey Rd. However the calibrations of water levels on the western side of FEMP toward the SP area are less than 1 ft utilizing, for example, a hydraulic conductivity (K_h) of 450 ft/day in model layer 1 of the FEMP flow model. A limited number of wells though were utilized in the calibration of the SWIFT III FEMP regional flow model with April 1986 data. However flow predictions made using SWIFT III continue to match at 95% confidence intervals the water levels measured in wells along Paddys Run. The pronounced flow gradient patterns along Paddys Run are also repeated. Elsewhere in the SP area, well control is too sparse to confirm whether the FEMP local flow model is predicting flow patterns adequately.

Sensitivity analyses are necessary to assess how (1) changing hydraulic parameters, particularly in model layer 1 of the Great Miami Aquifer affect model performance; and (2) localized hydraulic parameters influence model performance.

Sensitivity analyses were conducted on the regional FEMP flow model. Sensitivity of horizontal hydraulic conductivity, for example, was performed on two interim calibrated runs prior to completion of the final 1986 regional FEMP flow model calibration. Because the runs were only on model layer 4 and 5, and associated with the FEMP regional flow model, it is uncertain how variable conductivities and recharge impact the FEMP local flow model performance in the SP area. Model performance by the FEMP regional flow system apparently is not sensitive to horizontal hydraulic conductivity, for example, because of the influence of the seepage of the Great Miami River. This is not unexpected but the river's influence may be limited in the area of the SP. ASI/IT (1990) does show that Darcian velocities increase 13 % up to a distance of about 7250 ft from the SOWC collector field but those velocity vectors are not situated in the SP area. Still local differences in hydrauiic parameters may influence the SP predictions.

The range of horizontal/isotropic hydraulic conductivities that were bracketed by the sensitivity runs are attached; additional horizontal/isotropic hydraulic conductivities are provided that are

in ASI/IT (1990) and other reports.

Presently there is a task underway to validate the groundwater model in the vicinity of the south plume. This task is part of the design confirmation program as described in the South Plume Groundwater Recovery System, Design, Monitoring, and Evaluation Plan (Rev. 0, July 15, 1992). This task consists of a pump test, monitoring the groundwater elevation effects over the first quarter of the operation of the recovery well system, and validating the SWIFT site model using these data. Data collected from this validation process will be factored into model re-calibration work as deemed appropriate.

Sensitivity analyses will be performed for the upper model layers within the FEMP local flow/transport models. Spatially weighted statistical measures will also be performed to quantify the degree of uncertainty surrounding the wells south of Willey Rd.

Action: The report will be revised to emphasize the limitations of the modeling near the SP.

Comment 3: The Groundwater Report (ASI/IT, 1990) shows the predicted present plume (Figure 21-27) and the 70-year prediction (Figure 21-32), whereas this report shows the present plume (Figure 13). There is now way to easily inspect the simulated effects of the currently proposed well field. To illustrate the simulated effects of the proposed recovery well withdrawals, the report should display the predicted plumes at 5 or more years with and without the proposed well fields.

Response: DOE concurs with Ohio EPA comments.

Action: The report will be revised with figures and appropriate text describing the SP uranium transport with and without the planned recovery well field south of Willey Rd. Each figure will show output of the predicted uranium concentrations at 5, 10, 20, and 70 year intervals.

Comment 4: The predicted hydraulic head map (Figure 15) should include greater detail (i.e., a contour interval of 0.1 ft. on a separate smaller-scale figure) in the region near the well field. This will allow a better interpretation of the simulated capture zone.

Response: The accuracy of the hydraulic heads or water table elevations for model layer 1 are constrained by the FEMP regional flow model.

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Calibrated flow vector fields in the FEMP local flow model in the SP area may have error bars greater than 1 ft. This is actually uncertain because the sensitivity runs were limited to the lower layers of the model and do not have a bearing on model layer 1.

During pumping of the SP recovery well field the water table conditions will change and the drawdowns in the new potentiometric surface probably can be modeled with greater accuracy.

Action: DOE concurs with OEPA comment. The modeling report will be revised to include a predicted drawdown map with a smaller contour interval to obtain better definition of the drawdown in the vicinity of the recovery wells. The scale of the predicted potentiometric map will be enlarged to depict finer contour intervals.

Comment 5: There appears to be too much credibility placed on the predicted well performance in Figures 16 to 18. The simulated plume is a gross generalization near Paddy's Run. In the Groundwater Report, the two uranium measurements in layer 1 have residuals of -35.54 and 161.88 (Figure 21-11) and in layer 2 a residual of -116.19 ug/ is reported (Figure 21-12). Predicted concentration reductions in this area of the model are suspect as evidenced by the fact that deviations between measured and simulated uranium concentrations are on the order of the simulated well field concentration changes.

Response: The FEMP transport model is not satisfactorily calibrated south of Willey Rd. Three wells were utilized in model layer 1 and one was outside the 95% confidence limit. They are not triangulated across the predicted extension of the SP across Willey Rd.

The SP recovery well field locations were not based on the FEMP local uranium transport model. They were based on the FEMP local flow model. Particle tracking (STLINE) was imposed on the local flow regime as estimated by SWIFT III governing flow equations under steady state conditions. Model results were compared and integrated with field characterization data south of Willey Rd. DOE agrees that the model needs to be recalibrated but because of the SP recovery well field locations are not based on the FEMP local uranium transport model, the recalibration will not be addressed in the SP report.

Action: The SWIFT III FEMP local transport model will be re-calibrated using available and representative wells south of Willey Rd. and utilizing the original hydraulic parameters. This may improve the residuals and/or point out differences with the field-based uranium contour maps. Further, preparations will be made to perform a spatially

statistical analysis of the uranium concentrations of the SP. This will assist determining better the spatial variance of uranium. It has not been determined yet if a separate report for this activity will be issued or if the work will be appended to an existing or planned document.

Comment 6: The predicted heads in layer 1 of the local transport model (Figure 6) are clearly impacted by the assumed recharge distribution (groundwater report, Fig 20-15) and are not the same as those appearing in the groundwater report (Figure 20-19) in the area east of the village of Fernald and just west of the bedrock "island." The importance of this is that the spatial allocation of the recharge in this area significantly determined the convergence of the plume as it crosses Route 128. Furthermore, the degree of flow convergence directly determines the predicted easterly deflection of the particles from Paddy's Road Run Site. The sensitivity and importance of the recharge variations should be addressed and not simply dismissed on page 4-7.

Response: The predicted water table elevations of the GMA shown in Figure 6 are identical to those in Figure 20-19 of the Groundwater Report (ASI/IT, 1990). The isopleths in the area east of Fernald and west of the bedrock "island" are an artifact of the contouring package. The contouring program extrapolated points outside the model's aquifer cells and caused the contours to bend. The splining function in the contouring packages tend to "pull" contours toward the margin. This is evidenced by the flow arrows shown in the same figure, which do not flow out from the bedrock but flow near parallel with the model bedrock boundary. These same contours were deleted from Figure 6 of the Removal Action report due to their anomalous nature but were not edited out of the draft Groundwater Report (ASI/IT, 1990).

Action: No action required, as noted in response.

Comment 7: Results of the 72-hour aquifer test conducted in the vicinity of alternate water supply well AW-1 suggest that the hydraulic conductivity of the Great Miami Aquifer in the south plume area may be much greater than that used in the model. If this is the case, much higher pumping rates will be required for plume capture. DOE reports that the proposed recovery well locations will be optimum in any event (page 4-7, lines 25-26). However, if the pumping rates need to be doubled or tripled to achieve the desired plume capture, will the Part 3 IAWWT system have adequate capacity? DOE should conduct a bounding type analysis of its 72-hour pump test to

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estimate a range of hydraulic conductivity consistent with the test data; and then report its results. What are the consequences for the removal action if the hydraulic conductivity in the south plume area is significantly higher than estimated by DOE? What contingency options are available to deal with the consequences?

Response: Results of the 72-hour pump test, designed to confirm water supply for Albright & Wilson Co., did not quantify hydraulic conductivities for the Great Miami Aquifer. The test was not conducted long enough to stress the aquifer. A pump test conducted to the north at Production Well-2 (within the modeled domain) by the USGS in 1962, resulted in a horizontal hydraulic conductivity (K_h) calculation of 267 ft/d. It is possible that the K_h is actual larger due to the partial penetration of the test well used during the 1962 test. A higher value (450 ft/day) has been employed in the FEMP flow model for the upper model layer. This value was also utilized in the SP recovery design as it represents the high end value for the calibrated upper model layer where the pump inlets are planned.

Each of the five recovery well screens/casings are designed for 800 gpm. The pumps are designed to be operated at a nominal 400 gpm each, but will be capable of operating at an upper range of 650 gpm if necessary. At 400 gpm, the capture zone analyses suggest that a hydraulic barrier be achieved. The IAWWT is designed for a SP pumping rate of 2000 gpm at 140 ppb uranium. A margin of safety is available in the event that flow and/or the concentration of uranium is greater than anticipated. Operating parameters for the IAWWT may need to be revised to increase thruput in the event that the margin of error is too great. Continuous evaluation of all factors (i.e., actual rate & concentration from the south plume, waste pit runoff control project, existing waste-streams) affecting the makeup of the 1700#/yr will be conducted, when the systems are operational, to see if further adjustments are required.

Action: The DMEPP has defined a program of periodic monitoring and system evaluations to determine if the recovery system is meeting the removal action objectives. Based on these results, system modifications will be implemented as necessary.

Specific Comments

Comment 8: Pg.#1-1, Line #36. Mercury is not a contaminate associated with the Paddy's Run Road Site (PRRS) and should be removed from this line.

Response: DOE concurs with OEPA comments.

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Action: Mercury will be deleted as per the comment.

Comment 9: Pg.#1-4. The last sentence in this paragraph appears to be misstated. Part 3 was expanded to ensure that no more than 1,700 lbs. of uranium would be discharged annually to the Great Miami River.

Response: DOE concurs with OEPA comments.

Action: The line will be corrected to read "...no more than 1700 pounds per year..." as per the comment.

Comment 10: Pg.#1-4. "will not" should be changed to reflect probability associated with modeling efforts. While this may appear trivial, Ohio EPA wants to stress the limits of numeric modeling to DOE. A model is at best a tool which can help a hydrogeologist make decisions which are based upon a sound knowledge of the hydrogeology of a site. A model can never be a substitute for good data.

Response: DOE concurs with OEPA comments.

Action: The line will be changed to read "Groundwater flow and solute transport modeling has been performed to determine a location where pumping of the recovery well field is predicted to not significantly affect the PRRS plume and to not draw PRRS contaminants into the recovery wells."

Comment 11: Pg.#1-4, Line#20. It is unclear to Ohio EPA if this is based upon actual data or a model prediction. This should be clarified by DOE.

Response: The line will be changed to stress that the data cited is based both on actual field observations and on model predictions.

Action: Line #20 will be revised as per the response.

Comment 12: Pg.#2-9, Line#1. DOE should give specific references; do not simply reference "scientific literature".

Response: DOE concurs with OEPA.

Action: The references of Anderson (1984; 1989) and Borg (1976) will be added to this line and included in the references.

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Comment 13: Pg.#2-9, Line#7. If geochemical investigation showed "that uranium is in complexes which have neutral or negative charges; such charges imply low retardation," then why does DOE use a retardation factor of 12 in the ground water model? This should be explained in detail by DOE and should be supported with the appropriate field data.

Response: Site specific differential uranium leaching analyses for aquifer solids taken from split-spoon cores in the SP were collected to assist in the determination of retardation factors. South of Willey Rd., there were 3 samples collected from 2000-series wells and 1 sample collected from 3000-series wells. In combination with analytical results from groundwater in these wells, the arithmetic mean of uranium partitioning from solid to water was calculated as 2.38 l/kg (+/- 1.42 l/kg). The corresponding retardation factor is 25.75 (+/- 2 sigma = 10.98 - 40.52) employing a porosity of 0.25 and a bulk density of 2.60 g/cc.

This leaching technique recovers iron (FE) and manganese (MN) from any coatings on grains during the analyses. As a result, the uranium represents both recent uranium presumably from product releases at FEMP plus background uranium adsorbed onto solids in the GMA.

Aqueous speciation modeling of the groundwater in the GMA near the SP suggest a predominance of uranium carbonate complexes $UO_2(CO_3)_3^{-4}$, $UO_2(CO_3)_2^{-2}$, $UO_2(CO_3)^0$ and/or $UO_2(H_2PO_4)_2$. The predominance of negative-charged and neutral-charged uranium speciation in the sampled groundwater would suggest lower potential for uranium retardation. These complexes would tend to be repelled by negatively-charged clays in the GMA.

However, the presence of some Fe-compounds on aquifer solids in limited split-spoon cores would suggest that uranium may be retarded from entering into solution. The influence of Fe and Mn leaching influenced the selection of retardation factors of 9-12 into the FEMP local transport model. Equally significant, was the observation that lower retardation factors would have resulted in uranium predictions beyond the presently observed distribution of uranium south of Willey Rd.

Retardation is variable and competes with other geochemical processes that are difficult to model locally without site specific data south of Willey Rd. The governing equations of transport are dependent greatly on dispersivities which were estimated from the literature.

Action: The report will be revised to reflect the uncertainties associated with the model transport equations and emphasize the limited

laboratory analyses of aquifer solids and groundwater south of Willey Rd.

Comment 14: Pg.#2-9, Lines#17-31. A groundwater plume may not have a true mean concentration. If the concentration changes in time it may be, and probably is, related to temporal changes in geochemistry. Therefore, it is technically incorrect to average concentrations over a two year period of time for the sake of calibration.

Response: Time-averaged data were employed in the calibration of uranium at each well. It does not represent a mean of replicates at one time-slice at the well. With few wells available for calibration south of Willey Rd, in particular, multiple sampling rounds was the only viable substitute.

Aqueous speciation modeling suggests that the predominant uranium complexation will be carbonate or phosphate. It is unlikely that radical changes in speciation of uranium complexes will occur during the time-averaging period. Absolute concentrations will vary though as desorbtion occurs between the aquifer solids and the water column.

Selected time-series sampling and statistical autocorrelations will be employed to more fully measure absolute uranium concentration fluctuations. In the past, general inspection of uranium concentration vs. time plots for most wells did not exhibit great fluctuations. A 95% confidence limit on the time averages was employed in the calibrations. Outliers were not treated because the steady state modeling adjusts uranium predictive values to a normal distribution. The FEMP local transport model was not run under a transient mode. Dynamically changing uranium concentrations in the SP are difficult to predict under the present model design.

Action: The report will be revised to emphasize the uncertainties associated with time-averaging and the limitations of the FEMP local transport modeling.

Comment 15: Page#3-1, Lines#24-29: It is unclear to Ohio EPA as to how DOE determined that the error in the model indicates that source loading was greater in the past. Ohio EPA believes that this error could also represent incorrect values for attenuation and hydraulic conductivity.

Response: FEMP local transport model predictions of uranium are calibrated on a few wells south of Willey Rd. The residuals are poor and it is unclear if the input parameters are accurately reflecting the

transport processes beneath parts of FEMP. The gross geometric patterns of the SP component at FEMP match the observed gross patterns. Site specific parameters, such as retardation of uranium, dispersivity, and hydraulic conductivity, may significantly influence local perturbations of the SP.

The residuals are probably a combination of SWIFT III model performance, lack of site specific model input parameters, and uncertain loading patterns of uranium at FEMP.

Observed geochemical parameters including uranium distribution suggest at least two loading source regions for anomalous contamination on the western FEMP area (i.e., Waste Pit area and the SSOD area). The existing SP has either separated from its loading term under the waste pits and/or is sourced from historical releases in the SSOD area. There is an observed gap between the SP and the waste pit area. Present uranium data in the waste pit area suggest continued fingering between the 2000 and 3000-series depths. Transport from the 1000-series to the 2000 series depths appears to have been slowed. Presumably past loadings at the 2000 series have since been transported to the present SP configuration. Or that with the aid of Paddys Run losing reaches has allowed contamination to enter the water table of GMA near the confluence of the SSOD.

Action: The report will be revised to emphasize the uncertainty of the FEMP local transport model to simulate changes in the distribution of uranium.

Comment 16: Pg.#3-1, Lines#38-3-2. This section describes modeling of the alternate water supply area. DOE does not have any site specific hydrogeologic data for this area. Such data is necessary for model calibration.

Response: A water-supply type pump test was performed in AWS-1. The water table drawdown was measured on a datalogger for up to 72 hours in observation piezometers. The drawdown was minimal and time-drawdown plots could not resolve hydraulic parameters such as conductivity.

Nevertheless, particle tracking superimposed on the FEMP local flow model suggested no influence of the AWS-1 pumping (500 gpm) on the present observed configuration of the SP uranium.

Action: The report will be revised to clarify the applicability of the water-supply well testing and the FEMP regional and local flow modeling.

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Comment 17: Pg.#3-2, Lines#27-34. The Ohio EPA recommends that DOE develop contingencies which will allow for the installation of additional capture wells if it is determined that they are necessary to meet the goals of the interception system. Site specific data for this area will not be obtained until after the first recovery well is installed. As a result, DOE has used a ground water model which is not capable of accurately determining contaminant concentrations to provide information on the location of interception wells. This was deemed by GeoTrans to be an unacceptable use of the ground water model. This practice is inverse of the accepted use of ground water models. Ground water models are intended to provide a hydrogeologist with tools to take existing site specific hydrogeologic data and extrapolate out the effects of time and influence. Once the conceptual model is created, the standard scenario for modeling is:

1. Estimate hydrogeologic values based upon published data for the general area.

2. Obtain site specific data.

3. Input site specific data into the ground water model.

4. Calibrate the model based upon observed data and existing site specific data.

5. Verify the model over time.

Because DOE did not input site specific data and use regional area data, the effectiveness of the model is greatly reduced. When such a model yields contaminate concentrations twice those which are observed, the only logical conclusion is that the confidence in the ground water model to represent real conditions is further minimized.

Response: The design of this well field provides pipe stubs and flow capability for the installation of additional capture wells if it is determined that they are needed to meet the goals of the interception system. It has been suggested that alternative/additional recovery wells be orientated longitudinal to the axis of the plume. Capture zone analyses were performed on transverse well recovery fields at New Haven Rd. and at incremental distances toward Willey Rd. The combination of adequately calibrated regional flow modeling, particle tracking on the FEMP local flow model, observed SP uranium concentrations, and the general position of the PRRS plumes is sufficient to plan the first transverse recovery well field.

This first well field should act as a barrier and arrest the axial portion of the plume. Site specific data acquired during the pump testing will be used to better determine model parameters and thus improve predictive capabilities of the FEMP local flow model. In parallel, additional geochemical analyses are needed to better constrain the modeled geochemical input parameters to the FEMP local transport model.

It is arguable whether the transport modeling will ever accurately reflect the contamination transport processes. It may ultimately be necessary to rely more heavily on particle tracking.

The FEMP local flow model will be refined with a finer mesh and will benefit from the results of the SP pumping. Particle tracking will be seeded at more numerous increments throughout the thickness of the GMA.

The existing FEMP regional flow model has performed reasonably well. The residual water levels are about 1 foot and the simulated gradients are similar to those observed. It is recognized that the input data and scaling of the FEMP local flow model from the FEMP regional flow model will probably need to be modified after the SP pump test is completed. Residuals will be continuously improved as more wells become available.

Action: Additional modeling will be conducted using results of the SP pump test coupled with a finer model mesh.

Comment 18: Section#4.0. In order to allow the reader to better visualize the affects of various pumping scenarios on the PRRS plums, a current state or no action (baseline) scenario map should be provided within the work plan.

Response: A no-action alternative utilizing particle-tracking and 5-year predicted uranium concentration maps with text will be amended to the report.

Action: As noted in the comment.

Comment 19: Page 4-1, Section 4.X. The Ohio EPA comments on the modeling effort apply to this section as well as the ones previous. However, the actual final locations of the interception wells appear to be acceptable based upon the limited data which exists. These locations could change if the assumptions prove to be incorrect. As a safeguard, Ohio EPA recommends the use of a ground water monitoring

program specific to the interception system to determine the effects of the system upon the FEMP plume and the PRRS plume. Because the advanced waste water treatment system is not designed to treat contaminates found in the PRRS plume, the condition closely resembles a wellhead protection issue. It is important to closely monitor the PRRS plum to guarantee early warning of its impact on the interception system.

Response: The present Part 5 hydropunching program and Part 2 piezometer and monitoring well installation program are specifically designed to verify the vertical depth of the proposed five well recovery system. Provisions for future flexibility in system reconfiguration are being provided in the well field design. The Design, Monitoring, and Evaluation Program Plan (DMEPP), recently issued for U.S. EPA and Ohio EPA review, defines detailed programs to periodically monitor and evaluate the operation of the recovery well system so that South Plume Removal Action objectives are continually met. The DMEPP also includes provisions to modify the system based on the evaluation findings.

Action: None beyond those currently planned and discussed in the response.

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Attachment

Great Miami Aquifer Horizontal Hydraulic Conductivities:

ft/d	Reference	Source
330	Dove (1961)	pump test
328-534	Smith (1962)	pump test
120	Klaer (1968)	pump test
318-368	Kazmann (1950)	pump test
326-371	Shaefer and Walton(1956)	flow-net analysis
312-323	Klaer and Kazmann (1943)	pump test
267	Speiker and Norris(1962)	pump test
334-403	Lewis (1968)	pump test
774	Smith (1960)	pump test
270-446	Speiker (1968)	estimated
100-280	Papadopoulos (1984)	pump test
20(?)-520	ASI/IT (1990)	estimated
270-370	Dames and Moore (1985)	estimated
334-403	CH_2M-Hill (1987)	pump test
318-397	Geotrans (1985)	estimated
133-419	Fang (1992)	estimated