**UNDERGROUND TEST AREA SUBPROJECT
PHASE I DATA ANALYSIS TASK**

VOLUME VI

**GROUNDWATER FLOW MODEL
DOCUMENTATION PACKAGE**

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November 1996

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Preface

This report represents the groundwater flow documentation for the Phase I Data Analysis Task performed in support of the current Regional Flow Model, Transport Model, and Risk Assessment for the Nevada Test Site Underground Test Area Subproject. Because of the size and complexity of the model area, a considerable quantity of data were collected and analyzed in support of the modeling efforts. The data analysis task was broken into eight subtasks, and descriptions of the subtask activities are contained in the following eight volumes that comprise the Phase I Data Analysis Documentation.

- Volume I: Geologic Model Documentation Package
- Volume II: Potentiometric Data Documentation Package
- Volume III: Groundwater Recharge and Discharge Data Documentation Package
- Volume IV: Hydrologic Parameter Data Documentation Package
- Volume V: Transport Parameter and Source Term Data Documentation Package
- Volume VI: Groundwater Flow Model Documentation Package
- Volume VII: Tritium Transport Model Documentation Package
- Volume VIII: Risk Assessment Documentation Package

Each of the volumes details the results of one or two related subtasks. A summary review of project data and results will be contained in the Phase I Report (in progress).

The Underground Test Area Subproject Phase I Data Analysis Task was led by IT Corporation; Tetra Tech, Inc.; GeoTrans, Inc.; and Daniel B. Stephens Corporation. The task could not have been completed without the cooperative efforts of many other participants involved in work at the Nevada Test Site. Their organizations are listed in alphabetical order:

- Bechtel Nevada
- Desert Research Institute
- Lawrence Livermore National Laboratory
- Los Alamos National Laboratory
- Raytheon Services Nevada
- U.S. Geological Survey - Geologic Division
- U.S. Geological Survey - Water Resources Division
- U.S. Geological Survey - Yucca Mountain Project

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List of Acronyms and Abbreviations

AA	Alluvial Aquifer
AF	Alkali Flat
AM	Ash Meadows
AR	Amargosa River
ASTM	American Society for Testing and Materials
BARR	Barrier
BAQ	Basal Aquifer (Welded Tuffs)
BCF	Block-centered flow
BCU	Basal Confining Unit (Non-welded Tuffs)
BRT	Belted Range Thrust
CAU	Corrective Action Unit(s)
cm	Centimeter(s)
cm/yr	Centimeter(s) per year
d	Depth below land surface
DOE	U.S. Department of Energy
DOE/NV	U.S. Department of Energy, Nevada Operations Office
DV	Death Valley
EM	Eagle Mountain
EPA	U.S. Environmental Protection Agency
ERMA	Environmental Restoration Management Applications System
ET	Evapotranspiration
EYF	East Yucca Flat
FFACO	Federal Facility Agreement and Consent Order
FARM	Amargosa Farm
FF	Frenchman Flat
FL	Franklin Lake
GHB	General Head Boundary
GIS	Geographical Information System
HSU	Hydrostratigraphic unit(s)
I	Intrusives
ICRP	International Commission on Radiation Protection
in.	Inch(es)
IS	Indian Springs
IT	IT Corporation

List of Acronyms and Abbreviations (Continued)

K _h	Horizontal Hydraulic Conductivity
K _v	Vertical Hydraulic Conductivity
km	Kilometer(s)
LCA	Lower Carbonate Aquifer
LCA1	Lower Carbonate Aquifer (Upper Plate)
LCA2	Lower Carbonate Aquifer (Lower Plate)
LCA3	Lower Carbonate Aquifer (Yucca Flat Upper Plate)
LCCU2	Lower Clastic Confining Unit
LCCU1	Lower Clastic Confining Unit (Upper Plate)
LCCU	Lower Clastic Confining Unit (Lower Plate)
m	Meter(s)
m ²	Square meter(s)
m/d	Meter(s) per day
m ³ /d	Cubic meter(s) per day
ME	Maxey-Eakin
msl	Mean sea level
MWR	Mean weighted residual
NAD	North American Datum
NRTH	Northern Area
NTS	Nevada Test Site
OV	Oasis Valley
PAHR	Pahranagat Valley
PCG2	Preconditioned conjugate - gradient solver
PM	Pahute Mesa
PP	Pahrump
PV	Penoyer Valley
QA	Quality Assurance
RMS	Root Mean Square residual(s)
SHON	Shoshone
SHRG	Sheep Range
SPMT	Spring Mountains
T	Top
TMBR	Timber Mountain
TBA	Welded Tuff

List of Acronyms and Abbreviations (Continued)

TC	Tuff Cone
TCB	Non-welded Tuffs (Bullfrog Confining Unit)
TMA	Timber Mountain Aquifer (uppermost Welded Tuff)
TSDV	Tertiary Sediments, Death Valley Section
UCCU	Upper Clastic Confining Unit
UGTA	Underground Test Area
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
VA	Volcanic Aquifer
vcont	Vertical leakance
VCU	Volcanic Tuff Confining Unit
VOIC	Volcanic Aquifers
VU	Volcanics Undifferentiated
WP	Working point
WRMS	Weighted square root mean of the residuals
WSD	Weighted standard deviation
WT	Water table
WYF	West Yucca Flat
yrs	Years
2-D	Two-dimensional
3-D	Three-dimensional
%	Percent
8	Lambda

1.0 Introduction

The Nevada Test Site (NTS), located in Nye County in southern Nevada, was the location of 908 nuclear detonations conducted in shafts and tunnels between 1951 and 1992. About one-third of these nuclear underground detonations were conducted near or below the water table (Duncan, 1993). As an unavoidable consequence of these testing activities, radionuclides have been introduced into the subsurface environment, impacting groundwater. The U.S. Department of Energy, Nevada Operations Office (DOE/NV) has been in the process of investigating the effects of these underground nuclear detonations as part of the Underground Test Area (UGTA) Subproject. Descriptions of the project, the data analysis task, and the Groundwater Modeling Subtask are briefly discussed.

1.1 Subproject Description

This subsection includes descriptions of the purpose, scope, objectives, strategy, and organization of the UGTA subproject. The documentation that supports this effort is outlined in [Section 1.2.5](#) of this report.

1.1.1 Subproject Purpose and Scope

The purpose of the subproject is to collect data and perform technical evaluations to support decisions about the corrective actions necessary to ensure that the weapons testing areas do not pose a significant risk to human health and the environment.

The scope of the UGTA project includes the following activities:

- New and existing data collection and evaluation
- Quantification of risk to human health and the environment
- Selection of the corrective actions to reduce risk from the sites
- Implementation of corrective actions and closure of the testing areas.

1.1.2 Subproject Objectives

The UGTA subproject objectives are prerequisite to generating the necessary end products to complete the subproject. The objectives provide the framework for subproject strategy. The subproject definition establishes the starting point, and the objectives focus on the end products.

The overall objective of the UGTA subproject is to evaluate the effects of the weapons testing areas on groundwater and to identify and implement the appropriate corrective actions. This objective ensures that risks to human health and the environment from impacted groundwater are within protective levels.

Meeting the overall objective requires that several specific project objectives be achieved:

- Effectively plan and scope the UGTA subproject so that the necessary data are properly collected and relevant evaluations are properly performed.
- Prepare UGTA subproject plans as guidance and information tools for efficiently conducting the subproject.
- Determine the characteristics of the groundwater system and the nature and extent of contamination at a level necessary to support a baseline risk assessment.
- Develop credible predictions of contaminant fate and transport.
- Quantify the risk to human health and the environment, in the absence of any present or future remedial action, to an acceptable level of uncertainty.
- Evaluate an appropriate range of remedial technologies applicable to the various contaminants and impacted media.
- Select appropriate corrective action alternatives.
- Implement selected corrective actions.
- Close the underground test areas.

1.1.3 Subproject Strategy

The Nevada Division of Environmental Protection regulates U.S. Department of Energy's (DOE) Nevada corrective actions through the *Federal Facility Agreement and Consent Order* (FFACO, 1996). Appendix VI of the agreement, "The Corrective Action Strategy," describes the processes that will be used to complete the corrective actions, including those in the UGTA subproject. The individual sites covered by the agreement are known as Corrective Action Sites, and they are grouped into Corrective Action Units (CAUs). The UGTA subproject comprises six CAUs, generally reflecting the geographic locations and geologic and hydrologic environments of the weapons testing areas.

1.1.4 Subproject Organization

Because of the complexity of the problem at hand, the UGTA scope was separated into two major phases. During Phase I, project activities have been focused on a regional investigation. During Phase II, several localized investigations focusing on the CAUs will be conducted.

Phase I has consisted of existing data assessment, groundwater flow and solute transport modeling, and a preliminary risk assessment which has been a key portion of the data assessment

activities. The risk assessment has been designed to determine whether or not there is an imminent risk to human health and the environment and to provide input to a value-of-information analysis that will identify and prioritize potential data needs. The results of Phase I will be directly used in developing the work scope for the weapons testing areas and in implementing Phase II. Further information on the Phase I data analysis task is provided in the following subsection.

1.2 Phase I Data Analysis Task Description

This subsection includes a more detailed description of the purpose and scope, objectives, approach, and data requirements and organization of the UGTA Data Analysis Task.

1.2.1 Task Purpose and Scope

The overall purpose of the Data Analysis Task is to compile and analyze existing as well as new data. During Phase I, the focus of this analysis task has been a regional investigation. The Phase I Data Analysis Task scope of work includes the evaluation of regional groundwater flow conditions, the transport of tritium from the weapons testing areas, and the determination of the presence or absence of imminent risk to human health and the environment.

1.2.2 Task Objectives

The following were the objectives of the Phase I Data Analysis Task:

- Evaluate the regional groundwater flow conditions using a groundwater flow model.
- Evaluate the transport of tritium in groundwater using a groundwater transport model.
- Develop a preliminary assessment of risk to human health and the environment from the weapons testing areas.

1.2.3 Task Approach

The approach for the Phase I Data Analysis Task has included the following steps:

- Selection of a regional groundwater flow system, large enough to encompass the NTS
- Selection of an area of investigation, large enough to include the selected regional groundwater flow system
- Collection and analysis of data
- Simulation of regional groundwater flow with a three-dimensional numerical code
- Definition of the major flow paths from the weapons testing areas using a particle-tracking code

- Simulation of the transport of tritium using a numerical, one-dimensional transport code
- Calculations of risk to humans and the environment from exposure to tritiated groundwater

The NTS regional groundwater-flow system ([Figure 1-1](#)), which fully encompasses the groundwater flow system underlying the NTS, was selected for this investigation; however, the boundary of this groundwater flow system has not been well defined in some areas. The flow system boundary defined by Waddell et al. (1985) was evaluated at the start of this investigation and is shown on [Figure 1-1](#). The selected area of investigation had to be large enough to allow for a reevaluation and potential expansion of the groundwater flow system boundary. This area covers a large part of Southern Nevada and part of Inyo County in eastern California. The area extends from Death Valley, north to Antelope Valley, and from the Palmetto Mountains east to the Sheep Range, extending over an area of 80,650 square kilometers (31,140 square miles).

Data collection and analysis activities are dictated by the type of data needed. Data types and their methods of analysis are, in turn, dictated by the modeling approach and will not be discussed in this section; however, the documentation of necessary data types as well as the methods of analysis are discussed in the preceding volumes of this documentation.

The computer code selected to simulate groundwater flow is MODFLOW (McDonald and Harbaugh, 1988). This code was developed by the U.S. Geological Survey (USGS) for the numerical simulation of fully three-dimensional saturated groundwater flow in porous media, and it was designed to simulate flow under both steady-state and transient conditions. The code will also be used to simulate flow in fractured media by invoking an equivalent porous media assumption. This assumption implies that at the scale of the model, the hydraulic behavior of fractured geologic units is analogous to that of porous media.

The code selected to simulate pathlines is MODPATH (Pollock, 1989). This code was developed by the USGS to compute and display three-dimensional pathlines based on results from steady-state simulations from MODFLOW (McDonald and Harbaugh, 1988).

The program uses information on layer geometry, boundary conditions, and flux rates to calculate the velocities and positions of particles at different times. MODPATH was used to compute and display pathlines originating from individual underground nuclear testing locations located throughout the weapons testing areas. MODPATH also provides Darcy velocity distributions along the pathlines, which are required by the transport code.

The code used to simulate contaminant transport is MC_TRANS (GeoTrans, 1995), and it was developed specifically for this subproject. This finite-element, one-dimensional, radionuclide transport model is capable of simulating advection in a dual-porosity, fractured system with dispersion, sorption, and first-order decay. The code was used to simulate the concentrations of tritium downgradient from selected nuclear test sites under the “no-action alternative.” The code was used in the stochastic mode to evaluate the uncertainties associated with the predicted tritium concentrations.

The code used to estimate human health risk from exposure to tritium-contaminated groundwater is GW-RISK (IT, 1996a), also developed specifically for this subproject. The code implements the appropriate U.S. Department of Energy (DOE, 1993), International Commission on Radiation Protection (ICRP, 1991), and U.S. Environmental Protection Agency (EPA) approaches (EPA, 1989a, EPA 1989b; and EPA, 1991). The code uses tritium concentrations simulated by MC_TRANS (GeoTrans, 1995) as input for three of the most conservative predicted pathlines. The ecological risk assessment determines tritium concentrations below which no adverse effects should be expected to ecological receptors. These concentrations were compared with measured and modeled tritium concentrations in surface water and groundwater. Although no formal guidance exists on how to assess ecological risks associated with exposure to radionuclides, the general format suggested in the EPA *Framework* document (EPA, 1992) was used in conjunction with published radiation dose models (Baker and Soldat, 1992; Blaylock et al., 1993). Both human and ecological risk assessments included examination of data, exposure assessment, toxicity assessment, risk evaluation, and evaluation of uncertainties.

1.2.4 Task Data Requirements and Organization

Task data requirements and organization are briefly described in this section. Data required to achieve the objectives of the Phase I data analysis are as follows:

- Geologic data for regional groundwater flow and transport modeling
- Hydrologic data for regional groundwater flow modeling
- Transport parameter and tritium source data for tritium transport modeling
- Risk-related data for assessment of risk to human health and the environment

MODFLOW (McDonald and Harbaugh, 1988) data requirements include hydrogeologic framework data, potentiometric data, hydraulic conductivity/transmissivity data, and groundwater recharge and discharge data. Data needs also include estimates of the uncertainties which are used to define the input variable bounds and the output variable target ranges for use in the model calibration process. MODPATH data requirements are MODFLOW data and porosity data. In addition to the Darcy velocities calculated by MODPATH, the transport model, MC_TRANS,

requires transport parameter data including bulk and fracture porosity, dispersion, and tritium matrix diffusion data. Data for the tritium source needed for the transport model include the tritium source initial spatial extent and concentration. Data needed for the risk assessment include the peak tritium concentration generated by the transport model from the flowpath at each receptor location. In addition, exposure scenario, tritium dosimetry, and tritium detriment and risk data are required.

The data analysis task was organized into several subtasks based on the approach and the major types of data needs. Data needs of the flow model were fulfilled under four subtasks: Geologic Model, Potentiometric Data, Groundwater Recharge and Discharge Data, and Hydrologic Parameter Data. Porosity data are needed by both MODPATH and MC_TRANS and were collected under the Transport Parameter Subtask, together with data on dispersion and matrix diffusion. Data needed to define the source term were collected and analyzed under the Source Term Subtask. Data needed for risk assessment were collected and analyzed under the Risk Assessment Subtask.

1.2.5 Task Documentation

Work performed under the data analysis task is documented in eight volumes:

- Volume I - Geologic Model Documentation Package (IT, 1996b)
- Volume II - Potentiometric Data Documentation Package (IT, 1996c)
- Volume III - Groundwater Recharge and Discharge Data Documentation Package (IT, 1996d)
- Volume IV - Hydrologic Parameter Data Documentation Package (IT, 1996e)
- Volume V - Transport Parameter and Source Term Data Documentation Package (IT, 1996f)
- Volume VI - Groundwater Flow Model Documentation Package (this package)
- Volume VII - Tritium Transport Model Documentation Package (IT, 1996g)
- Volume VIII - Risk Assessment Documentation Package (IT, 1996a)

A separate documentation package was not prepared for the Source Term Subtask; however, results of this subtask are reported in Volume V of the task documentation.

The documentation packages are meant to fulfill several subproject needs. The first five packages serve as a repository of available and pertinent data collected for possible inclusion into the modeling process. There is little relationship between these five packages; instead, they are directly related to Volumes VI and VII, the packages that document flow and transport modeling process and results. Volume VIII, the *Risk Assessment Documentation Package*, is most directly related to the transport package, Volume VII. Concentrations of tritium at specific locations and times required by the risk assessment are provided by the transport model. [Figure 1-2](#) illustrates how information from each of the packages was utilized and how they related to each other.

A second subproject need was the ability to centralize and make the information required readily available for a highly technical review of the modeling process. The intended audience of these eight documents is the technical reviewer. A report of the entire project that contains information related to regulatory and risk management issues is contained in the *Regional Groundwater Flow and Tritium Transport Modeling, and Risk Assessment of the Underground Test Area, Nevada Test Site, Nevada* (DOE, in press). This document is intended to serve as the primary subproject summary that reaches a broader audience.

1.3 Flow Model Subtask Description

This subsection includes descriptions of the purpose and scope, objectives, and approach of the Groundwater Flow Model Subtask.

1.3.1 Subtask Purpose and Scope

The groundwater flow model uses the laws of physics (such as conservation of mass and momentum) to simulate the distribution of hydraulic head in model layers that generally correspond to major hydrostratigraphic layers. The flow model integrates the recharge, discharge, geologic, and aquifer property data into a consistent description of the groundwater flow system. The simulated hydraulic heads are used to calculate groundwater flow paths which, in addition to porosity and hydraulic conductivity data, are used to determine groundwater velocity.

The regional three-dimensional (3-D) flow model of the Nevada Test Site region was developed to provide a framework for performing preliminary regional-scale, one-dimensional transport simulations which, in turn, were used to quantify baseline risk to human health and the environment at downgradient receptors. The 3-D groundwater flow model will also be used as a basis for future, detailed (near-field) modeling in the individual weapons testing areas. Flux estimates are not well-known in the vicinity of the weapons testing areas; however, fluxes are better known along the boundaries of the regional model. The calibrated regional model gives

Figure 1-2
Data Utilization in Phase I Modeling

internal flux values across model cell boundaries that can then be used as boundary fluxes for the near-field models, ensuring that the near-field models are consistent with the regional water budget. This provides a means to evaluate the uncertainty in prediction of radionuclide transport resulting from uncertainty in regional hydrologic parameters.

The regional flow model was designed and developed to evaluate flow directions and velocities within and downgradient of the primary area of interest, the NTS. The model was not developed to evaluate flow in areas other than the NTS such as the Spring Mountains and the Amargosa Desert. If more detailed hydrologic modeling is to be conducted in these areas, corresponding geologic data would first have to be integrated into the model. The preprocessing programs developed for the flow model allow easy incorporation of the modified geologic framework model.

The regional groundwater flow model was not developed for detailed modeling on the near-field scale. The geologic data have been grouped into 20 hydrostratigraphic units (HSUs) that are appropriate for the regional scale modeling; however, more detailed geologic information will be necessary for the near-field modeling. Additionally, the model assumes that the parameter values used in the model provide good estimates of the average flow behavior within fractured rock, characterized by the concept of the representative elementary volume (Bear, 1979). This concept, or continuum approach, may not be valid on the local scale where fracture-flow characteristics dominate the flow pattern.

It is important to realize that the numerical groundwater flow model is only an approximation of the groundwater flow system, and that there is uncertainty in both the three-dimensional distribution of the rocks and their hydrologic properties. The values of parameters used in the calibrated model result in a reasonable fit between modeled and measured hydraulic heads and between modeled and measured/estimated discharge rates. However, different parameter values may provide similar agreement between simulated and observed data, but result in different estimates of radionuclide transport. The model provides a technique with which to evaluate the impacts of parameter uncertainty on the transport estimates.

1.3.2 Subtask Objectives

The objectives of the Groundwater Flow Model Subtask are as follows:

- Provide an integrated tool with which to understand the groundwater flow system in the vicinity of the Nevada Test Site.
- Calculate flow rates within and downgradient of the weapons testing areas and identify flowpaths for use in estimating transport of contaminants on the regional scale.

- Provide a mechanism (parameter sensitivities) for determining the importance of regional-scale hydraulic parameters on estimates of contaminant transport.
- Provide a three-dimensional framework on which to base more detailed models of the weapons testing areas so that the near-field models are consistent with the regional water budget.
- Evaluate the effects of uncertainty regarding the groundwater flow system on predictions of tritium transport.

1.3.3 Subtask Approach

As discussed earlier, a numerical groundwater flow model and a particle-tracking numerical model were developed to attain the subtask objectives using the MODFLOW and MODPATH numerical codes. The approach includes the following steps:

- Develop the numerical groundwater flow model, including discretization of the flow domain, identification of the model area boundaries ([Figure 1-3](#)), and discretization of the geologic and hydrogeologic data to match the groundwater flow model grid and to serve as input data sets for MODFLOW.
- Calibrate the steady-state groundwater flow model by adjusting model parameters after each model run until simulated hydraulic heads and fluxes match the observed data based on predetermined calibration criteria.
- Generate pathlines and corresponding velocity distributions for selected nuclear shots using the hydraulic heads simulated by MODFLOW.
- Analyze sensitivity of MODFLOW and MODPATH results to the various input variables.

The following assumptions, deemed appropriate for a regional investigation, were made during the performance of this subtask:

- Flow in the fractured media of the NTS regional groundwater-flow system is equivalent to flow through porous media.
- The conceptual model used as the basis for the numerical flow model, as described in the *UGTA Operable Unit Work Plan* (DOE, 1995), is representative of the NTS regional groundwater-flow system.
- Spatial variations in groundwater density due to changes in temperature or chemistry are negligible and are not accounted for in the flow model.

The modeling approach used to develop the groundwater flow model is discussed in more detail in [Section 3.0](#) of this report. The use of MODPATH is discussed in detail in [Section 5.0](#). The results of the sensitivity analysis, in which model parameters are changed to evaluate the effect of

the change on the model-calculated output, are also discussed in [Section 5.0](#). These results are incorporated into the uncertainty analysis of estimates of tritium movement and concentrations presented in Volume VII (IT,1996g). The uncertainty analysis uses estimates of the frequency distributions of modeling parameters and results of the sensitivity analysis to estimate the uncertainty in the transport modeling results.

1.4 Report Organization

The remainder of the report discusses the modeling approach, calibration process, modeling results, conclusions, and recommendation.

[Section 2.0](#) - Discusses the approach used to develop the groundwater flow model

[Section 3.0](#) - Presents the development of the model which includes a description of the model grid and assignment of parameter values

[Section 4.0](#) - Addresses the procedure for model calibration and introduces the model calibration targets

[Section 5.0](#) - Presents the modeling results, including particle-tracking from selected shot locations and sensitivity analyses

[Section 6.0](#) - Summarizes the results

[Section 7.0](#) - Lists the references cited

2.0 Modeling Approach

The characteristics of any groundwater flow system are determined by the spatial distribution of the rocks present in the subsurface environment, their hydrologic properties, and the locations and rates of influx to the system. The locations and rates of discharge of water from the system are determined by these characteristics as are the water levels throughout the system. The approach taken in the development of the NTS numerical flow model was to simulate this type of system to the extent possible. Discharge rates were calculated by the model based on rates and distribution of inflow to the model and the spatial distribution of hydraulic conductivities.

There were, therefore, three basic sets of information used as input to the model: the geologic framework, the hydraulic properties of the rocks, and the locations and rates of fluxes into the system. The physical locations of discharge areas were also specified in the input dataset, but the flux was determined by the model. These components are described in the following text.

The model was based on a comprehensive regional geologic model constructed specifically for this task; development of the geologic model is described in the *Geologic Model Documentation Package* (IT, 1996b). While this model necessarily contains simplifications, it is considered to be a reliable and valuable compilation of information about the 3-D distribution of the geologic units present within the study area.

The stratigraphic units identified within the area were grouped into 20 HSUs ([Table 2-1](#)) based on their origin and hydrologic characteristics. Data products developed as part of the Geologic Modeling Task included two-dimensional (2-D), regularly-spaced grids consisting of elevations of the upper surface of each of the 20 HSUs. Each of the 2-D grids, or arrays, contains elevation data at the intersections of all grid lines which are oriented north-south and east-west on 2-kilometer (km) spacings. There are a total of 114 columns (north-south) and 140 rows (east-west). The northwestern corner of the grid is located at Universal Transverse Mercator (UTM) (North American Datum [NAD] 27, Zone 11) coordinates 454,000 East and 4,263,000 North.

A missing value flag of 9,999.0 was assigned to all nodes in each 2-D array where rocks comprising the respective HSU are absent. In addition to the 20 HSU arrays, two additional arrays were also constructed: one for land surface elevation and one corresponding to a uniform, artificial base for the geologic model of -7,600 meters (m) below sea level.

Table 2-1
Hydrostratigraphic Units Defined in the Geologic Model

HSU Number ^a	HSU Abbreviation	HSU Description
20	AA	Alluvial Aquifer
19	TMA	Uppermost Welded Tuff (Timber Mountain Aquifer)
18	TC	Tuff Cone
17	TCB	Non-welded Tuffs
16	TBA	Welded Tuffs Above BCU
15	BCU	Non-welded Tuffs (Basal Confining Unit)
14	BAQ	Welded Tuffs (Basal Aquifer)
13	VA	Volcanic Tuff Aquifer
12	VCU	Volcanic Tuff Confining Unit
11	VU	Volcanics Undifferentiated
10	TSDV	Tertiary Sediments, Death Valley Section
9	LCA3	Lower Carbonate Aquifer (Yucca Flat Upper Plate), Upper Carbonate Aquifer in NTS Area
8	UCCU	Upper Clastic Confining Unit
7	LCA	Lower Carbonate Aquifer
6	LCCU	Lower Clastic Confining Unit
5	LCA1	Lower Carbonate Aquifer (Upper Plate)
4	LCCU1	Lower Clastic Confining Unit (Upper Plate)
3	LCA2	Lower Carbonate Aquifer (Lower Plate)
2	LCCU2	Lower Clastic Confining Unit (Lower Plate)
1	I	Intrusives

^aThe HSUs were numbered starting from the bottom of the flow system.

The second set of information required for the flow model is an estimate of the hydraulic conductivity for each HSU. One approach is to assign values based on aquifer test data. However, test data are available only over a very limited part of the study area, usually within the NT boundaries. Additionally, hydraulic conductivity values can vary over several orders of magnitude (IT, 1996e), which introduces an unacceptable degree of uncertainty in the parameter estimates.

The approach that was employed was to assume that, unless otherwise known, rocks of similar origin have similar hydrologic properties and should be assigned the same value of hydraulic conductivity. For example, there are several different HSUs that are classified as welded-tuff aquifers. These rocks were considered to be of similar origin and were initially assigned the same hydraulic conductivity value. During model calibration, hydraulic conductivity values were modified as necessary to derive the best fit between observed and model-generated data; this approach was better constrained by the hydrogeologic data and would provide more reliable estimates of both hydraulic conductivities and flow rates.

Areal variability exists within HSUs, especially if the unit is wide-spread, such as the Lower Carbonate Aquifer (LCA). To address spatial variation within a unit, preprocessors were developed to allow for division of an HSU into zones of constant hydraulic conductivities; zones within HSUs were only created when supported by hydrogeologic data or interpretations, or when designation of a separate area was necessary for sensitivity analysis.

Hydraulic conductivity data collected at the NTS indicate that conductivity values decrease with depth. The relationships between depth and hydraulic conductivity for three classes of HSUs, the Alluvial Aquifer (AA), the volcanic aquifers (VOLC), and the LCA are shown in [Figure 2-1](#). The conductivity data used to generate the conductivity vs. depth functions include all nonlaboratory data that are qualitatively ranked as either high or medium confidence, based on test type, test quality, and method of analysis (IT, 1996e). The equation developed from the data and used to construct the lines in [Figure 2-1](#) is:

$$K_{\text{depth}} = K_h(10^{-8d}) \quad (2-1)$$

where:

- K_{depth} = horizontal hydraulic conductivity at specified depth [L/T];
- K_h = horizontal hydraulic conductivity at land surface [L/T];
- 8** = depth-decay coefficient (calculated from linear regression) [1/L]; and
- d** = depth from land surface.

It should be noted that data are available for the Alluvial Aquifer at depths of up to about 900 meters. Based on these data, hydraulic conductivity values in the model were modified to decrease exponentially with increasing depth. The depth-decay coefficients calculated for the three lines are shown on [Figure 2-1](#). Information on the *in-situ* vertical hydraulic conductivity of the rocks is rare. Fracture orientation information (Erickson and Waddell, 1985) has been used to

Figure 2-1
Relationship Between Conductivity and Depth

estimate the ratio of vertical to horizontal conductivities in homogenous fractured rock, but this approach ignores the changes in lithology perpendicular to bedding and, therefore, overestimates the ratio in sections where, for example, welded and nonwelded tuffs are both present.

For the model, initial estimates of the ratios were made based on assumptions about the interlayering of rocks of different hydraulic conductivities and their respective conductivities. These estimates were on the order of 10^{-1} (carbonate rocks) to 10^{-3} (volcanic rocks).

The final components required as input to the flow model were locations and rates of fluxes into and out of the system. The influxes included recharge from precipitation and underflow from areas located outside of the model boundary. Discharges from the system included losses due to evapotranspiration (ET), spring flow, and underflow across model boundaries. Because the model is simulating steady-state, natural-stress conditions, losses caused by pumping water from the system are not considered; sufficient data were not available to examine temporal changes. Fluxes into and out of the system as well as the way they are represented in the model are discussed in [Section 3.4](#) of this document.

Once the hydrogeologic framework was complete, preprocessors were used to transform the data into input datasets used by the flow model, and the flow model was run. Flow model results consisted of an areal distribution of water levels (also called hydraulic heads, or heads) for each of the model layers and input and output fluxes at each of the boundary condition cells. These model-calculated or simulated heads were then compared to a dataset consisting of measured or observed heads that were representative of steady-state conditions (IT,1996d). The model-simulated fluxes were compared to measured and estimated boundary fluxes.

Modeling parameters were then adjusted, the model rerun, and simulated heads and fluxes again compared to the observed or target heads and fluxes. This process of adjusting modeling parameters to improve the agreement between calculated and observed values is called “calibration.” The general calibration approach consisted of modifying HSU hydraulic conductivities and the ratio of horizontal-to-vertical conductivities (vertical anisotropy) until model output satisfied the calibration criteria within acceptable levels. Obtaining good agreement to measurements of water levels within and downgradient of the testing areas was given a higher priority than other areas located within the model boundary.

Because of the complexity of the geologic model and the large amounts of data that needed to be handled, the modeling effort was very dependent not only on the numerical codes themselves, but

on many support programs developed for the project. Pre- and postprocessor codes were written to perform the following tasks:

- Generate model input datasets from the original geologic and hydrologic datasets.
- Contour simulated heads and post target heads.
- Calculate “goodness-of-fit” measured for hydraulic heads in different areas.
- Identify areas where the simulated water table was above the land surface.
- Graphically display input data sets (i.e., recharge, transmissivity, and vertical leakance values by model layer).

Descriptions of these codes and their functions are included in [Appendix A](#). The objective of using the codes was three-fold:

- Make the process easily adaptable.
- Minimize hand-entry of the data in order to make the process cost- and time-efficient and decrease the likelihood of errors.
- Create a log of the process and make it easily repeatable to facilitate quality assurance (QA) checks.

3.0 Model Development

3.1 Numerical Code Description

The 3-D numerical code selected for the simulation of the groundwater flow system is the finite-difference code, MODFLOW (McDonald and Harbaugh, 1988). The code uses finite-difference equations to approximate the following partial differential equation for 3-D groundwater flow of constant density in a heterogeneous, anisotropic medium:

$$\sum_{i=1}^3 \frac{M}{M_{k_i}} \left(K_{ii} \frac{\partial h}{\partial x_i} \right) - W = S_s \frac{\partial h}{\partial t} \quad (3-1)$$

where:

- i = Cartesian coordinate index [L];
- K_{ii} = hydraulic conductivity along major axis of hydraulic conductivity tensor [L/T];
- h = hydraulic head [L];
- W = volumetric flux per unit volume [1/T];
- S_s = specific storage [1/L]; and
- t = time [T].

For steady-state simulations, hydraulic head values do not change with time, and the right-hand side of the equation is zero.

Application of the finite-difference approximation used in MODFLOW requires that the study area be discretized into a grid of rectangular blocks, or cells. The finite-difference equations are then solved, resulting in the calculation of hydraulic heads at the center of each of the cells, called “nodes.” The calculated heads from the current iteration are compared to those of the previous iteration. This process is repeated until the difference in heads at all nodes between the current and previous iterations is less than a specified criterion. The solver used for the NTS model, the preconditioned conjugate-gradient solver (PCG2) (Hill, 1990), also requires that the maximum absolute value of the flux residual between successive iterations is less than a second specified convergence criterion before the solution is considered to have converged.

MODFLOW is a versatile code in that its structure is based on a main program and independent subroutines or modules that represent different features of the hydrologic system or external stresses applied to the system. For example, there are modules that simulate areal recharge, extraction from wells, evapotranspiration, and aquifer-stream interactions. The user is able to

select the necessary modules to describe the system being modeled. The group of modules or packages included as part of the NTS flow model are described in [Section 3.4](#) of this report.

The MODFLOW design also allows the introduction of additional modules that address new features or provide alternative approaches to previous features. An example of this was the development of a second block-centered flow (BCF) package, BCF2 (McDonald et al., 1991). BCF packages 1 and 2 include all modules necessary to calculate conductances and flow between adjacent cells. Both packages allow cells to go “dry” if the simulated water level drops below the bottom of the cell. This redefines the cell as a “no-flow” cell, and flow will not occur between it and neighboring cells. The BCF2 Package has the added capability of allowing the same cell to resaturate, or “rewet,” if the water table rises above the bottom of the cell. This feature is required to accurately model many hydrologic systems.

In the NTS model, for example, the extreme change in head values between the upgradient and downgradient areas of the model resulted in water-table fluctuations between model iterations which caused the simulated heads to drop below and then rise above the bottom of certain cells. If the BCF1 Package had been used, it would have reassigned these cells as “dry,” when many of the model cells were actually rewetted in subsequent iterations. Because so many model cells desaturated and resaturated during the model iterations, the BCF2 Package was used.

The package used to solve the set of finite-difference equations was the preconditioned conjugate-gradient solver, PCG2 (Hill, 1990). The solver converges when the following two criteria are met: the maximum absolute value in change in hydraulic head between two successive iterations is less than a specified convergence criterion, and the maximum absolute value of the flux residual between successive iterations is less than a second specified convergence criterion. The head change convergence criterion used for the NTS model is 0.005 m; the flux residual criterion is 0.25 cubic meters per day (m^3/d). These closure criteria resulted in mass balance errors of less than 0.03 percent.

3.2 Model Grid

3.2.1 Lateral Discretization

The NTS model grid, presented in [Figure 1-3](#), consists of 68 columns by 76 rows. The nonuniform grid consists of 1.5-km by 1.5-km cells in the vicinity of the site, grading to a coarser spacing along the model boundaries where detailed geologic and hydrologic data are sparse and where numerical accuracy is less important. The origin for the grid is in the upper left-hand corner, corresponding to UTM (NAD 27, Zone 11) coordinates 507,220 East and 4,231,307

North. The grid is rotated 5 degrees clockwise about this point to align the columns with the average fracture direction in the primary testing areas, Yucca Flat and Pahute Mesa. By orienting the grid in this manner, the principal directions of hydraulic conductivity in these areas are coincident with the two major grid axes.

The model grid is reproduced in [Figure 3-1](#). Two types of cells are presented in the figure: inactive (or no-flow) cells and active cells. The finite-difference approach requires a rectangular grid of cells; however, because of the irregular outline of the model boundary (see [Figure 1-3](#)), some of the grid cells fall outside of the boundary line. These cells are designated as inactive cells and have no impact on flow within the model domain. Active cells are cells for which hydraulic heads are calculated by the model.

The boundary between the majority of active and inactive cells along the model boundary is a no-flow boundary ([Figure 3-1](#)) (the general-head and well boundary conditions, applied at the remaining boundary cells, are discussed in [Section 3.4.2](#) and [3.4.3](#)). These no-flow boundaries represent both groundwater divides and flow lines that are coincident with the model boundary (IT, 1996c.). Groundwater divides are high points in the water table or potentiometric surface; groundwater can move radially or laterally away from these divides, but not across the divides. Similarly, flow lines cannot cross other flow lines; therefore, both divides and flow lines are well-represented by no-flow cells. Groundwater divides occur along the model boundary in the Sheep Range, Spring Mountains, Cactus Range, the Quinn Canyon Range, and the Timpahute Range.

The majority of the no-flow cells along the model boundary represent flow lines. Flow lines that are coincident with the boundary are present (clockwise, from the southeastern corner of [Figure 3-1](#)) between the Sheep Range and the Spring Mountains, across the Resting Spring and Greenwater Ranges to Death Valley, from Death Valley across the Grapevine Mountains, north along the eastern flanks of those mountains, across Bullfrog Mountain, north to the Cactus Range, from the Cactus Range across the Kawich Range to Railroad Valley, and from the Timpahute Range down the length of the Pahrnagat Range. Where it was evident that recharge was occurring, the hydrologic model boundary was selected to be coincident with hydrographic basin boundaries.

Boundaries based on groundwater divides are more reliably known than those based on flow lines. Thus, the extent of much of the flow system is not well-known. The modeling approach addresses this uncertainty by using recharge values that result in reasonable agreement with the estimated total discharge from the system.

EXPLANATION

- Active Cells
- Inactive Cells
- GHB
- Well Cells

Drain Cells

- AF
- AM
- ARiv
- DV
- FL
- IS
- OV
- PV

Figure 3-1
Location of Active, Inactive and Boundary Condition Cells

There is also uncertainty about the location of the flow-system boundary in the vicinity of the southern Sheep Range. The interpretation used in this model incorporated the Sheep Range within the NTS regional flow system, while others (i.e., Dettinger et al., 1995) have suggested that water recharged in the Sheep Range may flow toward the Las Vegas Valley. Water level data can be interpreted both ways, depending on the configuration of the shear zone and its properties. The Sheep Range was included within the model because the top of the LCCU is highest near the crest of the Sheep Range, and it slopes down to the west. This geometry favors flow to the west rather than to the south. Additional water level data would be needed to resolve this area of uncertainty; recently collected data favor the interpretation used in the flow model (Pal Consultants, 1995).

Flux into the model in the form of underflow was simulated both at the Pahrangat Valley and Pahrump Valley boundaries. Underflow out of the model was simulated in the area to the south of Eagle Mountain. Along the boundary with Sarcobatus Flat, it is not clear whether flux is into or out of the model; the model was calibrated assuming that there was zero flux across this boundary.

3.2.2 Vertical Discretization

MODFLOW requires that the model be discretized both horizontally and vertically. Vertical discretization consists of dividing the model into layers. Commonly, an HSU is represented by either a single model layer or by multiple model layers. If the HSU corresponds to an aquitard, it can be represented explicitly as a distinct layer, or it can be represented implicitly in the vertical conductance term. However, this general approach was not applicable for the NTS model because of the geologic complexity in the study area. Several problems would be encountered using this type of approach.

First, many of the HSUs are present only in isolated areas within the study area (i.e., TBA, the welded tuffs located above the non-welded tuff confining unit [[Table 2-1](#)]). If an HSU with limited areal extent were represented as a single model layer, then the bottom of the layer above it would coincide with the top of the layer beneath it at all cell nodes where the HSU did not exist, creating areas of zero thickness. MODFLOW is not capable of handling model layers that include cells of zero thickness.

Second, several major faults occur in the NTS region, for example, the Belted Range Thrust (IT, 1996b). Vertical displacement across these faults is greater than the thicknesses of many of the hydrologically important HSUs, placing units of significantly different hydrologic properties in contact with each other. If each HSU were assigned as a separate model layer, an HSU that was separated across a vertical fault would be treated as if the two displaced sections were

hydrologically connected, incorrectly simulating flow within the unit across the fault. An example is shown in [Figure 3-1](#) of the *Geologic Model Documentation Package* (IT, 1996b). In the left-hand section of the figure, the three HSUs (TBA, BCU, and BAQ) are physically separated across a normal fault, placing the units against a fourth HSU (TMA). If the four HSUs were each represented as separate model layers, MODFLOW would incorrectly simulate flow across the normal fault within HSUs: TBA, BCU, and BAQ.

A different approach was developed to address these concerns. Instead of selecting model layers based on hydrostratigraphy, model layers were selected based on elevation, where the top of each model layer was assigned a constant elevation value. Within any one model layer, one or more HSUs would be present in each model cell, and each cell would have a finite thickness greater than zero. The hydraulic properties assigned to each cell are composites of the properties of all HSUs present within that cell. [Figure 3-2](#) illustrates this concept. Cell 1 in Model Layer 1 includes portions or all of three HSUs whereas Cell 2 in Model Layer 1 contains only one HSU: HSU 3. The hydraulic properties assigned to Node 2 will be equivalent to those of HSU 3, whereas the hydraulic properties assigned to Node 1 will represent a weighted average of the properties of HSUs 1, 2, and 3 based on their thickness within the cell.

The drawback of implementing this approach is that thin model layers are necessary to preserve the geologic complexity. This results in many model layers and longer run times. For example, vertical flow within Yucca Flat is controlled by the location of the Alluvial Aquifer, the Volcanic Tuff Aquifer, and the Volcanic Tuff-Confining Unit; the first two aquifer units enhance vertical flow compared with the tuff confining unit. If the HSUs shown in [Figure 3-2](#) are representative of the three Yucca Flat HSUs, then the hydraulic conductivity assigned to Model Layer 1, Node 1, will be a composite of the three units, and the geologic complexity will be lost. Obviously, a compromise is necessary to minimize the number of layers included in the model (optimize solution time) while maintaining the influence of hydrologically important strata.

To accomplish this, numerous test models were constructed, each having different numbers of model layers and variations in model-layer elevations. The number of HSUs falling within each model layer was dependent upon the number of model layers selected and the designated model-layer elevations. Cross sections were developed from the geologic model using different numbers and thicknesses of layers to evaluate each configuration's ability to preserve the detail present in the geologic model. The greatest attention was devoted to Pahute Mesa and Yucca Flat because of the weapons testing performed there and because of the thin, hydrologically significant HSUs that were present.

Example Model Layer with 3 HSUs

Figure 3-2
Relationship of HSUs to Model Layers

Initial examination of the cross sections generated from the various test models indicated that seventeen model layers would adequately retain the characteristics of the hydrologically important units in Yucca Flat and Pahute Mesa. The number of layers was later increased to twenty to improve the convergence speed of the model (see [Section 4.5](#)). The uppermost layer was divided into two layers, and the lower two layers were increased to four layers.

The cross sections discussed here are based on the twenty layers used in the model. The elevations of the tops and bottoms of the layers are shown in [Table 3-1](#).

The geologic grid and location of two cross sections are shown in [Figure 3-3](#), and the cross sections are presented in [Figures 3-4](#) and [3-5](#). The cross sections show the HSU with the greatest thickness within the cell; units of lesser thickness are not shown but are included in the calculation of hydraulic parameters used in the model. A vertical exaggeration of 10:1 is present in the sections.

The east-west cross section shown in [Figure 3-4](#) coincides with row 84 of the geologic model and crosses the southern ends of Timber Mountain and Yucca Flat. Comparison of this figure with [Figure 3-1](#) presented in the *Geologic Model Documentation Package* (IT, 1996b) indicates that the volcanic aquifers and confining units in both the Timber Mountain Caldera and Yucca Flat are well-represented in the flow model layers. The uppermost welded tuff of the Timber Mountain Caldera is in the left-central section of the cross section, overlying non-welded tuffs and BAQ welded tuffs on the eastern section of the caldera. All overlie the Lower Clastic Confining Unit. Only the welded tuffs above the BCU are not properly represented in this area since the unit is so thin that approximately two-thirds of the cell thickness is composed of uppermost welded tuff of the Timber Mountain Caldera.

The eastern edge of the caldera is in contact with the Upper Clastic Confining Unit on the western edge of Yucca Flat. Yucca Flat consists of alluvium overlying Volcanic Tuff Aquifer which, in turn, overlies both the Lower Carbonate Aquifer, Yucca Flat Upper Plate (LCA3), and the Volcanic Tuff Confining Unit. The alluvium and VCU are well-differentiated on the cross section; however, the LCA3 and VA are not as well-defined because of the thinness of the units. All HSUs beneath Yucca Flat overlie the regional carbonate aquifer, LCA.

Comparison of [Figure 3-4](#) with cross sections included in the *Geologic Model Documentation Package* (IT, 1996b) indicates that the LCCU, projected to be present beneath the LCA in Yucca Flat, is not represented in this area in the flow model. This is because the base of the flow model was arbitrarily selected to be the maximum depth at which the LCA is believed to be present in

Figure 3-3
Geologic Grid and Location of Cross Sections

Figure 3-4
Cross-Section Corresponding to Row 84 of the Geologic Model

Figure 3-5
Cross-Section Corresponding to Column 50 of the Geologic Model

Table 3-1
Elevations of Model Layers
 (from Top to Bottom of Model)

Model Layer	Elevation (m above msl) ^a
1	1,750 to 2,000
2	1,500 to 1,750
3	1,350 to 1,500
4	1,200 to 1,350
5	1,050 to 1,200
6	900 to 1,050
7	700 to 900
8	600 to 700
9	475 to 600
10	350 to 475
11	225 to 350
12	100 to 225
13	-50 to 100
14	-250 to -50
15	-500 to -250
16	-1,000 to -500
17	-1,500 to -1,000
18	-2,000 to -1,500
19	-3,000 to -2,000
20	-4,000 to -3,000

^aMean Sea Level

the study area, approximately -4,000 m below mean sea level (msl). At all other points in the flow model, this depth corresponded to either low-conductivity intrusives or the LCCU. Although properties of the LCCU are included in the model when the LCCU is present above the -4,000 m elevation, the LCCU is considered to be the basement rock in the study area, and minimal flow is believed to occur within this unit. The -4,000 m elevation is considered conservative since data exist supporting a maximum depth of -3,000 m below which flow would be minimal, as described in the *Hydrologic Parameter Data Documentation Package* (IT, 1996e).

Figure 3-5 presents a north-south cross section coinciding with Column Number 50 of the geologic model. The cross section traverses from north to south, the western part of Pahute Mesa, Timber Mountain, Yucca Mountain, and Jackass Flat. This figure, when compared to Figure 3-3 of the *Geologic Model Documentation Package* (IT, 1996b), indicates that the alluvium, tuff aquifers, and confining units are very well-represented in the flow model layers. The following discussion summarizes the HSUs that are present on the cross section, from north (left) to south (right). On the left-hand section of the figure, undifferentiated volcanics are present beneath the alluvium in Gold Flat, and both overlie the LCA and LCCU. To the immediate south (right) is Pahute Mesa, with the tuff cone and welded and non-welded tuff sequence (TBA, BCU, and BAQ) clearly represented. Continuing to the south, the uppermost welded tuff in the Timber Mountain Caldera is encountered, followed by the sequence underlying Yucca Mountain consisting of the Volcanic Tuff Aquifer, the Volcanic Tuff Confining Unit, and the Lower Carbonate Aquifer. Finally, Jackass Flat and the Amargosa Desert are underlain by AA, LCA, and LCCU.

Further decreasing the layer thicknesses did not significantly improve the vertical differentiation between HSUs. The use of fewer, thicker layers, however, resulted in the loss of the distinction between hydrologically significant HSUs, which would have impacted the model-calculated gradients, flow directions, velocities, and particle transport results. After the number of layers was increased from 17 to 20 during the calibration process, the layers ranged in thickness from 125 m in the elevation range of greatest interest in the Pahute Mesa and Yucca Flat testing areas, to 1,000 m in the lower two layers.

3.3 Specification of Unconfined Versus Confined Model Layers

Model layers can be classified in three different ways with respect to the potentiometric (hydraulic head) surface: unconfined, confined, or convertible between the two. The unconfined specification is allowed for either single-layer models or the top layer of a multiple-layer model in which water table conditions will be present for the entire simulation period. The confined condition is used when the potentiometric surface remains above the top of the unit at all times during the simulation or if the change in hydraulic head in an unconfined aquifer is a small fraction (usually less than 10 percent) of the aquifer thickness. The final condition is the most flexible of the three and accurately represents the model layer as either confined or unconfined depending upon the location of the potentiometric surface.

In the NTS model, the potentiometric surface varies significantly over the site, from greater than 1,600 m above msl in the north-central section of the NTS to below sea level in the Death Valley area. The convertible option was necessary to accurately simulate the variability in water levels

between cells in the upper 15 model layers. The top elevations of the bottom five model layers (Table 3-1) were at least 400 m below measured or interpolated water levels present in the study area (IT, 1996c; Plate 2) and were, therefore, represented as confined layers, which requires less computation time than the convertible option. The top elevation for Model Layer 15, (-250 m) is also below the lowest head measured within the study area, but this layer was maintained as a convertible layer as a precaution because it was not known, *a priori*, how closely model-simulated heads would match measured heads. At the conclusion of the calibration process, model-simulated water levels were compared to top elevations for Model Layers 16 through 20. The water levels were all above the respective top elevations, indicating that representation of these layers as confined was correct.

3.4 Boundary Conditions

To solve the finite-difference approximation of the partial-differential flow equation, boundary conditions must be specified. Boundary conditions are needed to identify areas where water enters or leaves the system and are commonly applied at the outer boundary (lateral or vertical) of the model, but may be applied at any of the cells within the model. Three types of boundary conditions are commonly used: specified head, specified flux, and head-dependent flux.

The specified-head boundary condition is used when the hydraulic head is specified within a model cell. Water either enters or leaves the model at a rate necessary to keep the head constant at these cells. An example of this type of boundary condition is a lake in contact with an aquifer with the lake water levels remaining stationary during the simulation time period. At specified flux boundaries, water is supplied to or removed from the system at a specified rate, and the model adjusts the hydraulic head as necessary to accept or discharge the water at that rate.

A special case of the flux boundary is the no-flow boundary where water is not permitted to enter or leave the cells across this boundary. An example of this is the no-flow cells representing groundwater divides as discussed in Section 3.2 of this document.

The head-dependent flux boundary condition is an adaptation of the specified-head boundary condition that provides greater flexibility in the specification of boundary conditions. The specified head is applied at a point external to the model, and the rate at which the water enters or leaves the system is a function of the difference in head between the external specified head and the head at the internal model cell where the boundary condition is applied.

As described in Section 3.1, MODFLOW contains submodules or packages that are selected as necessary to describe the hydrologic regime that is being modeled. The following packages were

included in the NTS model to simulate recharge and discharge boundary conditions: the Recharge, General-head Boundary, Well, and Drain Packages. The Recharge Package applies a specified flux boundary condition over the uppermost active cells within the model. The Well Package is used to specify a constant flux into the model while the GHB and Drain Packages apply head-dependent flux boundary conditions. The four packages and their site-specific application to the NTS model are described in the following subsections.

3.4.1 Recharge Package

Recharge to the groundwater flow system occurs either as infiltration from precipitation or as underflow across upgradient model boundaries. The MODFLOW Recharge Package simulates recharge from precipitation; underflow is simulated using the GHB Package described in [Section 3.4.2](#).

In Nevada, recharge is commonly estimated by assuming that a specified percentage of precipitation will infiltrate the groundwater flow system and that the percentage specified is directly correlated to elevation. The higher the elevation, the greater the precipitation, and the higher the recharge rate. An approach was developed by Maxey and Eakin (ME) (1949) using a precipitation map developed by Hardman (1936) based on estimates of discharge from thirteen groundwater basins in the northern part of the state. The Hardman isohyetal map had contours of 8, 12, 15, and 20 inches per year. Maxey and Eakin developed coefficients for each of the precipitation ranges (i.e., 8 to 12 inches per year) which are multiplied by the mapped precipitation and surface area to estimate the recharge. The ME coefficients, which were the initial estimates used in the modeling effort, are provided in [Table 3-2](#). The recharge areas do not necessarily coincide to areas of precipitation because of runoff, slope, soil type, and other factors.

Table 3-2
Precipitation Zones and Maxey-Eakin Coefficients

Precipitation (in.) ^a	Precipitation (cm) ^b	ME Coefficient (%) ^c
>20	>50.8	25
15-20	38.1-50.8	15
12-15	30.5-38.1	7
8-12	20.3-30.5	3
<8	<20.3	0

^aInch
^bCentimeter
^cPercent

As shown in [Table 3-2](#), the ME recharge coefficient is zero for all zones that receive less than 8 inches (approx. 20 cm) of precipitation annually. However, recharge is known to occur in several areas of the NTS which receive less than this amount, for example, stream channels and basin-fill deposits. To address this, the ME procedure was modified to redistribute some of the water estimated to become recharge from the area where the precipitation occurs to downstream areas. Redistribution was performed for seven hydrographic subbasins located on or within the vicinity of the NTS; these subbasins are identified in the *Groundwater Recharge and Discharge Data Documentation Package* (IT, 1996d). The seven subbasins were internally divided into three zones:

- Upgradient recharge areas (Type A zone): Receive greater than 8 inches of annual precipitation per year. This is the area where the majority of infiltration occurs.
- Canyon-wash recharge areas (Type B zone): Receive less than 8 inches of precipitation per year, but include alluvial fans and streams through which recharge may occur.
- Areas of no recharge (Type C zone): Receive less than 8 inches of precipitation per year, but contain no alluvial fans or stream reaches to facilitate infiltration.

The total amount of recharge calculated for each subbasin based on the ME coefficients was redistributed between the A and B zones as described in the *Groundwater Recharge and Discharge Data Documentation Package* (IT, 1996d). The B zone was further subdivided into three recharge sub-areas: upland canyons and valleys (B1), mountain fronts (B2), and valley bottoms (B3). The initial redistribution percentages used in the flow model are listed in [Table 3-3](#). It is important to emphasize that the total volume of recharge calculated for each subbasin was not modified, only the areal distribution of the recharge.

The original Hardman precipitation map (1936) covered the Nevada area only; therefore, the map was modified to include the section of Inyo County, California, incorporated in the NTS flow model (James, 1993). The modified Hardman map was then digitized to create a grid of precipitation values on a 1-km spacing. The hydrographic basin tied to each grid point was determined for use in redistributing the recharge. The estimates of discharge and underflow were used to estimate the volume of recharge needed for the model, and the ME-type coefficients were adjusted to produce the needed recharge within the modeled area (see [Section 4.6.1](#)).

3.4.2 General-Head Boundary Package

The model boundary was selected to correspond as much as possible to areas of groundwater divides or flow lines which have been simulated as no-flow boundaries. However, in certain areas, no-flow boundaries were not present. These areas represented sections of the boundary

Table 3-3
Recharge Redistribution in Seven Hydrographic Subbasins
in the Vicinity of the NTS

Hydrographic Subbasin ^a	Redistribution to Type B (Canyon-Wash) Zone (percent)	Percent of Type B Zone Subdivided Among Three Subareas (see text)		
		B1	B2	B3
Topopah Wash (227C)	20	10	70	20
Beatty Wash (228A)	20	50	40	10
Thirsty Canyon (228)	20	70	20	10
Lower Forty Mile (227B)	20	30	60	10
Upper Forty Mile (227A)	20	60	30	10
Frenchman Flat (160)	20	10	80	10
Yucca Flat (159)	20	20	40	40
Silent Canyon (147A)	20	40	40	20
Kawich Valley South (157A)	20	40	20	40
Groom Lake (158C)	20	40	20	40

^aNumber in parentheses corresponds to subbasins described in the *Groundwater Recharge and Discharge Data Documentation Package* (IT, 1996d).

where groundwater is believed to be either entering or exiting the model as underflow. The groundwater flux can be simulated by specifying either constant head, flux, or head-dependent flux boundaries. Estimated ranges in boundary fluxes, taken from the *Groundwater Recharge and Discharge Data Documentation Package* (IT, 1996d) are provided in [Table 3-4](#).

Table 3-4
Estimated Ranges in Fluxes across External Model Boundaries

Boundary Area	Estimated Flux Range (m ³ /d)
Pahranagat Valley	5,400 to 60,800
Pahrump Valley	5,000 to 7,600
Sarcobatus Flat	-1,700 to 1,700
Eagle Mountain	-850 to -3,400

General-head boundary conditions were used for inflow from Pahrump Valley across the Resting Springs Range and for outflow near Eagle Mountain. This boundary condition was selected because the amount of flux is not well-known, but hydraulic heads outside the model near these boundaries are reasonably well-known and because the flux is expected to be low, based on the

types of rocks present. This modeling approach has the added advantage over constant-head boundaries of facilitating data entry and QA checking since the boundary head values are input separately from the initial head arrays. The initial head arrays are large, complex, and subject to data entry errors. If constant-head boundary conditions had been applied instead of the head-dependent flux boundaries, the values of hydraulic head at these boundary condition cells would have been entered as part of the initial head arrays.

The General Head Boundary Package requires both head values external to the boundary cell and boundary conductances. The boundary conductance is calculated by multiplying the boundary cell transmissivity by the cell horizontal dimension, perpendicular to the primary flow direction for the cell, and dividing (by half) the cell dimension parallel to flow. This procedure places a constant head value at the outer model boundary. The flux across the boundary is then based on the difference between the boundary head and the head calculated at the cell node by MODFLOW.

3.4.3 Well Package

The Well Package, which is needed to model a constant-flux boundary condition at individual cells, was used to describe boundary conditions for inflow near Pahrnagat Valley and to allow evaluation of inflow or outflow at Sarcobatus Flat. The Well Package, rather than the General Head Boundary Package, was used for more explicit control of the flux. The greatest underflow is projected to occur between Pahrnagat Valley and Desert Valley along the southern part of the Pahrnagat Range. Winograd and Friedman (1972) estimated that the flux across this boundary is approximately one-third of the discharge at Ash Meadows; a similar estimate that approximately 40 percent of the Ash Meadows discharge originates as flux across the southern Pahrnagat Range was developed by Thomas (1996). Although these studies provide good initial estimates for the boundary flux, it should be emphasized that information on the groundwater system near Pahrnagat Valley is limited. The Well Package was used at these cells to allow sensitivity analyses on the flux values to be performed.

For the boundary with Sarcobatus Flat, a zero-flux condition was used during calibration. The Well Package was applied at these cells to allow an analysis of the sensitivity of model results to changes in this flux value.

With the Well Package, the flux into or out of the model is specified for each boundary cell. A pre-processor was written that calculates the flux for each cell in a vertical column of boundary cells based on the following parameters: the assigned flux for the column of cells, the assigned elevation of the water table, and the relative transmissivities of the cells in the column. The assigned water table elevations for the boundary cells were based on the potentiometric surface

map developed of the study area (IT, 1996c). If the simulated water table is lower than the assigned value, then upper cells with an assigned flux may become inactive, and the total boundary flux will change. On the other hand, if the simulated water level is higher, the total flux will remain the same, but no flux will be assigned for those cells above the assigned water table. A postprocessor was written to sum the boundary fluxes for specified groups of cells as a quality assurance check.

For the boundary with Pahrnagat Valley, four vertical columns of cells were assigned a flux of 6,750 m³/d each, resulting in a total flux into the model of 27,000 m³/d. For the boundary with Sarcobatus Flat, seven columns of cells were used, but the flux for each column was set to zero for the calibration process.

3.4.4 Drain Package

Groundwater can exit the system by underflow, simulated using the GHB Package, or as discharge to the surface via springs or evapotranspiration. In order for water to be able to leave the modeled system at springs or in the form of ET, boundary conditions have to be applied to model cells in these areas. Eight areas were identified as probable surface-discharge boundaries (Figure 3-1, “Drain Cells”). These areas include:

- Penoyer Valley (PV) to the north of the NTS
- Indian Springs along the Las Vegas Valley Shear Zone
- Oasis Valley (OV) to the west of the NTS in the vicinity of Beatty
- Alkali Flat (AF), also known as Peter’s Playa, located northeast of the Ash Meadows discharge area
- Ash Meadows (AM)
- Franklin Lake/Alkali Flats (FL)
- Amargosa River (AR)
- Death Valley (DV)

The model cells were selected based on identification of vegetated areas and spring locations on the respective U.S. Geological Survey 1:24,000-scale (7½ minute) topographic maps.

Within the study area, water discharging from springs either reinfilters the groundwater system a short distance downstream from the discharge point or is evaporated or transpired. Therefore, water lost from the groundwater system through surface discharge is in the form of evapotranspiration, and estimated ET rates were used for model calibration.

There is one exception to this. Water does exit the modeled system via surface discharge along the Amargosa River west of Eagle Mountain. Streamflow measurements have not been located, but flow was visually estimated in the Fall of 1992 (Waddell, 1992) to be less than one cubic foot per second. Because this value is minimal compared to rates from the remaining discharge areas, discharge across the model boundary due to streamflow in the Amargosa River was ignored.

Surface discharge from the model due to ET losses could have been simulated using either the ET or Drain Packages. The ET Package requires specification of an “extinction depth” (the elevation below which ET does not occur), land surface elevation, and an ET rate at land surface. Modeled evapotranspiration linearly increases with the rise in the water table above the extinction depth until land surface is reached, at which time a maximum ET rate is reached. The discontinuous function used to represent ET at land surface has been problematic in previous studies (Prudic et al., 1993). Additionally, the function does not have the flexibility of representing increasing discharge as heads continue to rise above land surface, which would be necessary to simulate the change from an ET to a spring discharge mechanism. Therefore, ET was handled using the Drain Package.

The Drain Package requires specification of a drain elevation which is equivalent to the extinction depth specified in the ET Package. Discharge is zero when the simulated hydraulic head is below the elevation of the drain and increases linearly as a function of the conductance as the difference between the calculated head and the drain elevation increases. The drain function is not discontinuous at land surface; discharge continues to increase as the heads increase above the elevation of the drain. Therefore, simulated discharge fluxes were carefully monitored during model calibration to ensure that they were reasonable representations of estimated fluxes.

The Drain Package requires the specification of drain elevation and conductance values. The model grid was compared to the appropriate USGS 7½ minute topographic maps, and model cells falling within discharge areas were identified. The drain elevation was initially set to an elevation approximately 5 m below the land surface elevation, which was selected to approximate the ET extinction depth. The land surface elevation used in the calculation of the drain elevation was the lowest point in each model cell that fell within the discharge area.

The conductance values required for the Drain Package represent composite conductances due to all head losses resulting from converging flow in the discharge areas. Commonly, conductances are difficult, if not impossible, to measure, so they were estimated using the following formula:

$$\text{Cond}_{i,j,k} = \frac{A_{i,j,k}}{A_{D.A.}} \times \frac{\text{Flux}_{D.A.}}{(h_{i,j,k} - d_{i,j,k})} \quad (3-2)$$

where:

- $\text{Cond}_{i,j,k}$ = conductance of drain cell i,j,k [L^2/T];
- $A_{i,j,k}$ = area of drain cell i,j,k [L^2];
- $A_{D.A.}$ = total area of specified discharge area (e.g., Oasis Valley, OV) [L^2];
- $\text{Flux}_{D.A.}$ = total estimated discharge flux from specified discharge area [L^3/T];
- $h_{i,j,k}$ = head in drain cell i,j,k [L]; and
- $d_{i,j,k}$ = drain elevation in cell i,j,k [L].

In calculating the conductance using the above formula, the difference between the head in the boundary cell and the respective drain elevation was assumed to be 3 m, the estimated extinction depth. This will tend to result in simulated heads being slightly below land surface because the drain elevation was set to 5 m below land surface. In areas where ET is significant, the water table is generally present a short distance below land surface.

The estimated ranges in discharge fluxes for each of the eight discharge areas were presented in Table 8-1 of the *Groundwater Recharge and Discharge Documentation Package*, and are again listed below in [Table 3-5](#). [Table 3-5](#) also provides target flux ranges for each of the discharge areas. In some cases, the target discharge range is narrower than the estimated range. The target ranges for those areas were based on either review of literature values or discussions with experts in those specific areas and their most current estimates of ET rates. The ranges were narrowed, when possible, to help provide more realistic goals during model calibration.

3.5 Hydraulic Conductivity and Vertical Conductance Calculations

The lateral and vertical distribution of the HSUs and their hydraulic conductivity values help determine flow patterns and rates; therefore, it is extremely important to map or translate these values as accurately as possible into the model. To accomplish this, several pre-processing programs were written ([Appendix A](#): TMSMOD06.FOR, VCONT04.FOR, and BCFMAK03.FOR). These programs translate information on the 3-D distribution of HSUs and their hydraulic conductivities into transmissivity and vertical conductance values for each model

Table 3-5
Estimated and Target Ranges
in Discharge Fluxes for Eight Discharge Areas

Discharge Area	Estimated Discharge Range (m ³ /d)	Target Discharge Range (m ³ /d)
Alkali Flat (or Peter's Playa, [AF])	3,000 - 35,000	5,000 - 7,300
Amargosa River (AR)	2,040 - 5,100	2,040 - 5,100
Ash Meadows (AM)	67,000 - 101,400	67,000 - 87,300
Death Valley (DV)	17,500 - 60,200	17,500 - 60,200
Franklin Lake/Alkali Flats (FL)	14,200 - 42,600	14,200 - 42,600
Oasis Valley (OV)	17,000 - 27,000	17,000 - 27,000
Penoyer Valley (PV)	13,000 - 27,000	13,000 - 27,000
Indian Springs	1,600 - 2,400	1,600 - 2,400

cell. The input datasets are generated in the same manner, using the same pre-processors, each time a model calibration run is conducted to facilitate the QA process. The procedure used for construction of the hydraulic conductivity (or transmissivity) and vertical conductance datasets is described in the following text.

3.5.1 Hydraulic Conductivity Parameters

The transmissivity of a cell is calculated by summing the transmissivities of all HSUs present in the cell. The transmissivity of each HSU within the cell is calculated by integrating the product of the parameter, K_h (the horizontal hydraulic conductivity projected to a depth of zero), and the depth-decay function over the depth interval occupied by the HSU (Figure 3-6). The depth-decay coefficient, λ , describes the decrease in hydraulic conductivity with increasing depth (refer to Figure 2-1). For example, model Cell 1 in Figure 3-6 has three HSUs that fall within it; the transmissivities of each of the HSUs are calculated and summed, resulting in transmissivity values of 1029 for layer m and 1509 for layer $m+1$ (units of length²/time). This process results in some averaging of hydraulic conductivity values; however, model layer thicknesses were initially selected to represent the properties of hydrologically important HSUs as much as possible (Section 3.2). Therefore, averaging should have little effect on areas that are important in controlling flow directions and rates.

The transmissivity is calculated for each model layer at each cell on the uniform 2-km by 2-km geologic grid. A pre-processing program is used to translate and rotate the hydrologic grid

$$\int_{z_1}^{z_2} K_h \cdot 10^{(-\lambda z)} dz = \frac{K_h}{(2.303)(-\lambda)} (10^{(-\lambda z)} \Big|_{z_1}^{z_2}) \quad (3-3)$$

Where:

z = depth below land surface (m)

K_h = horizontal hydraulic conductivity at land surface (m/d)

λ (depth-decay coefficient) = 0.001 assumed for all HSUs

Then:

$$T_m = \frac{1}{(2.303)(-\lambda)} (10(10^{-\lambda(10)} - 10^{-\lambda(0)}) + (20(10^{-\lambda(30)} - 10^{-\lambda(10)}) + (30(10^{-\lambda(50)} - 10^{-\lambda(30)}))) = 1029 \quad (3-4)$$

$$T_{m+1} = \frac{1}{(2.303)(-\lambda)} (30(10^{-\lambda(70)} - 10^{-\lambda(50)}) + (40(10^{-\lambda(100)} - 10^{-\lambda(70)}))) = 1509 \quad (3-5)$$

Where:

T_m = Transmissivity for model layer m

T_{m+1} = Transmissivity for model layer $m+1$

Figure 3-6
Calculation of Transmissivity Values

relative to the geologic grid and to interpolate values for the center of each active flow model cell based on the four closest points on the geologic grid, (Figure 3-7). The interpolation is performed using bilinear interpolation, an accurate and computationally efficient scheme for calculating values at new points from data on an orthogonal grid. In this manner, each active cell within the flow model was assigned a horizontal hydraulic conductivity value; these values were output from the pre-processors in a form consistent with the input data sets required by MODFLOW.

Within a geologic unit, hydraulic conductivity can be constant with respect to direction (isotropic), or it can vary depending on direction (anisotropic). If a system is anisotropic, the hydraulic conductivity is a function of direction. The three principal hydraulic conductivity directions are assumed to be parallel to the x (column), y (row), and z (layer) axes specified in MODFLOW. In the NTS model, the grid is oriented so that the column direction is parallel to the average orientation of faults within the Pahute Mesa and Yucca Flat testing areas. However, fracture strike and the orientation of the principal direction of hydraulic conductivity in the horizontal plane are not constant over the study area. For example, fractures with both north-south and northeast-southwest strikes are present in the southern part of Yucca Flat. MODFLOW requires that the principal directions of conductivity must be parallel to the model axes and that the anisotropy ratio assigned to a model layer must be constant (although different model layers may have different ratios). Because data do not exist to support a regional anisotropy, each model layer was treated as laterally isotropic (the hydraulic conductivity value in the x and y directions is equal).

Isotropy and anisotropy indicate the dependence of a parameter on direction, whereas homogeneity and heterogeneity indicate the dependence of a parameter on location. For example, a volcanic deposit may consist of areas of welded tuff with relatively high values of hydraulic conductivity and non-welded tuff with significantly lower conductivity values. This is a heterogeneous unit because of the different hydraulic conductivity zones associated with the degree of welding.

The pre-processors developed for the NTS model allow an HSU that is heterogeneous with respect to a hydrologic parameter to be divided into zones of homogeneous parameter values. In the above example, the tuff itself is heterogeneous with respect to hydraulic conductivity, but the unit can be subdivided into zones which are assumed to be homogeneous (have constant conductivity values).

- ⊕ - Centroid of model grid cell 2.
- - Geologic grid points used to calculate transmissivity for model grid cell 2, based on the location of the centroid of the model cell.

Figure 3-7
Interpolation of Data from the Geologic to Hydrologic Grid.

3.5.2 Vertical Leakance

Vertical flow between model layers is described by the vertical conductance. The vertical conductance for each cell is the product of the vertical leakance, or “Vcont”, parameter, which is the required input to MODFLOW, and the cell area. The higher the Vcont term, the greater the flow rate between layers. Vcont is calculated between the center of each cell in the current layer (i,j,k, where the indices represent the x,y,z locations of the center of the cell) and the layer below it (i,j,k+1, where the model layer increases with increasing depth). Commonly, the vertical interval between the two nodes is composed of n hydrogeologic layers or, in the case of the NTS model, n HSUs with vertical hydraulic conductivities $K_{v1}, K_{v2}, \dots, K_{vn}$ and thicknesses $z_1, z_2, \dots, z_n$. Vcont is then calculated from the following relationship:

$$Vcont_{i,j,k+1/2} = \frac{1}{\sum_{g=1}^n \frac{z_g}{K_{vg}}} \quad (3-6)$$

where:

- g = HSU designator;
- K_{vg} = vertical hydraulic conductivity of HSU layer g [L/T]; and
- $i,j,k+1/2$ = vertical interval between node _{i,j,k} and node _{$i,j,k+1$} [L].

The vertical hydraulic conductivity is the product of the horizontal hydraulic conductivity value (determined by calculating the transmissivity of the HSU within the layer, as described in [Section 3.5.1](#), and dividing by its thickness) and the anisotropy ratio specified for each HSU. The anisotropy ratio, defined as the ratio of the vertical to horizontal hydraulic conductivities, is indicative of the preference for lateral versus vertical flow within an HSU. For example, an anisotropy ratio of “1” indicates that the HSU is isotropic (does not change with direction) with respect to conductivity, while a ratio of 0.05 indicates that the horizontal conductivity is 20 times greater than the vertical conductivity.

The vertical conductances for each model layer are calculated in a similar manner to the transmissivity values. The major difference is that all HSUs within a model layer are used to calculate transmissivities, whereas HSUs within the lower half of the current model layer and the upper half of the model layer below it are used to calculate Vcont for the current layer ([Figure 3-8](#)).

Assume: 1) λ (depth-decay coefficient) = 0.001 for all HSUs
 2) Anisotropy ratio (K_v/K_h) - α = 0.1 for all HSUs

Then:

$$K' = \frac{\alpha K_h}{\Delta z} \int_{z=1}^{z=2} 10^{(-\lambda z)} dz = \frac{\alpha K_h}{(2.303)(-\lambda)\Delta z} (10^{(-\lambda z)} \Big|_{z=1}^{z=2}) \quad (3-8)$$

Where:

z = depth below land surface

K_h = horizontal hydraulic conductivity at land surface

And:

$$V_{\text{cont of } m} = \frac{\alpha K_h}{\sum_{g=1}^6 (b/K')_g} = \frac{1}{(10/0.88) + (20/1.28) + (20/1.63) + (10/1.57) + 40/1.85} = 0.015 \quad (3-9)$$

Figure 3-8
Calculation of Vcont Values

To calculate V_{cont} , model layer m and model layer $m+1$ are divided in half. All HSUs that fall within the lower half of layer m and the upper half of layer $m+1$ are identified along with their respective thicknesses. The depth-averaged vertical hydraulic conductivity for each HSU is calculated. This average hydraulic conductivity is used as K_{vg} in Equation 3-6. As an example, examination of [Figure 3-8](#) indicates that all or portions of four HSUs are present between the nodes of model layer m and subjacent model layer $m+1$. The K_h parameter (which represents the horizontal hydraulic conductivity value at a depth of zero) of each of the HSUs is multiplied by its vertical anisotropy value and by an exponential factor describing the decrease in conductivity at the depth corresponding to the midpoint of the HSU within the model layer. The modified hydraulic conductivities and respective thicknesses are then used to calculate a V_{cont} value of 0.015 (units of time^{-1}).

As with the hydraulic conductivity values, V_{cont} is calculated for each model layer at each cell on the uniform 2-km by 2-km geologic grid. A program (BCFMAK03.FOR, [Appendix A](#)) was used to translate and rotate the hydrologic grid relative to the geologic grid and to interpolate values for the center of each active flow model cell. In this manner, each active cell within the flow model was assigned a V_{cont} value; these values were output from the pre-processors in a form consistent with the input data sets required by MODFLOW.

3.6 Model Assumptions

The assumptions on which a model is based dictate when and under what conditions it can be applied. The assumptions used in developing the NTS model have been described in appropriate sections and are summarized as follows:

- The model represents steady-state conditions representative of natural stresses to the system prior to groundwater development and underground nuclear testing.
- The system is laterally isotropic and vertically anisotropic.
- Each HSU is homogeneous or can be divided into homogeneous zones.
- The hydraulic conductivity is assumed to decrease in an exponential manner with increasing depth.
- At the scale of the regional model, movement of water in fractured rock can be adequately described by a porous media model.

- Because of the steady-state assumption, the volumetric recharge is based on estimates of discharge from the basin.
- Recharge can be adequately simulated by using a technique similar to that used by Maxey and Eakin (1949), modified to account for runoff (recharge redistribution).

4.0 Calibration Process

4.1 Introduction

The process of model calibration consists of adjusting various modeling parameters to develop an acceptable agreement between the model-related values and those values measured in the groundwater system. Modeling parameters are the model input values such as aquifer thickness, horizontal hydraulic conductivity projected to land surface (K_h), and boundary conditions. Agreement is desired for values such as hydraulic head, boundary fluxes, and general flow direction. This chapter will describe the process used to calibrate the UGTA model of the regional flow system in the vicinity of the NTS. Steps taken to achieve calibration include the following:

- Establish the calibration criteria for the model.
- Assess the degree of agreement between simulated and measured water levels and boundary fluxes within an estimated range of uncertainty specified by the calibration criteria.
- Modify the hydraulic conductivity parameters (K_h , vertical anisotropy, and λ), the boundary conditions (recharge distribution, boundary heads, and Drain Package conductances), and the geologic model to achieve the calibration criteria.

The calibration procedure used for the regional flow model as well as a short history of the calibration process is discussed in the following text. The calibration process was performed in three separate sequences. The initial calibration sequence identified four geographic areas where the digital geologic model was insufficient to explain some of the features of the groundwater system. The second sequence included refinement of the geologic model in key areas and recalibration followed by an extensive peer review. One of the reviewer's suggestions was that the recharge dataset be reevaluated. This reevaluation concluded that the co-kriging process used in the earlier models did not satisfactorily portray the distribution of precipitation in the northern part of the model area. A second precipitation dataset, based on older isohyetal maps of Nevada (Hardman, 1936) and on eastern California precipitation data included in a newer map by James (1993), was developed for the third and final sequence of calibration.

This section primarily describes the third sequence of calibration. However, discussions of changes to the geologic model performed during the second sequence are included because of their importance. The calibrated model results and sensitivity analyses are presented in Section 5.0 of this report.

4.2 Procedure

The calibration of the regional flow model was an iterative process that involved establishing site hydrogeologic conditions and performing simulations until calibration criteria were achieved to the extent possible. Datasets that were adjusted during calibration of the hydrologic model included the geologic model, the hydrologic properties of the HSUs, and the boundary conditions. The pre-processors were designed so that implementing changes to the conductivity parameters was very easy. For each model run, one file (cond.mdl) contained the information about the geologic model version number, the conductivity zonation arrays, and the hydrologic parameters for the HSUs. A descriptive log of the runs was appended to this file to provide a record of the changes in the hydrologic properties that were made during calibration.

Changes to the other datasets were more labor-intensive. For example, changing the geologic model required editing the grids while ensuring that these changes did not result in negative HSU layer thicknesses or areas where the geology was not defined. Only minor, experimental changes (i.e., developing a test model to determine whether raising the top of the LCCU would provide a better match to observed water level data or discharge rates) were made by the hydrologic modelers. If a change in the geologic model was considered important, the hydrologic modelers would request that the responsible geologist reevaluate the interpretation of the geology in that area. The geologist would then evaluate the current data, consulting with other geologists who were familiar with the area, prior to determining whether the change was consistent with the data and whether the model could be appropriately modified. The changes would be processed through the Environmental Restoration Management Applications system (ERMA) and checked for errors by developing geologic sections using VOXELTM. The completed and checked dataset was then provided to the hydrologic modelers for use.

The hydrologic modelers made changes to boundary conditions which included adjustments of recharge rates, boundary heads, and Drain Package conductances. These changes were implemented by creating new versions of input data files. A separate file (files996.in) contained the names of the control and boundary condition files that were used for each simulation; contents of that file were printed with the simulation results. The printed output for each run consisted of the following items:

- The run name
- The cond.mdl file
- The contents of the batch file used to control the run, listing all programs called during the simulation

- The files996.in file which directs MODFLOW to the input files to read for control parameters and boundary conditions
- The flux rates for the two GHBs, eight drain areas, and two constant-flux boundaries
- The head-residual statistics for the fifteen residual zones and for the overall model
- A map of the simulated water table
- Maps of the simulated heads for the 20 model layers with posted values of weighted residuals by model layer calculated by RESIDL02
- A map of areas where the simulated water table is above the land surface
- A map of particles pathlines
- A plot of measured versus simulated heads

In addition to this printed record, logs of the flux information and head-residual statistics were also recorded for the majority of the runs. Plotting the log information provided a means to judge progress and to determine when changes in datasets caused significant changes in model fit.

4.3 Development of Calibration Criteria

In recent years, the American Society of Testing Materials (ASTM) has produced standard guides for the development and application of groundwater models which define calibration as "the process of refining the model representation of the hydrogeologic framework, hydraulic properties, and boundary conditions to achieve a desired degree of correspondence between the model simulation and observations of the ground-water flow system" (ASTM, 1994). In their document the *Standard Guide for Comparing Ground-Water Flow Model Simulations to Site-Specific Information* (1994), the ASTM further describes several approaches for evaluating the agreement between the model and the flow system being modeled. These procedures include qualitative and quantitative comparisons between model results and:

- Measured water levels
- Water-balance information (recharge and discharge fluxes)
- Flow-direction information
- Flow-system hydraulic parameters.

The *Standard Guide* recommends the use of quantitative measures for the agreement of hydraulic head and suggests quantitative measures for water-balance information if possible (ASTM, 1994). For the NTS region, use of quantitative measures of the fit with hydraulic-head data is appropriate. However, the estimates on recharge and discharge rates have a wide range, so the

calculation of discharge residuals would be complicated by a need to develop different weighting factors for different boundary flux areas based both on the magnitude of the flux and the uncertainty in the flux estimate. Rather than developing numerical values for flux residuals, the boundary fluxes were calculated for each run and compared against the estimated range.

For the flow-direction category, the *Standard Guide* does not provide quantitative measures. It suggests that it may be more important to stress agreement between simulated and actual flow directions over minimizing head residuals (ASTM, 1994). However, in the NTS region, flow directions are primarily surmised from water level data, recharge and discharge information, and geologic data rather than being based on movement of tracers such as contaminants. Interpretations of geochemical data are consistent with interpretations of hydrologic data, but do not currently provide additional constraints. Therefore, comparison of flow directions can only be approximated.

The *Standard Guide* also states " ... a qualitative check on the degree of correspondence between a simulation and the physical hydrogeologic system should include an assessment of the likely ranges of hydraulic properties for the physical hydrogeologic system *at the scale of the model* [emphasis added] or model cells and whether the properties used in the model lie within those ranges" (ASTM, 1994). Although there have been many tests of transmissivity at the NTS, the data are highly variable because the tests have primarily been conducted without observation wells, and the drawdowns observed in the pumping wells are sensitive to the properties of the fractures that are penetrated by the borehole.

Typically, the transmissivity data for a borehole are dominated by a small percentage of the fractures that are present. Hydraulic conductivity values determined from these tests range over orders of magnitude. These data can then be considered to be representative at the scale of the borehole (or slightly larger), but not at the scale of the model cells. Because of the high variability, these data would not be expected to provide a significant constraint to the calibration of the model.

4.3.1 Target Hydraulic Heads

One of the primary objectives of model calibration is to match simulated heads calculated by the model with the measured, or target, heads. A listing of the target heads is included in [Appendix B](#). The list includes information about 928 wells or springs which fall within the model grid (797 of these wells fall within the active region of the model grid). [Appendix B](#) also contains additional information necessary to calculate the statistical goodness-of-fit parameters for the

calibration effort. As would be expected, some wells penetrate more than one model layer, and information on the completion interval is necessary for properly evaluating the goodness-of-fit.

Prior to beginning the calibration, the water level database was evaluated to identify those measurements that were not representative of regional conditions; these data were not included on head contour maps or in the residual or sensitivity calculations presented in [Section 5.0](#). For example, water levels indicating perched conditions were flagged as not being representative. These included many springs at higher elevations in the northern part of the model area and in the Spring Mountains. Also excluded are measurements in NTS wells made during or shortly after drilling when it was questionable whether water levels had stabilized.

Additional measurements were eliminated from the set of target heads during the calibration process when inclusion of the measurement would bias the calibration process and when the well or spring was located in an area distant from the NTS. For example, a well high in the Spring Mountains had a measured head of 2454 m, considerably higher than water levels at lower elevations. Neither the geologic nor hydrologic models were constructed to model the hydrology of the Spring Mountains since heads in this area would have little effect on predictions of transport from the testing areas. Matching heads in the lower part of the Spring Mountain area was considered more important than those at higher elevations. Because of the high residual associated with this high head, the mean residual and root mean square of the residuals would be greatly influenced by its inclusion in the target head database. As the calibration process was based, in part, on minimizing the mean and root mean square of the weighted head residuals, there would be a tendency to compensate for this high residual by simulating heads higher than what was present in the more important wells at lower elevations. To avoid this, the well was removed from the target head database. A similar decision to eliminate measurements from the target head database was made for five other wells. These wells are listed at the end of [Appendix B](#).

4.3.2 Hydraulic Head Residuals

There are several measures of fit that have been used in the modeling community. These are calculated, in part, from the head residual which is defined for this model as the difference between measured, or target, and simulated hydraulic heads. A positive residual means that the model-calculated head is less than the measured value. The goals of calibration, with respect to water levels, are as follows:

- The average of the residuals is close to zero.
- The residuals themselves are small.
- The residuals are normally distributed and not spatially correlated.

Because the range in measured heads can differ depending on the gradient and size of the modeled area, it is common to base measures of fit on the range in measured heads. In addition, the residuals can be non-zero because of both measurement error and model mismatch. Therefore, it is common to calculate weighted residuals, which consists of multiplying the residual by a weighting factor that is indicative of the reliability of the measurement; the greater the reliability of the measurement, the higher the weighting factor should be. The weighting factor was calculated as the inverse of the square root of the total variance associated with the mean value (in this case, head) calculated for an observation point. For a low variance, the weighting factor is high, and the reliability of the mean target value will be high.

The total variance, or estimate of the uncertainty, in a target water level elevation is a composite of three main sources of error: the error associated with quantifying the elevation of the measuring point, usually land surface elevation; the observed temporal variation in depth-to-water measurements; and the error associated with the modeling process. The error associated with the measurement technique is assumed to be contained within the temporal variation between measurements. The total variance was calculated as the sum of the variances associated with the elevation of the observation point, the variation in depth-to-water measurements, and the model error. The error associated with the model is difficult to quantify and is normally ignored. In this model, a model variance of 1 m^2 was used, with the expectation that the model error is likely greater than this.

Model error is due to discretization effects, averaging of hydraulic properties, partial penetration of target-head wells, and many other factors. For many wells, it was not possible to quantify the measurement variance because needed information was lacking. These measurements were assigned a variance of 100 m^2 , which assumes that the combined error in the measuring point elevation and depth-to-water measurements is about 10 m.

It should be noted that the model calculates head values at the center of each grid cell, but the target wells are generally at locations other than the center of the cell. An interpolation routine from the code MODFLOWP (Hill, 1992) was used to calculate head values for the location of the well. Because the wells can extend over more than one model layer, the simulated head is calculated as the transmissivity-weighted average head for the layers that the well penetrates. If the cell in which the measurement was made is dry, the hydraulic head in the layer below is used in calculating the residual.

There are many different ways to measure the goodness-of-fit between simulated and measured hydraulic heads. Several of these are discussed in the following text, and the ones that have been selected for use are indicated. It should be emphasized that in the following discussions, the term “residual” refers to the hydraulic-head residual.

Measures of the Mean Residual

The mean residual, the simplest of the four discussed here, is simply the average of the residuals. It is a good measure of whether the calculated heads are, on average, in agreement with the measured heads. It does not necessarily provide information on the magnitude of the residuals, which may be large but which may still have an average that is near zero. It also does not reflect the range in measured water levels within the modeled area or the reliability of the water level measurements. The related, mean-weighted residual is similar to the mean residual, but it reflects the reliability of the measurements. It is calculated by dividing the sum of the weighted residuals by the sum of the weights. Both of these measures may be normalized by dividing by the range in measured heads, thus incorporating the natural change in head in the area. These normalized measures are called the normalized mean residual and normalized mean-weighted residual. The mean-weighted residuals (in meters) were used as calibration criteria.

Root Mean Square Residual

The square root of the mean-squared residual (root mean square, RMS) gives information on the spread and magnitude of the residuals. The larger the RMS, the larger the residuals, and the greater the mismatch between the model and the measurements. The spread can also be expressed by the RMS of the weighted residuals, the normalized RMS of the residuals, and the normalized RMS of the weighted residuals. The RMSs of the weighted residuals (in meters) were used as calibration criteria.

Correlation Between the Measured and Calculated Heads

Plots can be developed using the measured head along one axis and the calculated heads along the other. If the model matches observed heads perfectly, all points would lie on a straight line with a slope of 45 degrees and an intercept of zero. A regression line would have the same characteristics, and the correlation between measured and calculated heads would be 1. In this modeling effort, because of the decision to emphasize the goodness-of-fit in some areas (i.e., the testing areas) over other areas such as the Spring Mountains, calculating the regression line and the correlation coefficient could be misleading. Instead, plots were prepared as described with the goal of reducing the distance between the plotted points and the 1:1 line.

Maximum Residual

The maximum residual (in absolute value) has been used by some modelers as a measure of the goodness-of-fit. However, it places too much emphasis on a single point and has little usefulness in guiding model calibration. Maximum residual will not be used as a calibration criterion.

Delineation of Residual Zones

Often the goodness-of-fit measures are applied over an entire model. For the NTS model, this approach would have resulted in de-emphasis on the fit in the areas of the NTS because of the large number of water level observations outside of the NTS boundaries, for instance, in Oasis Valley, and in the Farm Area in the Amargosa Desert. The goodness-of-fit measures would also be greatly impacted by mismatches in high-gradient areas. High gradients develop where the hydraulic conductivity is low. Hydraulic heads within the high-gradient area are determined largely by the geometry of the barrier rather than its hydraulic properties. For the regional model, the presence of low-hydraulic conductivity barriers is very important, but their precise geometry is not, since water tends to flow around barriers rather than through them.

For these reasons, goodness-of-fit measures were developed for different areas, termed “zones” or “residual zones” within the regional model. This approach allows emphasis or greater weighting to be placed on the model characteristics expected to be important to solute transport from the testing areas. Fifteen zones were defined within the model. Each zone includes observation data from all model layers that fall within the zone. The 15 zones are shown in [Figure 4-1](#), and the calibration goals for each of the zones are presented in [Table 4-1](#). [Table 4-1](#) also includes the range in measured heads within each zone. Within the NTS, separate zones are defined for Pahute Mesa, the Timber Mountain area, the Shoshone Mountain area, the high gradient area associated with the LCCU, Frenchman Flat, western Yucca Flat, and eastern Yucca Flat. Regional zones include the Amargosa Farm area, the LCA (beneath the Amargosa Desert [excluding the Amargosa Farm area], Jackass Flats, and areas east of the NTS), Oasis Valley, Death Valley, the Spring Mountains, the Sheep Range, the area southwest of Pahranaagat Valley, and the area north of the NTS.

The goals for the calibration measures reflect the fact that the model was developed to help predict transport from the weapons testing areas. The goals are more stringent for the weapons areas and those areas downgradient from them, which is consistent with the greater detail in the geologic model in these areas. Areas such as the Spring Mountains and the area north of the NTS, while important with respect to the value of the groundwater resource in general, were

Figure 4-1
Distribution of Residual Zones for the NTS Model.

Table 4-1
Calibration Criteria for Weighted Hydraulic-Head Residuals by Zone

Zone	Area	Mean Weighted Residual (m)	Root Mean Square of Weighted Residuals (m)	Range in Measured Heads (m)
	All	20	100	1687.4
1	Northern Area (NRTN)	100	150	202.7
2	Oasis Valley (OASI)	15	75	533.7
3	Pahute Mesa (PM)	25	35	230.7
4	Barrier (BARR)	300	350	565.3
5	W. Yucca Flat (WYF)	45	110	632.2
6	E. Yucca Flat (EYF)	35	80	101.3
7	Shoshone (SHON)	20	50	285.8
8	Death Valley (DV)	80	100	728.4
9	Lower Carbonate Aquifer (LCA)	5	40	205
10	SW. of Pahrnagat Valley (PAHR)	40	40	15.3
11	Spring Mtn. (SPMT)	150	150	278.9
12	Sheep Range (SHRG)	100	100	39.9
13	Timber Mtn (TMBR)	100	100	220.7
14	Amargosa Farm (FARM)	10	50	58.3
15	Frenchman Flat (FF)	10	50	20.6

thought to be less important with respect to solute transport than those areas within and downgradient from the testing areas. In addition, there are fewer subsurface data available for these areas, thus the geologic model is correspondingly less well-defined.

The 15 zones and their abbreviations used in the corresponding tables and figures are defined as follows:

Zone 1: Northern Area (NRTN)

The Northern Area zone consists of the area to the north of the NTS and extends eastward to the high gradient area east of Penoyer Valley. It includes several ranges where appreciable recharge

occurs and high vertical gradients exist. The geologic model is not sufficiently complex in these areas to match these vertical gradients, and high residuals are expected and acceptable.

Zone 2: Oasis Valley (OASI)

Oasis Valley consists of the discharge area near Beatty and upgradient areas west of Timber Mountain. This area was delineated as a separate zone because of its importance as a possible downgradient receptor from the Pahute Mesa testing area.

Zone 3: Pahute Mesa (PM)

The Pahute Mesa testing area has been designated as a residual zone because it is a testing area from which radionuclide transport is of concern and because of the plan to perform more detailed modeling of this area. By calibrating the regional model to result in a good fit to hydraulic heads in this zone, subsequent development of the detailed model using the regional model for establishing boundary conditions will be more successful.

Zone 4: Belted Range Barrier (BARR)

This zone is a high-gradient area associated with the LCCU northeast of the NTS. It has been designated as a residual zone because of the anticipated difficulty in accurately matching heads in this high-gradient area. The important feature that needs to be simulated in the model is the existence of the high-gradient zone, rather than closely matching the individual head measurements.

Zones 5 and 6: Western Yucca Flat (WYF) and Eastern Yucca Flat (EYF)

The Yucca Flat testing area has been selected as an area of greater interest for the same reasons as Pahute Mesa. However, because Yucca Flat has higher heads in the western half (which is underlain by the Upper Clastic Confining Unit, UCCU, [Table 2-1](#)) than in the eastern half, it has been divided into two separate zones. The Western Yucca Flat residual zone is characterized by a wider range in heads and higher gradient than the Eastern Yucca Flat zone.

Zone 7: Shoshone Mountain (SHON)

The Shoshone Mountain zone, located west of Yucca Flat, is an area with relatively high water levels, presumably because of recharge in the area and the presence of the UCCU underlying the volcanic rocks. It is designated a separate residual zone in order to prevent the heads in this area from affecting the residual statistics in Yucca Flat and Frenchman Flat.

Zone 8: Death Valley (DV)

The Death Valley residual zone extends from the Amargosa Desert west of Death Valley Junction into Death Valley. It includes the high-gradient area on the northeastern side of Death Valley and is separated from the neighboring LCA zone because of this difference in gradient.

Zone 9: Lower Carbonate Aquifer (LCA)

This zone is underlain by the LCA and is generally characterized by low hydraulic gradients. It is the largest residual zone in the model and extends from the Amargosa Desert eastward to nearly the Sheep Range. This zone was separated from the Sheep Range, Spring Mountain, and Southwest of Pahrangat Valley zones because of their higher gradient, and it was separated from the Frenchman Flat zone because of its importance as an underground testing area.

Zone 10: Southwest of Pahrangat Valley (PAHR)

This zone is east of the LCA residual zone and is characterized by shallower LCCU and higher hydraulic heads than in the LCA zone.

Zone 11: Spring Mountains (SPMT)

The Spring Mountain zone covers the area south of and including the Las Vegas Valley Shear Zone. The heads in this area are higher than those to the north because of an apparent reduction in hydraulic conductivity caused by movement along the shear zone.

Zone 12: Sheep Range (SHRG)

The Sheep Range zone is northeast of the Las Vegas Valley Shear Zone between the Sheep Range and the Spring Mountains. Because of the geometry of the LCCU and the high precipitation rate, the gradient within this zone is high.

Zone 13: Timber Mountain (TMBR)

The Timber Mountain zone lies between Pahute Mesa and the high-gradient area north of Yucca Mountain and Jackass Flats. The gradient within this zone is relatively low. It was separated from the Pahute Mesa zone because of its lower gradient and the occurrence of testing beneath Pahute Mesa.

Zone 14: Amargosa Farm Area (FARM)

This residual zone is in the northern part of the Amargosa Desert, and contains a large number of target-head wells. It was defined as a separate zone within the LCA to keep the area from dominating the statistical measures for the LCA zone.

Zone 15: Frenchman Flat (FF)

The Frenchman Flat residual zone was separated from the LCA zone because of its importance as an underground testing area, and because of the plan to perform more detailed modeling of this area.

4.3.3 Fluxes

The calibration procedure also consisted of comparing computed fluxes with estimated and measured field fluxes. MODFLOW calculates the boundary fluxes for all individual flux boundary cells. Postprocessors were written to sum these fluxes for the eight internal discharge areas and the four external flux boundaries (Figure 3-1) so that simulated flux values could be compared to estimated and target flux ranges (Tables 3-4 and 3-5). In Section 4.6.1, a discussion is presented concerning the selection of a target flux rate for each of the eight internal discharge areas and the four external flux boundaries. The calibration goal was to have the model-calculated fluxes fall within the target flux range, as close as possible to the target flux rate.

4.4 Modification of Geologic Model

Because the gross regional geology is better known than the distribution of hydraulic conductivities within the model area, the procedure for model calibration consisted of using the original interpretation of the geologic model without modifications and then adjusting HSU hydraulic conductivities within acceptable ranges to match target heads. However, calibration efforts indicated that there were four areas within the model where simulated heads were significantly different than measured heads, despite modifications to conductivity values. These four areas were:

- The area between Emigrant Valley and Yucca Flat
- The eastern part of Penoyer Valley adjoining the Timpahute Range
- The Timber Mountain Caldera region
- Tongue Wash located to the southeast of Rainier Mesa and to the west of the northern extension of the Eleana Range

The modeling results indicated that reexamination of the initial geologic interpretations in these areas was necessary. This iterative procedure was advantageous in that it helped to further the understanding of both the hydrologic and geologic models in a highly complex hydrogeologic region. The interpretations incorporated in the final geologic model are discussed in the following text by area. The discussion has been directly taken from the *Geologic Model Documentation Package* (IT, 1996b; Appendix H) which also includes detailed structural maps of the areas of

concern. Modifications to the geologic grid in the Emigrant Valley-Yucca Flat area were included in the first sequence of the calibration. Modifications to the latter three regions were incorporated during the second sequence.

Area Between Emigrant Valley and Yucca Flat

Regional groundwater potentiometric data show a relatively high gradient between Emigrant Valley and Yucca Flat (IT, 1996c; Plate 2); however, initial modeling results indicated a much lower potentiometric gradient in this area. The original geologic model contains LCA extending from northern Yucca Flat, northward into Emigrant Valley. This carbonate corridor allowed groundwater in the flow model to readily flow into the northern end of Yucca Flat from the north, thus producing a low simulated hydraulic gradient between Emigrant Valley and Yucca Flat.

In order to produce the high gradient between Emigrant Valley and Yucca Flat, a hydraulic barrier is necessary; however, the barrier must be consistent with regional geology. In this region, clastic rocks of the LCCU exposed in the Groom and Papoose Ranges dip eastward. The Groom Range is the east limb of a regional scale, north-south-trending, pre-Tertiary structural high, with the axis centered in Emigrant Valley. Over a large portion of this area, the LCA was eroded away, and the Sterling Quartzite and Wood Canyon Formations of the LCCU were exposed prior to deposition of the Tertiary volcanics. In the Papoose and Groom Ranges, Tertiary volcanic rocks were deposited directly on the LCCU.

Based on examination of geological and geophysical maps and discussions with Dr. W. Taylor of the University of Nevada at Las Vegas (Taylor, 1996), an alternate interpretation has been forwarded that results in downdropping of LCCU along normal faults into the Tertiary-aged Emigrant Valley graben. As on the adjacent structural high, Tertiary undifferentiated VU and AA are interpreted to rest directly on the LCCU beneath Emigrant Valley, and the LCA is absent.

A pre-Tertiary syncline (Syncline Ridge) runs along the western margin of Yucca Flat and plunges southward from the structural high of the Emigrant Valley area. In the northern extension of the plunging syncline, the LCCU is projected to subcrop at a relatively high structural position within the Emigrant Valley. With the LCCU present at high structural levels and the LCA absent, a relative barrier to southward flow exists from Emigrant Valley to Yucca Flat.

In the geologic model, the LCCU top elevation was raised to the previous elevation of the LCA, and the LCA was removed from the model in this area. Further, the LCCU and the VU surfaces were edited to conform more with the general shape of the Tertiary basin defined in Saltus (1994).

Penoyer Valley-Timpahute Range

In Penoyer Valley (also known as Sand Spring Valley) northeast of the NTS, water levels in wells are near the surface. Desert Valley is separated from Penoyer Valley by the Timpahute Range. Water levels in Desert Valley and in the area to the southwest of Pahrnagat Valley are approximately 400 meters lower than in Penoyer Valley.

In the original geologic model, alluvium in Penoyer Valley is floored with VU which overlies carbonate rocks. In that model, LCA occurs throughout the area between Penoyer Valley, Timpahute Range, and Desert and Pahrnagat Valleys. Although the structure in the LCA is complicated by thrusting and other faulting (Taylor et al., 1994), the LCA is thought to be interconnected between the areas.

The geologic model contains a pre-Tertiary structural high in the Groom Range where LCCU is exposed at the surface. The structural high plunges to the north and has been dropped down by Tertiary faulting into the Penoyer basin. Just how far northward the clastic high extends before it drops into the valley and is then covered by alluvium and younger volcanics is open to interpretation. In the original geologic model, it plunged deeply to the north where the LCCU was as low as minus 5,000 meters in elevation beneath Penoyer Valley.

The geologic map of Nevada (Stewart and Carlson, 1978) shows a very small outcrop of Precambrian quartzite (LCCU) at Sand Spring. This outcrop is not present on the more detailed map by Tschanz and Pampeyan (1970), but is verified by Van Denburgh and Rush (1974). The presence of the LCCU outcrop in the middle of Penoyer Valley indicates that the ridge of LCCU exposed in the Groom Range extends further north than was expressed in the original geologic model.

The structural high is bounded on the east by a series of north-south-trending regional thrust faults. One of the faults in the Timpahute Range, the Lincoln thrust, has been correlated with the Freiberg thrust in the Worthington Mountains and with the Rimrock thrust further north in the Grant Range (Taylor, 1996). The east side of the thrust fault system is the downthrown side. Paleozoic carbonates occur near the thrusts and to the east along the fault trend. The west side of the thrust fault system is the upthrown side with LCCU exposed locally along the north-south trend. LCCU is exposed along the trend in the Papoose Range, the Groom Range, the Penoyer Valley/Sand Spring outcrop, and in several locations in the Quinn Canyon Range.

Based on the information presented here and in discussions with Dr. W. Taylor, an alternate interpretation to the geology originally presented in the geologic model in the Penoyer Valley area

has been forwarded. This interpretation includes the structural uplift of the LCCU following the north-south thrust fault trend to connect LCCU exposures in the Papoose and Groom Ranges, the Penoyer Valley/Sand Spring outcrop, and the Quinn Canyon Range outcrops; this is the same structural uplift that was described in Emigrant Valley. It is further interpreted that most of Penoyer Valley is floored with LCCU underneath the alluvium and/or VU. This model provides the confining units at sufficient elevation to support water levels near the surface and to produce the observed gradients between Penoyer and Desert Valleys.

Timber Mountain Caldera

In the area of the southern part of the Timber Mountain Caldera and southward to Yucca Mountain, simulated heads following the first sequence of calibration did not satisfactorily match target head data. North of Yucca Mountain, model-generated heads were too low, and the relatively steep gradient observed in the field could not be simulated by the model. Because the water-level differences were fairly large, the cause of the discrepancy was believed to be the geometric distribution and elevations of confining units in the geologic model. The original geologic model did not provide confining units high enough in elevation to form a relative barrier to southward flow to the south and southeast of Timber Mountain.

The dominant pre-Tertiary structural feature in the western NTS is the Belted Range Thrust fault system. The fault strikes southwestward from Rainier Mesa and is thought to connect with a thrust at Bear Mountain, located to the west of Yucca Mountain, where the same structural relationships (LCCU faulted above the UCCU) are displayed (Caskey and Schwickert, 1992; Cole et al., 1994). Between Rainier Mesa and Bear Mountain, the fault is projected to lie to the north of the UCCU outcrops in Calico Hills and to the north of well UE-25p#1, near Yucca Mountain, which penetrated Silurian rocks of the LCA.

The exact location of the fault subcrop between Timber Mountain and Yucca Mountain is not known. In the original geologic model, it was located coincident with the southern boundary of the southern and eastern caldera structural blocks. After reviewing geological and geophysical maps and having discussions with U.S. Geological Survey scientists working in the Geologic Division and Yucca Mountain Project, the Belted Range Thrust subcrop was moved southward from the caldera boundary near Yucca Mountain to subcrop under Tertiary volcanic rocks near well USW-G2. This alternate interpretation is supported by regional structural trends. At Bare Mountain, the structural trends are east-northeast. The strike of the thrust would project east-northeast toward the vicinity of well USW-G2 which is north of Yucca Mountain, but south of the caldera. Near Shoshone Mountain, the structural trends become more northeasterly in both the hanging wall and footwall.

The outline of the caldera has also been changed to be consistent with recent interpretations by the U.S. Geological Survey (Sawyer et al., 1995). This change, which is supported by gravity data, effectively moved the caldera boundary northward from the one in the original geologic model. Immediately south of the caldera boundary of Sawyer et al. (1995), gravity values are relatively high, suggestive of Paleozoic or Precambrian rocks shallowly underlying the Tertiary volcanics (Sawyer, 1996). The gravity high is interpreted to represent buried LCCU, which results in subcropping LCCU to the northwest of the Belted Range Thrust and subcropping UCCU to the southeast of the fault.

In the original geologic model, VA was mapped above the VCU at Yucca Mountain, and both units extended from Yucca Mountain northward to the caldera boundary. The Timber Mountain volcanics were initially thought to be transmissive, which resulted in southward flow across the caldera and the Belted Range Thrust into the VA. This provided a conduit for flow from Timber Mountain to Yucca Mountain and resulted in the simulated low hydraulic gradient in this area and the poor match to observed heads.

Based on discussions with the U.S. Geological Survey (Sawyer, 1996), the volcanic hydrostratigraphy has been redefined. It has been observed that rocks within the Timber Mountain caldera are extensively zeolitized inside the ring fracture. Zeolitization decreases outward from the fracture ring to the caldera topographic wall and is also present outside the wall. The occurrence of the zeolitization indicates that hydraulic conductivity values of the caldera volcanics should be lower than previously modeled. In Fortymile Canyon, outside the topographic wall, rocks at the surface are also zeolitized. This indicates that VCU is present at the surface, and VA is absent in this area. Therefore, the geologic model was revised to place VCU at the surface from the caldera boundary, southward to the north of well USW-G2.

This reinterpretation places low-conductivity caldera volcanics laterally against confining unit VCU to the south of the caldera and places VCU directly on top of confining unit LCCU, which structurally overlies the UCCU. This stacking of confining units from the surface down produces a barrier to southward groundwater flow from the Timber Mountain Caldera to Well USW-G2.

Tongue Wash

Tongue Wash is located to the southeast of Rainier Mesa, west of the northern part of the Eleana Range. The original geologic model correlated the Devonian/Silurian carbonate outcrop in Tongue Wash with the LCA and assigned the completion interval in well ER-12-1, located within Tongue Wash, to the LCA. The structurally complex stratigraphic relationships found within well ER-12-1, however, remain enigmatic (Cole, 1993). Relatively thin UCCU observed in the

borehole, which separates an upper carbonate interval from a lower carbonate interval, was omitted from the first geologic interpretation because of high uncertainty in the structural geometry.

Well ER-12-1 has five isolated completion intervals. Model calibration indicated that simulated heads in well ER-12-1 were significantly lower than heads observed within the upper three completion intervals in the well. Hydrostatic heads measured in the upper dolomite and Eleana intervals ranged from 1329 m to 1343 m in elevation, while hydrostatic heads in the two intervals within the dolomite below the Eleana ranged from 933 m to 937 m (Russell, 1993). This results in a decrease in hydraulic head of over 300 m between the upper and lower carbonate intervals, a vertical gradient of between 0.7 and 0.8. The potentiometric data, therefore, indicate that the upper carbonate interval in well ER-12-1 is isolated from the lower carbonate interval by the UCCU. The original geologic model could not affect these head differences because the well was modeled as occurring only within the LCA.

In the alternate geologic interpretation, the lower carbonate zone is correlated with the LCA, while the upper carbonate interval is correlated with the LCA3. The distribution of this portion of the LCA3 is considered to be its outcrop area as well as the area extending beneath the volcanic rocks southwest to Rattlesnake Ridge where dolomite was encountered in Test Well #1. The UCCU subcrop is interpreted to cover all the area underlying LCA3 and extends further west to its truncation by the Belted Range Thrust.

4.5 Grid Definition

The initial development of the model grid was intended to provide accurate solutions to the finite-difference equations for the area encompassing the NTS and nearby downgradient areas. The grid spacing was set to 1.5 km by 1.5 km over these areas to maintain third-order accuracy in the horizontal directions. This spacing is smaller than that used to develop the geologic model (2 km by 2 km). The vertical spacing ranged from 125 to 150 m within the elevation ranges of the underground detonations and increased above and below these elevation ranges. During the second sequence of the calibration process, numerical accuracy problems were apparent near the Sheep Range and were also of concern in other areas. As a result, a reduction in grid spacing in these areas appeared to be advantageous. These changes included:

- Decreasing the spacing near the Sheep Range in the east-west direction - Because of the high hydraulic-conductivity contrast between the LCCU and the LCA, the rapid rise in elevation of the top of the LCCU as the Sheep Range is approached from the west, and the coarse grid spacing, head differences of hundreds to thousands of meters were resulting over a distance of one grid cell in several of the simulations. The grid spacing

was reduced in an attempt to help mitigate this problem. Eventually the problem was addressed, in the numerical sense only, by increasing the hydraulic conductivity of the LCCU in this area ([Section 4.7](#)). Simulated heads in this area are, therefore, not reliable.

- Decreasing the grid spacing at the northern end of the model, in the north-south direction - There had been no indications that accurate solutions were not being obtained; however, while the change to the grid in the Sheep Range area was being made, it was easier to concurrently change to a smaller grid spacing in the northern-most part of the model, rather than to do it later if it was determined to be desirable. These changes did not have a significant effect on the model results.
- Splitting the uppermost layer (which had a thickness of 500 m) into two layers 250 m thick - This change was made to improve the accuracy of the model with respect to assumed vertical gradients associated with the ranges where greater recharge occurs. With the larger vertical spacing, there were areas in the northern part of the model that were dry, but that should be wet according to measured water levels. The addition of another layer would allow a vertical gradient to be simulated in this area. This did not result in a significant change, since the upper layer is almost completely dry.
- Dividing the lower two layers into four layers - Evaluation of the listing that MODFLOW provides of cells with the largest head and flux residual changes between iterations indicated that the cells in the lower two layers were commonly the last to converge. Dividing the lower two layers (with initial thicknesses of 1000 m and 2000 m) into four model layers with thicknesses of 500 m, 500 m, 1000 m, and 1000 m resulted in more rapid convergence and presumably more accurate solutions.

At the beginning of the third sequence of calibration, minor adjustments in the boundary of the model area were made, resulting in the addition of another column of cells on the western edge of the model. This was the only change in the model grid.

4.6 *Modification of Boundary Conditions*

The simulated movement of water into and out of the model is determined by the boundary conditions. The model was developed on the premise that the major input of water was through precipitation and the resultant recharge and that the discharge of water from the system is determined largely by the distribution of the HSUs and their properties. Thus, the recharge was controlled through use of the MODFLOW Recharge Package, and discharge from the system was controlled through use of the Drain and General Head Boundary Packages. These latter two packages require the input of control heads and conductance parameters. By varying the values of the elevations and conductance parameters, the modeler can "influence" the head and boundary flux of the cell. At high conductances, the boundary condition behaves similarly to a constant-head boundary; the head in the cell is nearly identical to that of the specified (boundary) control head, and the discharge (or recharge) is largely determined by the conductances in the model cells, rather than the conductances specified as part of the boundary condition. At low boundary

conductances, the control head can be significantly different from the head in the cell, and the boundary flux is much more sensitive to the boundary conductance. Model calibration typically involves adjustment of the boundary-condition parameters. During the first two sequences of calibration, minor adjustments were made in the head-dependent boundary parameters. No adjustments were made during the third sequence.

4.6.1 Recharge

One of the primary types of information for characterizing a groundwater system is knowing the amount of water moving through the system as well as the location where it enters and leaves the system. The recharge generally is poorly known and is commonly approximated from both discharge estimates within the groundwater basin in addition to the concept that the higher the precipitation in an area, the higher the recharge is likely to be. Measurements of recharge are difficult, and many recorded years of data are needed to have a reliable estimate. As a result, recharge has been estimated by using an empirical model known as the Maxey-Eakin method, which was discussed in [Section 3.4.1](#) (Maxey and Eakin, 1949). In the development of the regional flow model, the basic Maxey-Eakin concepts were used, but the coefficients were adjusted to result in a total recharge flux that approximated the total estimated discharge from evapotranspiration and the external boundary fluxes. This estimate was developed by evaluating [Tables 3-4](#) and [3-5](#), and by selecting a target value for each flux area based on literature evaluations and discussions with experts in the respective areas. [Table 4-2](#) lists the target flux ranges ([Tables 3-4](#) and [3-5](#)), the target rate selected for each flux area, and the total estimated recharge flux based on the target discharge rates. Positive fluxes within the table indicate discharge from the model, whereas negative fluxes indicate flow into the model.

The parameters used in the recharge model are shown in [Table 4-3](#); the corresponding recharge flux is 204,080 m³/d. It should be noted that this value is slightly different from that presented in the Groundwater Recharge and Discharge Data Documentation Package (IT, 1996d); this is because the model grid boundary is an approximation of the hydrologic boundary within which the recharge flux was calculated. In [Table 4-3](#), note that the lowest value below which precipitation is not projected to occur has been decreased from 20 cm to 16 cm. This change was made to produce minor recharge in the higher areas of Yucca Flat, at Bullfrog Mountain, and the Wahmonie area and the Funeral Mountains where perched water is present.

The model coefficients in [Table 4-3](#) correspond to initial estimates of recharge used in the model (191,000 m³/d); that estimate was later increased to approximately 204,000 m³/d to account for larger estimated discharge fluxes in Oasis Valley and Ash Meadows. The larger flux was

Table 4-2
Calculation of Model Recharge Rate
Based on Model-Area Discharge Estimates

Discharge Area	Target Discharge Range (m ³ /d)	Target Discharge Rate (m ³ /d)
Alkali Flat (Peter's Playa)	5,000 - 7,300	6,100
Amargosa River	2,040 - 5,100	2,500
Ash Meadows	67,000 - 87,300	77,700
Death Valley	17,500 - 60,200	60,100
Franklin Lake/Alkali Flats	14,200 - 42,600	35,500
Oasis Valley	17,000 - 27,000	25,000
Penoyer Valley	13,000 - 27,000	20,300
Indian Springs	1,600 - 2,400	2,400
Eagle Mountain	850 - 3,400	3,400
Sarcobatus Flat	(-1,700) - 1,700	0
Pahrump Valley	(-5,000) - (-7,600)	-5,000
Pahrnagat Valley	(-5,400) - (-60,800)	*-27,000
Total Estimated Recharge Flux:		201,000

Table 4-3
Comparison of ME Coefficients and Coefficients Used in the Model

Maxey-Eakin ^a		Model	
Precipitation (cm)	ME Coefficient (%)	Precipitation (cm)	Model Coefficients (%)
>50.8	25	>50.8	18
38.1 - 50.8	15	38.1 - 50.8	11
30.5 - 38.1	7	30.5 - 38.1	6
20 - 30.5	3	16 - 30.5	1.5
<20	0	<16	0

^aSource: Maxey and Eakin, 1949

incorporated into the model by uniformly increasing the recharge at all model cells by a factor of 1.0678, the ratio between the final and initial recharge estimates.

The Maxey-Eakin method was developed without regard to the local factors that determine recharge. Clearly precipitation is an important factor. However, the amount of recharge that occurs at a location is also determined by the characteristics of the soil or rock at or below the surface or the slope and whether the location is facing towards the south or whether surface flow

is present. There are additional factors to consider, for example, recharge is favored in an area with coarse sands and gravels and with surface flow providing additional water. Some stream channels have these characteristics, as do the upper parts of alluvial fans. In the recharge code developed for the NTS model, some of the recharge within and adjacent to the NTS was distributed downstream from the highland areas to lower alluvial fans/stream channels. This recharge model was described in [Section 3.4.1](#). Only minor adjustments to these distribution coefficients were made during the calibration process.

4.6.2 External Boundary Fluxes

The approach used to apply external boundary fluxes (underflow into or out of the model boundary) using either the MODFLOW GHB or Well Packages was described in [Section 3.4.2](#). The head values used by the GHB Package (Pahrump Valley and Eagle Mountain) and Well Package preprocessor (Pahrnagat Valley and Sarcobatus Flat) for the calibrated model are provided in [Table 4-4](#). The GHB heads assume no vertical gradient along the boundary. During the second sequence of calibration, the Eagle Mountain head was reduced from 600 m to 599 m to prevent flow into the model after the drain elevations in Franklin Lake playa were lowered. No changes were made during the final calibration sequence.

Table 4-4
Hydraulic Head Values Used in the
GHB and Well Packages

Boundary Area	Boundary Head (m)
Pahrnagat Valley	965.0
Sarcobatus Flat	1215.0
Pahrump Valley	775.0
Eagle Mountain	599.0

4.6.3 Evapotranspiration

During the latter part of the second sequence of the calibration process, adjustments were made to both the drain elevation and conductance parameters in a few areas. The drain conductances were increased by 50 percent in Ash Meadows to increase the discharge and decreased by 50 percent along the Amargosa River to decrease the discharge. Both changes had minor effects to discharge rates within these cells. In Death Valley, additional cells were added to better describe the basin floor, and the drain conductances were decreased by approximately 7 percent to account for the larger surface area. Drain elevations in the southernmost two cells within the Franklin

Lake discharge area were reduced by approximately 12 m to more accurately represent land surface elevations in the Alkali Flats discharge area. Finally, drain elevations were decreased in Penoyer Valley to be consistent with drain elevations set in the remaining discharge areas. The resulting drain elevations and conductances are provided in [Appendix C](#) and were used during the third sequence without further change.

4.7 Adjustment of Hydraulic-Conductivity Parameters

During the calibration process, it became clear that it would be necessary to subdivide some of the hydrostratigraphic units into several conductivity zones in order to achieve an acceptable calibration. These HSUs include: the Lower Carbonate Aquifer; the Alluvial Aquifer; the Lower Clastic Confining Unit; the Timber Mountain Tuffs, Tuff Cone, and welded and non-welded tuffs; the Volcanic Aquifer; the Volcanic Tuff Confining Unit; Undifferentiated Volcanics; and the Tertiary Sediments/Death Valley Section. (Note: Explanations of HSU abbreviations are contained in [Table 2-1](#).) Maps of the zones are presented in [Figures 4-2, 4-3, 4-4, 4-5, 4-6, 4-7, 4-8, and 4-9](#). The zone arrays are developed using the geologic grid spacing and orientation and are applied using the subroutines TMSMOD06 and VCONT04.

Lower Carbonate Aquifer (LCA)

The Lower Carbonate Aquifer was separated into nine zones ([Figure 4-2](#)). Zone LCA(1) covers the eastern part of the NTS and the low gradient area to the east of the NTS. LCA(2) is a small area upgradient of the Ash Meadows discharge area which has been proposed as being very permeable on the basis of the low gradients within this area and the high discharge at Ash Meadows (Winograd and Thordarson, 1975; Waddell, 1982). Winograd and Thordarson (1975) had also indicated that a barrier was present along the Las Vegas Valley Shear Zone (Zone LCA(3)) on the basis of a high gradient developed across it near Indian Springs. Zone LCA(4) is beneath Jackass Flats, the Amargosa Desert, and Death Valley; model calibration indicated that a different transmissivity was needed here than in LCA(1). The zone covering the northern half of the model (LCA(5)) was defined to allow assignment of lower conductivities resulting from the greater shale content in the Paleozoic section in the northern part of the model.

Another facies change occurs over a broad zone further to the west where there is a change to deep-water carbonate rock deposition. This latter facies change is represented in the geologic model by modeling the lower, more shaley part of the lower carbonate section as LCCU.

The sixth zone represents the Spring Mountains area south of the Las Vegas Valley Shear Zone where a lower hydraulic conductivity was needed to approximate heads in this area. However, there was no significant attempt to match water levels at high elevations in the Spring Mountains, and the geologic model should be considered as approximate in this area.

Figure 4-2
Distribution of Conductivity Zones for the LCA Hydrostratigraphic Unit.

A seventh zone was defined for the carbonate rock west of Timber Mountain, so that sensitivity testing could be performed with respect to the presence of the LCA in this area.

The eighth zone is in the east central part of the model (Desert Valley) where there is an increase in gradient coincident with an increase in the shale content in the northeastern part of the model area, demonstrated by the Pilot and Chainman Shales.

The ninth zone is at the southeastern end of the Funeral Mountains. The properties of the LCA here have a significant impact on the simulated discharge in Death Valley. This area was zoned separately from Zone 4 to allow for their independent adjustment.

lluvial Aquifer (AA)

The AA was divided into six zones (Figure 4-3). There are four zones (1, 4, 5, and 6) which represent coarser-grained alluvium and two (2 and 3) which represent finer-grained alluvium. The identification and distribution of the fine-grained vs. coarse-grained deposits were estimated from satellite imagery. Of the coarse-grained zones, Zone 1 represents all areas except for Zone 4 (Yucca Flat), Zone 5 (Frenchman Flat), and Zone 6 (Amargosa Desert). These were defined separately in order that sensitivity analyses could be performed for the respective areas. The fine-grained zones were divided into Zone 2 (Amargosa Desert and Death Valley) and Zone 3 (other areas). The responses noted during the calibration process indicate that Zone 2 primarily affects the rate of discharge at Ash Meadows and Alkali Flat, while Zone 3 affects the head gradient across the Las Vegas Valley Shear Zone.

Lower Clastic Confining Unit (LCCU)

The LCCU has been divided into three zones (Figure 4-4). Zone 1 covers most of the LCCU. The LCCU beneath and near the Sheep Range was designated as Zone 2 so that a higher value of conductivity could be used to eliminate numerical problems associated with the steep gradient and large grid spacing there. A third zone was defined beneath and near the Amargosa Desert and Death Valley. Zone 3 was defined because adjusting the conductivity of the LCCU at Beatty affects the discharge rate in Oasis Valley and because of reported higher conductivities encountered in a well drilled on the northwestern side of the Grapevine Mountains to monitor effects of water use at the Bullfrog Mine. This zone lies within the area affected by lateral shear related to Death Valley and Walker Lane tectonics, thus it may be more fractured than other areas as a result.

Figure 4-3
Distribution of Conductivity Zones for the AA Hydrostratigraphic Unit.

Figure 4-4
Distribution of Conductivity Zones for the TMA, TC
TCB, TBA, BCU, & BAQ Hydrostratigraphic Units

Timber Mountain Tuffs (TMA), Tuff Cone (TC), Non-Welded Tuffs (TCB and BCU), Welded Tuffs Above BCU (TBA), and Welded Tuffs (BAQ)

The TMA was zoned to allow for potential effects on conductivity of alteration within the Timber Mountain and Black Mountain calderas (Figure 4-5). TMA(1) comprises the extra-caldera tuffs. TMA(2), TMA(3), and TMA(4) form approximately concentric cylinders with increasing radii from the center of the caldera. Zone 5 is in an area where TMA is absent from the geologic model, but the TC associated with the Claim Canyon caldera segment south of Timber Mountain is present. This zone, TC(5), is altered in contrast to the TC that is present beneath Pahute Mesa, TC(1). A sixth zone surrounding Black Mountain was added during the third sequence to account for alteration associated with heating during caldera formation.

Hydrostratigraphic units TCB, TBA, BCU, and BAQ were rezoned identically to TMA/TC in order to include the Black Mountain zonation.

Volcanic Aquifer (VA)

Three zones were defined for the VA (Figure 4-6). VA(1) covers the southern part of the NTS, and VA(2) covers Yucca Flat. The distinction was initially made to allow these two areas to be evaluated separately during the sensitivity analysis, but calibration results indicated that a slightly lower conductivity was necessary for VA(2) than for VA(1) to improve the fit in Yucca Flat. A third zone beneath Crater Flat was defined during the third sequence to see if lower conductivities would result in higher simulated heads beneath Crater Flat. This approach was not successful, and the conductivities used in the current model for VA(3) are the same as those in Zone 2.

Volcanic Confining Unit (VCU)

The VCU, which underlies an area from Yucca and Frenchman Flats westward beneath Crater Flat, has two zones defined (Figure 4-7). Nearly all of its occurrence is in Zone 1. Beneath Frenchman Flat, an interpretation of aeromagnetic data by the U.S. Geological Survey (Grauch and Hudson, 1995) indicates that the VCU is discontinuous along a northwestward trend through Frenchman Flat. Zone 2 was defined to allow sensitivity analyses to be performed on particle movement because Frenchman Flat is one of the CAUs being evaluated.

Volcanics Undifferentiated (VU)

The VU was separated into three zones (Figure 4-8). The first covers most of the model area. The second is coincident with Zone 6 for the TMA and TC, to allow for inclusion of effects associated with Black Mountain. The third zone is the area between Pahute Mesa and Beatty, to allow for better matching of heads in this area without impacting the model to the north.

Figure 4-5
Distribution of Conductivity Zones for the VA Hydrostratigraphic Unit.

Figure 4-6
Distribution of Conductivity Zones for the LCCU Hydrostratigraphic Unit.

Figure 4-7
Distribution of Conductivity Zones for the VCU Hydrostratigraphic Unit.

Figure 4-8
Distribution of Conductivity Zones for the VU Hydrostratigraphic Unit.

Tertiary Sediments/Death Valley Section (TSDV)

Two different stratigraphic units were combined into the TSDV hydrostratigraphic unit in the geologic model because they occur approximately at the same stratigraphic position and because they do not overlap. This step saved disk space, but required the development of separate zones in order to treat them separately. Zone 1 of TSDV comprises the Tertiary Sediments while Zone 2 comprises the Death Valley sediments ([Figure 4-9](#)).

4.8 Calibration Activities

The first sequence of model calibration began after development of the geologic model and the pre- and post-processors. This system was designed to allow easy modification of conductivity parameters used in the model while linking the resulting MODFLOW datasets back to the digital geologic model. The application of boundary conditions for the model has already been described.

The first sequence of the calibration was completed in September 1995, resulting in a set of modeling results that were reviewed by hydrologists and modelers familiar with the NTS region. By the time this peer review occurred, recommendations had been developed for changes in the geologic model that were expected to result in improvements in the agreement between the model and field observations. The peer review committee affirmed that the modeling approach was valid and that calibration should be continued.

The two areas in the geologic model that limited the match to water levels and discharge fluxes during preliminary calibration efforts were the northern extension of the LCCU in the Groom Range to the east of the Penoyer Valley discharge area and the area north of Yucca Mountain/Crater Flat. In both areas, an effective barrier to flow was missing, making it difficult or impossible to match discharge rates in Penoyer Valley and Oasis Valley. For example, the modeled discharge in Penoyer Valley in the initial iterations was 5,500 m³/d, in contrast to estimated discharge rates of 13,000 to 27,000 m³/d ([Table 3-5](#)). At Oasis Valley, the modeled discharge was 3,490 m³/d, compared with estimates of 17,000 to 27,000 m³/d. Adjustments of conductivity parameters over reasonable ranges were not successful in increasing the modeled discharge using the geologic model (geol_06.mdl) as it existed.

The second sequence began with reevaluating the geology in these areas. Rather than immediately developing new versions of the digital geologic model in the ERMA database, which was both time-consuming and had attendant Quality Assurance procedures, proposed changes were first evaluated by hand-editing geologic and hydrologic datasets. For the area near Penoyer Valley, the geologic model datasets were edited to raise the top of the LCCU in the western part

Figure 4-9
Distribution of Conductivity Zones for the TSDV Hydrostratigraphic Unit.

of the Penoyer Valley discharge area and northward. North of Crater Flat, the geologic model was more complex, and a second approach was used to evaluate effects of modifying the location of the Belted Range Thrust in this area. Additional conductivity zones were temporarily defined within the LCA to simulate properties of the LCCU in this area. Zonation of the LCA allowed development of low conductivity barriers, while still using the existing digital geologic model. The locations and orientations of the barrier were then evaluated based on discussions with the geologist responsible for the geologic model. Test runs performed with these modifications indicated that implementing the changes in the digital geologic model in these areas would result in increased discharge rates in Penoyer Valley and Oasis Valley. The geologic model dataset used in these test runs was `geol_09.mdl`.

During model testing of the revised geologic interpretations, the number of model layers was increased from 17 to 20 to improve the convergence behavior of the model and to allow vertical gradients to be simulated in the northernmost part of the model. This change, described earlier, helped convergence, but did not result in higher vertical gradients as hoped, presumably because of the lack of detail within the geologic model of the volcanic rocks north of the NTS.

Once the preliminary evaluation of the likely effects of changing the geologic model was completed, a more careful evaluation of the geology in these two areas was performed, and a new version of the digital geologic model was developed ([Section 4.4](#)). Briefly, the changes involved raising the top of the LCCU north of the Groom Range, moving the trace of the Belted Range Thrust to the south of where it was in the earlier version (which allowed the LCCU to be present at a shallower depth south of Timber Mountain), and replacing the volcanic structural block model in Crater Flat. In conjunction with this change, the TC present in the Claim Canyon caldera segment north of Yucca Mountain and rocks stratigraphically equivalent with rocks of the VA were interpreted as having lower hydraulic conductivity due to alteration. The digital geologic model which incorporated these changes was `geol_10.mdl`.

After `geol_10.mdl` was implemented, the model provided greater discharge at Penoyer Valley and Oasis Valley, as expected. Adjustment of conductivity parameters produced better matches between measured and observed heads and between simulated and estimated flux rates. However, the model did not appear to be numerically stable near the Sheep Range because of the large grid spacing in this area, which, together with the steep relief on the top of the LCCU, resulted in steep hydraulic gradients. The instability was apparent in large changes in simulated head at the top of the Sheep Range from one run to the next. Decreasing the grid spacing appeared to be necessary. While changes were implemented for this area, the grid spacing in the northernmost part of the model was also decreased to avoid possible numerical inaccuracy in that area, even

though instability had never been observed. As a result of these changes, the number of rows increased from 72 to 76 and the number of columns from 64 to 68.

After the model grid had been revised, a digital record of the model fluxes and head residuals was started; prior to this, the data were saved in hard copy only. The digital runs were named cf1 through cf127, where the “cf” preface referenced the refinement to the model grid.

[Figures 4-10](#) and [4-11](#) present the mean weighted residuals and the root mean square (RMS) of the weighted residuals for the thirteen residual zones for the “cf” calibration runs. These figures show the impacts of efforts to improve the match of the model to the calibration goals. The objective of the early runs (up to cf29) was to improve the agreement between observed and simulated heads in western Yucca Flat. Measured heads in this area are generally higher than 900 m. Initially, parameters within the MODFLOW BCF2 Package were changed to allow rewetting from the sides and bottom of the cells instead of just from the bottom. This effort was only marginally successful and caused longer run times.

The greatest mismatch occurred near Rainier Mesa. The geologic interpretation in the digital geologic model for these runs had the UCCU as a discontinuous layer beneath part of Rainier Mesa. The LCA was interpreted as being thrust upwards so that it was directly underneath the volcanic rocks. This interpretation prevented higher heads near Rainier Mesa as the LCA provided an effective drainage pathway into the deeper part of the aquifer which had hydraulic heads of approximately 740 m. An alternate interpretation of the structure (geol_12.mdl) simulated the UCCU as a continuous sheet through this area which resulted in higher calculated heads in the units above the UCCU. After the geologic model was revised, rewetting of cells from the bottom only produced good results, and use of the other approach was stopped.

Runs cf23 through cf34 involved evaluation of different recharge models. These tests changed both the overall recharge rate and the minimum precipitation value below which no recharge is assumed to occur. The adjustment of the recharge coefficients was discussed in [Section 4.6.1](#). This recharge model was used for all runs after cf34.

Additional drain cells were added to the floor of Death Valley to prevent shallow heads from greatly exceeding the land-surface elevation. A drain cell was also added for Navel Spring in Furnace Creek Wash. These changes improved the match with observed heads within the DV residual zone.

Figure 4-10
Mean Weighted Residuals versus Calibration Run Number

Figure 4-11
Root Mean Square of Weighted Residuals versus Calibration Run Number

The value of lambda for LCA and LCA(3) was changed from 0.00035 to 0.0015 in run cf41. This change was made because the regression analysis of log (K) versus depth indicated a higher value than had been previously used. The change caused a significant increase in calculated heads, which was expected. Adjustments in conductivity parameters resulted in improved model fit, but residuals increased significantly in some zones.

A revised geologic model (geol_14.mdl) was introduced with run cf43. It corrected several minor problems, such as cells where the elevation of the top of the uppermost HSU did not correspond to the land surface elevation. The value of lambda for LCA and LCA(3) was decreased first to 0.0011 and then to 0.0009 after reevaluation of the regression data. The lower lambda value was used so that K_h of the LCA would be higher, but the 0.0009 value had little effect when compared to the 0.0011 value.

Later runs primarily made minor adjustments in the zonation arrays, drain elevations and conductances, and conductivity parameters. Drain elevations normally were lowered by 3 m - 5 m. Alluvial Aquifer (6) in the central part of the Amargosa Desert was defined to lower heads in the Amargosa Farm Area, based on the concept that sediments deposited by Fortymile Wash and the Amargosa River would be coarser than those deposited by smaller streams or in closed basins. Reducing LCA(6) in an effort to increase heads in the Spring Mountains (run cf71) also significantly increased heads in the Sheep Range, creating the sharp rise in the RMS for the SHRG residual zone.

The final fifty-six runs included small adjustments to improve the fit to heads and boundary fluxes. These changes did not result in significant changes to the model. Changing parameters normally would result in an improved fit for some of the criteria, but a poorer fit for others. A good example is the relationship between the heads in the Amargosa Farm Area and the discharge at Ash Meadows. The simulated heads in the Farm Area are slightly higher than the measured heads. The simulated heads could be decreased by increasing the conductivity of AA(6) or LCA(4). However, when the heads were lowered, the flow in Jackass Flats from east to west increased. This in turn, decreased the flow toward, and discharge from, Ash Meadows. The discharge at Ash Meadows was toward the lower end of the estimated range so that reduction in the simulated discharge was undesirable. Thus these, and many other model parameters, are constrained by the head data and discharge estimates.

The third sequence of model calibration occurred following discovery that the co-kriging process used to develop the precipitation dataset did not correctly portray the long-recognized relationship between elevation and annual precipitation. The precipitation dataset was replaced by

a dataset digitized from the Hardman map (1936) which was extended southward into California using recent data from James (1993). In this calibration effort, comments by peer reviewers were also addressed. These comments largely addressed the treatment of uncertainty, including the amount of recharge, and noted that the conductivity values used for the alluvium appeared to be lower than aquifer test data indicated.

Subsequent to the completion of the second sequence of model calibration, different investigators have indicated that the amounts of discharge in Ash Meadows, Oasis Valley, and Death Valley have been larger than previously thought. Ongoing work by the U.S. Geological Survey in Ash Meadows (Laczniak, 1996) had indicated that discharge was greater than previously indicated by Winograd and Thordarson (1975); this information was used in the second sequence. More recent data are confirming this conclusion and decreased the range of estimates. In addition, evapotranspiration studies are beginning in Oasis Valley and suggest that ET is probably higher than previously estimated. Finally, Pal Consultants Inc. (1995) released a report prepared for the U.S. National Park Service providing an estimate of discharge in central Death Valley of approximately 60,000 m³/d. During the third sequence, the recharge within the model was increased to allow for greater discharge.

The model boundaries were also modified slightly to align them more closely with hydrographic basin boundaries defined for surface drainages. The previous model boundary was based on interpretation of water level data and flow directions, but the evidence for the locations of the boundaries is sparse. In earlier investigations, hydrologists have commonly drawn groundwater basin boundaries on the basis of surface topography. The present model adopts this practice, even though the actual boundaries are not necessarily coincident with the surface water boundaries. This change extended the model grid further to the west, and another column of cells was added on the western edge.

The method used to simulate inflow from Pahranaagat Valley was changed from use of a General Head Boundary to a constant flux boundary using the Well Package. This change allowed more control on the inflow, rather than having the inflow highly dependent on the value of the conductivity of the LCA, Zone 5. The boundary condition for Sarcobatus Flat was also changed to a constant flux boundary, but with the flux set to zero. This boundary condition was used to allow sensitivity testing.

Changes in the zonation arrays also were made during the third sequence. The most notable was the creation of separate zones for the TMA, TC, and VU at Black Mountain. A significant feature of the groundwater hydrology of Pahute Mesa is a potentiometric trough in the western

part of Area 20 of the NTS. The previous calibration sequences were unable to simulate this trough. There are several possible causes for the trough. Blankennagel and Weir (1972) note that the trough may be associated with the edge of the Silent Canyon caldera, where fracturing associated with caldera collapse may provide a higher conductivity zone which would create the trough. Another possible cause is the development of a barrier along the western side of the trough, with the higher heads in the west caused by higher recharge west of the barrier. A third possibility is that alteration associated with development of the Black Mountain caldera has reduced the conductivity of rocks west of the trough. Based on limited head data, it appears that hydraulic gradients beneath Black Mountain are slightly higher than beneath eastern Pahutevant mesa (areas 19 and 20). The zonation around Black Mountain evaluates the feasibility of this third explanation. Other changes in the zonation during the third sequence of calibration include:

- LCA - added Zones 7, 8, and 9
- AA - redefinition of all zones
- VU - added Zones 2 and 3
- VA - added Zone 3
- VCU - added Zone 2
- TSDV - separated TS (Zone 1) from DV (Zone 2)
- LCCU - added Zone 3

Minor additions to the geologic model were made in Death Valley to incorporate those areas included in the revised model boundary. This version, `geol_15.mdl`, is the final version of the geologic model.

The calibration runs for the third sequence are designated with the prefix 996 indicating September, 1996, the month the sequence started. The suffix is a sequential number beginning with 1 and continuing to 173. The mean weighted residuals and RMS values are plotted in [Figures 4-12](#) and [4-13](#), as a function of the run number. The process started with changes to the values of lambda and the use of a different recharge dataset. The recharge rate with this dataset was 190,962 m³/d. An additional column was added on the western edge of the model to extend the model further west in the Amargosa Desert south of Bullfrog Mountain and the model boundary revised lightly to more closely match the water divides. The AA zonation array was revised to improve the portrayal of the properties of the AA, based on geomorphic evidence. The FARM and FF residual zones were also separated from the LCA zone defined in sequence 2.

Additionally, the Pahrnagat Valley and Sarcobatus Flat had been converted from GHB to Well Package boundary conditions. These changes increased the magnitudes of the mean weighted residuals and resulted in poor agreement with the target boundary fluxes. After some initial adjustments to parameters to improve the fit, the `ibound` array was modified slightly to straighten

Figure 4-12
Mean Weighted Residuals versus Calibration Run Number

Figure 4-13
Root Mean Square of Weighted Residuals versus Calibration Run Number

the boundaries on the western and northern sides (run 996-011); the previous boundary included cells that were nearly isolated from the remainder of the model that appeared to be causing convergence problems. Minor problems with specification of boundary conditions were detected and corrected in runs 996-013 and 996-018.

By run 996-020, the mean residuals had been reduced, but the match to the boundary flux targets needed improvement. Much of the later work entailed improving this match while maintaining the head match. In run 996-033, the zones in the volcanic rocks associated with the Black Mountain caldera were implemented to develop the potentiometric trough. A third zone between Black Mountain and Beatty was defined in run 996-046 to allow better control of gradients in this area. Additional drain cells in Death Valley were defined in run 996-051. In run 996-054, a new zone (7) for the LCA was defined in the same area as VU(3); a new interpretation of gravity data in this area by the USGS suggested that the geologic model in this area should be reevaluated. As a result of this reevaluation, LCA(7) was modeled as having properties of volcanic rocks.

Prior to run 996-070, the designation of fine-grained deposits within the AA along the Las Vegas Valley Shear Zone was not continuous near Indian Springs, and the observed moderate gradient near Indian Springs could not be simulated. In runs 996-070 through 996-071a, two AA3 segments were connected and widened to achieve this gradient.

A depression in the water table was being simulated near Rainier Mesa, starting at approximately run 996-063. Runs 996-075 through 996-079 evaluated the source of this depression, and determined it to be the value of K_h of LCCU(1). This was reduced, and the depression was eliminated.

LCA(8), near Pahrangat Valley, was defined in run 996-087, in order to allow the properties of the LCA in the north to be adjusted separately from those in the new LCA(8). Previously, the properties in the north were determined by values needed in LCA(8) to match heads in the PAHR zone and to create the higher gradient needed to achieve discharge at Penoyer Valley. The new LCA(8) would allow the K_h of LCA(5) to be raised. However, raising this parameter resulted in a poorer fit, and it was later changed back to the same value used for LCA(8).

Additional information was received on Oasis Valley and Ash Meadows discharge estimates, which increased the recharge estimate from approximately 191,000 to 204,000 m³/d. This adjustment was made by changing the MODFLOW parameter SFAC for the recharge array from 1.0 to 1.0678 (run 996-115). This initiated another period of adjustment of conductivity parameters to match head and discharge rates.

A new zone array (run 996-119) was constructed which placed the LCA beneath Jackass Flats in LCA(1) rather than LCA(4), and which defined a new LCCU zone (3) for the Amargosa Desert and Death Valley. These changes were made to reflect the Walker Lane style of deformation in this area, in contrast with Basin and Range deformation to the north and east. Data from a monitoring well completed in the LCCU on the northeastern side of the Grapevine Mountains suggested the LCCU may have higher conductivity in this area than in other areas. In addition, the modeling results suggested that the LCCU near Beatty may have higher conductivities than elsewhere. The new LCCU zone would allow higher conductivities here than needed in other areas. In run 996-120, the AA beneath the Amargosa Desert was defined as a new zone (6) so that its properties could be modified separately from other areas. Eventually, the same properties were used for AA(1) and AA(6).

The last change to zonation was the development of LCA(9) covering the Funeral Mountains and Death Valley. The movement of water and the discharge rate in Death Valley was largely determined by the conductivity of the LCA in the Funeral Mountains. However, lowering the conductivity of the LCA for the old LCA(4) to reduce discharge in Death Valley resulted in poor head match in the FARM residual zone and poor agreement to discharge rates in the Amargosa Desert and Ash Meadows. Therefore, LCA(9) was subdivided from the old LCA(4) (run 996-149).

The remainder of the runs involved adjustments to conductivity parameters to improve the matches to target heads and boundary fluxes. The last run was 996-172, but the fit of run 996-171 was slightly better, so it was used as the base case.

The simulated heads for the calibrated model are plotted against observed heads in [Figure 4-14](#). The group of heads in the lower section of the graph represent Death Valley data. Following the line upwards, the tight grouping of points represent data from the Amargosa Farm area. The remainder of the line represent points from increasingly upgradient locations. Examination of the figure indicates that the fit of the model to measured data is very good. Model results for the calibrated model are presented and discussed in [Section 5.0](#) of this report.

Figure 4-14.
Simulated Heads from the Calibrated Model versus Observed Heads.

5.0 Flow Model Results and Sensitivity Analyses

Section 5.0 is data-intensive and provides the results for the calibrated regional flow model as well as the sensitivity analyses for hydrologic and geologic parameters. The following information is included:

- Hydrologic parameters from the calibrated model
 - Horizontal hydraulic conductivities
 - Vertical anisotropy values
 - Depth-decay coefficients
 - Final recharge distribution
- Plates showing the calibrated water table and example figures
- Results from sensitivity runs
 - Geologic models
 - Recharge parameters
 - Boundary fluxes
 - Horizontal hydraulic conductivities
 - Anisotropy values
 - Depth-decay coefficients
- Identification of parameters that have the greatest effects on model heads and fluxes
- Particle-tracking results showing pathlines (flow directions) from 14 underground nuclear test locations to downgradient discharge areas for the calibrated model and sensitivity runs
- Two overlays (Plates 3 and 4) displaying the simulated water tables for the calibrated models from sequences 2 and 3, respectively, for comparison to sensitivity runs, and a fifth overlay (Plate 5) containing the model grid and study area cultural features

Advective travel distances at times of 25 years (yrs), 50 yrs, 100 yrs, and 200 yrs are calculated for the sequence 3 base case (calibrated model) using effective porosities for the HSUs; these travel distances are then compared to those calculated for the sensitivity runs.

Supporting maps showing the distribution of the thickest HSUs per cell within each model layer, the distributions of transmissivity for each model layer and Vcont between layers, and contours of the simulated hydraulic head for each layer are included in [Appendices D](#) through [G](#).

5.1 Distribution of Recharge

[Figure 5-1](#) shows the distribution of recharge used in the model. Recharge primarily occurs in the northern mountains (Kawich, Reveille, and Quinn Canyon Ranges); the mountains immediately

Figure 5-1
Areal Distribution of Recharge

north and northwest of the NTS (Belted and Groom Ranges); Pahute Mesa, Shoshone Mountain, and Timber Mountain on the NTS; the Sheep Range to the east; and the Spring Mountains in the south. The effects of recharge redistribution from higher to lower elevations in and close to the NTS are apparent. For example, the recharge that is shown in the lower part of Fortymile Wash is due to this redistribution.

There are three details with respect to the recharge model that should be clarified. First, the recharge rate for a MODFLOW cell is calculated by summing the recharge associated with all of the recharge points that occur within a cell; these points have a spacing of 1 km. The sum for the cell is then divided by the surface area of the cell, which produces an average recharge rate for the cell. Because many of the cells are large, they can include points that have annual precipitation rates both less than and greater than the threshold value of 16 centimeters per year (cm/yr). The net recharge rate can then be below the estimated 0.32 cm/yr (2 percent of 16 cm/yr) threshold value.

The second item which needs clarification is that because of high land surface elevations within Penoyer Valley, simulated recharge is non-zero in the discharge area. The total recharge applied to these discharge cells is 708 m³/d, which is less than 4 percent of the simulated discharge value of 19,105.9 m³/d. While there is an inconsistency in applying recharge to this discharge area, the applied recharge is very minor and should have an insignificant effect on the simulations.

Finally, recharge distributions were not modified based on the presence of low-conductivity units at land surface. In two isolated locations within the study area, the Quinn Canyon Range north of the NTS and the Belted Range on the northern boundary of the NTS, high recharge areas correspond with intrusives subcropping near land surface. Comparison of the calibrated model water table elevation map with land surface elevations in these two areas indicates that the water table is above land surface; however, these effects are very localized and are expected to have minimal impacts on regional head and flux results.

5.2 *Hydraulic Parameters*

The final values for the hydraulic parameters included in the calibrated flow model are presented in [Table 5-1](#). For each HSU or zone within an HSU, there are three values which must

Table 5-1
Final Hydraulic Parameters for NTS Flow Model
(Page 1 of 2)

Model Layer	HSU & Zone No.	K_h (m/d) ^a	Anisotropy Ratio (K_v/K_h) ^b	Depth Decay Parameter (8) ^c
20	AA Zone 1,4,5,6 Zone 2 Zone 3	11.0 4.40 0.01	0.22 0.16 0.16	0.0037 0.0037 0.0037
19	TMA Zone 1 Zone 2 Zone 3 Zone 4 Zone 5 Zone 6	35.0 12.0 16.0 20.0 1.20 0.20	0.08 0.02 0.02 0.02 0.02 0.02	0.0026 0.0026 0.0026 0.0026 0.0026 0.0026
18	TC Zone 1 Zone 2 Zone 3 Zone 4 Zone 5 Zone 6	35.0 12.0 16.0 20.0 4.0 0.20	0.08 0.02 0.02 0.02 0.02 0.02	0.0026 0.0026 0.0026 0.0026 0.0026 0.0026
17	TCB Zone 1 Zones 2-5 Zone 6	0.30 0.03 0.02	0.02 0.02 0.02	0.0026 0.0026 0.0026
16	TBA Zone 1 Zones 2-5 Zone 6	35.0 2.0 0.2	0.02 0.02 0.02	0.0026 0.0026 0.0026
15	BCU Zones 1-5 Zone 6	0.3 0.2	0.02 0.02	0.0026 0.0026
14	BAQ Zone 1 Zones 2-5 Zone 6	35.0 2.0 0.2	0.02 0.02 0.02	0.0026 0.0026 0.0026
13	VA Zone 1 Zone 2 Zone 3	2.0 1.0 8.0	0.02 0.02 0.02	0.0026 0.0026 0.0026
12	VCU Zones 1,2	0.12	0.02	0.0026
11	VU Zone 1 Zone 2 Zone 3	1.5 0.2 0.4	0.02 0.02 0.02	0.0026 0.0026 0.0026

Table 5-1
Final Hydraulic Parameters for NTS Flow Model
(Page 2 of 2)

Model Layer	HSU & Zone No.	K_h (m/d) ^a	Anisotropy Ratio (K_v/K_h) ^b	Depth Decay Parameter (δ) ^c
10	TSDVS Zone 1 Zone 2	0.50 0.02	0.02 0.02	0.004 0.004
9	LCA3	0.1	0.02	0.001
8	UCCU	0.002	0.02	0.0015
7, 5, 3	LCA Zone 1,2 Zone 3 Zone 4 Zone 5,8 Zone 6 Zone 7 Zone 9	110. 0.01 8.0 0.8 0.4 2.0 5.0	0.015 0.015 0.015 0.015 0.015 0.020 0.015	0.0010 0.0010 0.0010 0.0010 0.0010 0.0026 0.0010
6	LCCU Zone 1 Zone 2 Zone 3	0.02 0.20 0.10	0.15 0.15 0.15	0.0012 0.0012 0.0012
4, 2	LCCU1 Zone 1 Zone 2 Zone 3	0.02 0.20 0.10	0.15 0.15 0.15	0.0015 0.0012 0.0012
1	I	0.001	0.5	0.0015

^a Meter(s) per day

^b The parameter K_h is the horizontal hydraulic conductivity that is projected to occur at the land surface, or a depth of zero.

The parameter K_v is the vertical hydraulic conductivity that is projected to occur at the land surface, or a depth of zero.

^c The parameter δ is the depth-decay coefficient.

be specified: the horizontal hydraulic conductivity projected to land surface (K_h); the anisotropy ratio (K_h/K_v), here defined as the vertical hydraulic conductivity divided by the horizontal hydraulic conductivity; and the exponential depth-decay parameter (λ , **8**). The larger the **8** value, the more rapidly the hydraulic conductivity decreases with depth. When an HSU has been divided into different zones (e.g., the LCA), multiple sets of the three parameters are listed.

Figures 5-2, 5-3, and 5-4 compare the depth-adjusted horizontal hydraulic conductivity values used in the model with conductivity values from aquifer tests for alluvium, volcanic rocks, and carbonate rocks, respectively. The upper line for the AA represents the zones (1, 4, 5, and 6) of coarse-grained deposits. The next lower line is the zone of finer-grained sediments in the Amargosa Desert and Death Valley. The hydraulic conductivities for zones 2 and 6 were well-constrained by the calibration, but a correlation between the conductivity values for the AA and LCA units exists in this area. If a lower value were used for the LCA, a higher one would be needed for the AA (and conversely). Additionally, the simulated heads and discharge rates are sensitive to the conductivities of these two HSUs. Higher values of hydraulic conductivity have been measured for the AA than used in the calibrated model. The effects of using higher values of K_h for Yucca and Frenchman Flat Zones 4 and 5, which are not as constrained by the calibration, will be investigated through sensitivity analysis.

The two lower lines in Figure 5-2 represent areas of low conductivities due to the formation of spring deposits; the values used in the model are consistent with values found in the reference literature for fine-grained sediments.

Figure 5-3 shows the comparison between measured and simulated conductivity vs. depth for volcanic rocks. The lines represent the minimum and maximum values for both the volcanic aquifers and confining units represented in the model. The lines fit nicely within the measurements, but there are many measurements with higher conductivities than were used in the model. The maximum K_h (horizontal hydraulic conductivity) value of 35 m/d was derived through calibration. Because of the paucity of data on conductivities for different volcanic aquifers, this value was assigned to all volcanic aquifers within the Timber Mountain/ Pahute Mesa area for consistency. Higher conductivity values could have been assigned to individual units locally without significantly affecting regional model results; however, increasing conductivity values for all of the volcanic aquifers in the western part of the NTS resulted in a significantly poorer model fit based on head and flux residuals. There are several possible reasons

Figure 5-2
Relationship of Hydraulic Conductivity to Depth for Alluvial Aquifers

Figure 5-3
Relationship of Hydraulic Conductivity to Depth for Volcanic Aquifers and Confining Units

Figure 5-4
Relationship of Hydraulic Conductivity to Depth for the LCA

for the differences between the high sample Kh measurements and the model values. These include:

- The aquifer-test results represent local effects rather than regional properties. The thicknesses of the volcanic units and the corresponding degree of welding and fracturing are greatly affected by pre-eruption topography and are, therefore, highly variable. Further, the conductivity measured in an aquifer test is greatly affected by the properties of fractures intercepted by the borehole, especially when the water level changes are measured only in the stressed well. Thus, it would be expected that there would be many tests with higher conductivities than the regional average.
- The modeling results do not explicitly incorporate local barrier effects due to the presence of faults. Detailed mapping of hydrologic heads on Pahute Mesa suggests that faults may be barriers to flow in some areas. Moderately high gradients exist from one fault-bounded block to another, and this is not incorporated in the regional model. The model-determined properties would implicitly account for these barriers, resulting in lower simulated values for conductivity in comparison to those provided by aquifer tests.

The lines for the volcanic confining units in [Figure 5-3](#) represent rocks that are nonwelded or that have been altered.

The comparison for the Lower Carbonate Aquifer is presented in [Figure 5-4](#); the lines for each of the nine LCA zones are displayed. The lines for LCA(1) and LCA(2) are at the upper end of the range in measured values. Zone 2 is upgradient from Ash Meadows and is believed to be quite permeable as indicated by the very low gradient through this area and the high discharge rate at Ash Meadows. The measurements plotted at depths less than 200 m are from the tracer site constructed south of Point of Rocks within this zone, so there is supporting evidence for the high conductivity of zone LCA(2). The remaining lines are consistent with the data. The values used for LCA(6) and LCA(3) in the model produced reasonable agreement with measured head values, but the only basis for the value for LCA(3) was the need to simulate the observed gradient along the shear zone; this value is lower than occurs in the field.

In the third sequence of calibration, LCA(5) of the second sequence was divided into Zones 5 and 8 to allow their conductivities to be adjusted individually. They were initially assigned different values of K_h during the calibration process; however, the model fit was not improved, and the two zones were reassigned the same values. Their values are the lowest of the LCA zones with the exceptions of Zones 3 and 6. Zone 7 is the zone west of Timber Mountain where the presence of LCA was predicted on the basis of an outcrop of Ordovician age near Black Mountain. However, recent interpretations of gravity data suggest that the pre-Tertiary rocks may be shallower than portrayed in the geologic model. Additionally, subsequent reinterpretation of the geology

suggested that the LCA in this area is much thinner than incorporated in the geologic model. In an effort to simulate the new interpretation, the value of **8** was increased so that the LCA(7) would have hydraulic conductivity values appropriate for carbonate rocks at shallower depth, but would have values appropriate for LCCU at greater depth. This change provided reasonable matches to heads and fluxes in Oasis Valley. Refinement of the geologic model should be considered prior to development of the Pahute Mesa detailed model. The value of **8** that was used was 0.0026, the same as used for the volcanic rocks.

The conductivity parameters listed in [Table 5-1](#) were processed by TMSMOD06.FOR, VCONT04.FOR, and BCFMAK03.FOR ([Appendix A](#)) to generate the transmissivity and Vcont data sets used by MODFLOW. As described in [Section 3.5.1](#), the transmissivity is calculated by summing the hydraulic conductivity times thickness for each HSU within a model cell. Obviously, the transmissivity will be affected by the number of HSUs, the range in conductivity values within those HSUs, and their thicknesses.

As discussed in [Section 3.2.2](#), model layer thicknesses were selected to represent the properties of hydrologically important HSUs as much as possible; therefore, within the NTS and downgradient from testing areas, transmissivities should reflect the dominant HSU within each model cell. To facilitate the examination of the transmissivity distributions, distributions by model layer of the HSUs with the greatest thickness per model cell are provided in [Appendix D](#). The HSUs are presented on the geologic model grid. Areal distributions of transmissivity and Vcont by model layer are presented in [Appendices E and F](#), respectively. These distributions are presented on the hydrologic grid.

The figures for the transmissivity and Vcont distributions show the logarithm (base 10) of the values used in the model. Although transmissivity and Vcont data are calculated everywhere on the hydrologic grids, the figures only show values for those cells that remained active after the model had converged. If the water table is below the bottom of a cell, no value is shown. Thus, the figures also portray the distribution of active, wet cells in the converged model. For Layer 1, active cells are present only in several very restricted locations: in the Kawich and Quinn Canyon Ranges north of the NTS, in the Belted Range along the northern NTS boundary, and in the central Spring Mountains and Sheep Range. This layer extends from 1,750 to 2,000 m above sea level ([Table 3-1](#)), so simulated water levels are higher than 1,750 m in these areas. In lower layers, the number of active cells increases as the bottoms of more and more cells drop below the simulated water table. Although hydraulic conductivity decreases with depth, model layer

thicknesses increase. Therefore, when comparing transmissivity and Vcont results from one model layer to another, it is important to remember that the two parameters are both functions of the thickness of the model layer.

The structure of the geologic model, combined with the hydrologic properties of the HSUs, is apparent in the transmissivity and Vcont figures. To illustrate this, the HSU, transmissivity, and Vcont distributions for Layer 8 are reproduced in [Figures 5-5, 5-6, and 5-7](#), respectively. In Model Layer 8, the LCA is present in the southeastern part of the model, extending up into Yucca Flat. The LCA, readily apparent on the eastern side of the flat, is bounded to the west by the Upper Clastic Confining Unit, which is, in turn, flanked to the west by the Lower Clastic Confining Unit (LCCU) and volcanics. The presence of the LCCU in this area is associated with thrusting along the Belted Range Thrust. The structural outline of the lower-conductivity volcanics associated with the Timber Mountain Caldera and the Tuff Cone to the south of the TMA is apparent.

By Model Layer 17 ([Figures 5-8, 5-9, and 5-10](#) for HSU, transmissivity, and Vcont distributions, respectively), the LCA is present beneath the majority of Yucca, Frenchman, and Jackass Flats. Differences in transmissivities within the LCA are due to zonations within the unit. The northwestern extent of the LCA is delineated by the Belted Range Thrust. The presence of the LCCU along the north-south structural uplift in Emigrant Valley, the Papoose and Groom Ranges, and Penoyer Valley is evident.

5.3 Hydraulic-Head and Residual Distributions

5.3.1 Hydraulic-Head Distributions

The distribution of simulated hydraulic heads for the 20 model layers are provided in [Appendix G](#). The process used to contour the heads requires that the simulated values, which are calculated on a nonuniform grid, be converted into values on a regular grid. The contouring procedure consisted of the following:

- Bilinear interpolation when the uniform grid point is surrounded by four active model grid points
- Interpolation using the equation of a plane passing through three model points when the uniform grid point is surrounded by only three active model grid points

Figure 5-5
Distribution of HSUs for Model Layer 8 (the thickest HSU in each cell is shown)

Figure 5-6
Distribution of Transmissivity for Model Layer 8

Figure 5-7
Log Leakance Values for Active Model Cells in Model Layer 8

Figure 5-8
Distribution of HSUs for Model Layer 17 (the thickest HSU in each cell is shown)

Figure 5-9
Distribution of Transmissivity for Model Layer 17

Figure 5-10
Log Leakance Values for Active Model Cells in Model Layer 17

- Interpolation using the equation of a plane passing through two model points and striking perpendicular to the line drawn between the two points when only two active model points are present
- Direct use of the model value when only one active model point is available

No uniform grid points are calculated if they lie outside the active cells within the layer. However, the contouring package may extend contour lines outside the model area; these should be ignored. A contour interval of 50 m is used for all 20 layers.

The contour plots include posting of all target heads that fall within the active model domain. Single-layer and multiple-layer wells are identified with separate symbols on the plots. The measured head value in each multiple-layer observation well is posted on each of the model layers over which the well is open.

Figure 5-11 is a map of the simulated water table for the calibrated model. This map was assembled by constructing an array of hydraulic heads where each entry is the calculated head in the uppermost model layer that is active for each cell. The same figure, with posted target heads and posted residual values, is presented in Plates 1 and 2, respectively; the plate sizes were included to allow for easier reading of the target and residual values in areas with concentrated data. Finally, an overlay (Plate 3), which includes the study area cultural features in addition to the model grid, was included to facilitate the following discussions on the potentiometric contour maps and the transmissivity and Vcont distribution maps.

In Figure 5-11, a steep gradient is present on the eastern side of Death Valley, caused by the LCCU in the Funeral Range and the Tertiary Sediment/Death Valley Section in the Greenwater Range. The Franklin Lake playa, also known as Alkali Flat, is present along the southern edge of the model. The playa provides a place for water to exit the model, and the 650-m contour line shows convergence of flow to this area. A low hydraulic gradient is present in the areas underlain by LCA(1), LCA(2), LCA(4), and LCA(9), with the exception of western Yucca Flat. In this area, the LCA(1) underlies the UCCU, which creates a higher water table because of its low conductivity and a much steeper gradient.

A steep gradient is also present along the Las Vegas Valley Shear Zone, a result of the lower conductivity used for LCA(3) and AA(2). South of the shear zone, heads rise because of the recharge in the Spring Mountains and the lower conductivity value used for LCA(6). The area in the western part of the Spring Mountains with a very high gradient has LCCU exposed at the

Figure 5-11
Elevation of the Simulated Water Table for the Calibrated Model

surface. A high gradient is needed to transmit the water that is recharged in the model. In the field, this water probably travels as surface flow until encountering higher conductivity rocks.

A steeper gradient is also developed across the Desert Range because the LCCU is shallow along its axis as well as in the Sheep Range because of shallow LCCU and local recharge. Recall that the grid spacing is coarse in this area, resulting in numerical instability when a low value for the hydraulic conductivity is used for the LCCU. The modeled heads in this area are not reliable, but the value for recharge in the Sheep Range in the input data set is incorporated accurately in the model.

North of the junction of the Desert Range and the Pintwater Range, the heads rise above 800 m. This gradient is caused by the lower conductivity associated with LCA(8). There is a “ramp” in hydraulic heads as they increase to above 1400 m near Penoyer Valley. To the west of the ramp is a steep gradient caused by the LCCU underlying the Groom Range in addition to a local recharge mound at the northern end of the Groom Range.

The NTS area is divided into three zones. The Lower Carbonate Aquifer underlies the first zone which is distinguished by the low hydraulic gradient present beneath eastern Yucca Flat, Frenchman Flat, Jackass Flats, and the Mercury area. This zone is separated from a second zone, which consists predominantly of volcanic rocks in the northwestern part of the NTS, by a third zone. The third zone consists of a pronounced high gradient area that borders Yucca Flat on the east and west and curves around until it is oriented approximately east-west beneath Calico Hills and northern Yucca Mountain.

The high gradient east of Yucca Flat is caused by the structurally high LCCU that borders northeastern Yucca Flat. The LCCU is also structurally high west of Yucca Flat (west of the trace of the Belted Range Thrust), but is located further west than the eastern margin of the high gradient area. The higher water levels beneath western Yucca Flat are caused by the presence of the UCCU which causes a high vertical gradient between the rocks which overlie it and the underlying LCA. The overlying units include LCA(3), several volcanic HSUs, and AA. The LCA(3) is believed to consist of several isolated blocks of both pre- and post-Mississippian carbonate rocks; however, it is simulated as a single block within the model. When the LCA(3) was assigned conductivity values that are representative of carbonate rocks, the water levels in western Yucca Flat dropped significantly. The calibrated model required a value much lower than expected for carbonate rock. This suggests that the LCA(3) is not as well-connected as represented in the digital geologic model.

The high gradient across Calico Hills, northern Yucca Mountain, and northern Crater Flat is due to a combination of factors. The LCCU is uplifted north of the Belted Range Thrust, which prevents easy flow from the volcanic rocks southward into the LCA, which underlies the UCCU to the south of the Belted Range Thrust. Second, the UCCU is structurally high in Calico Hills and in the northern part of Bare Mountain, helping to provide the barrier. Third, the volcanic rocks in the Claim Canyon caldera segment north of Yucca Mountain and in the northern part of Yucca Mountain have been altered and, thus, have a lower conductivity than the volcanic rocks further to the south.

The Timber Mountain area has a lower hydraulic gradient than is present further to the north beneath Pahute Mesa. This difference in gradient is a result of two factors included in the model. Moderate conductivity values were assigned to the thick sequence of volcanic rocks in the Timber Mountain area in contrast to the inclusion of structurally offset interbedded units of both higher and lower hydraulic conductivity values in Pahute Mesa. The second factor is the recharge occurring at Timber Mountain, which reduces the gradient on the northern side of Timber Mountain.

Beneath Pahute Mesa, the hydraulic gradient indicates that flow is generally to the southwest. During the first and second sequences of calibration, the model could not simulate the higher heads that have been measured west of the Boxcar Fault that have long been the basis for the interpretation of the potentiometric trough within Area 20. During the third calibration sequence, the area around Black Mountain was zoned so that the effects of possible alteration on conductivities could be simulated. In the model, the conductivity of the rocks within this zone is simulated as being approximately two orders of magnitude lower than those of the volcanic aquifers present east of this zone beneath the Pahute Mesa testing area. This zonation resulted in higher simulated heads west of the Boxcar Fault as desired and the development of the potentiometric trough. However, it is not known whether this hypothesis or another is the correct explanation for the observed water levels.

The area north of the NTS has moderate gradients with local divides due to recharge along the Kawich Range and the northern part of the Quinn Canyon Range. These divides are in agreement with the potentiometric map presented in the Potentiometric Data Documentation Package ([Plate 2](#)) (IT, 1996b). The discharge area at Penoyer Valley is evident by the bend in the 1,450-m contour line that indicates flow into the discharge area from the south, west and north.

The head distribution maps for Layers 5, 7, and 14 have been reproduced from [Appendix G](#) in [Figures 5-12, 5-13, and 5-14](#), respectively. Contours are not drawn in areas where there are no

Figure 5-12
Simulated Heads for Model Layer 5

Figure 5-13
Simulated Heads for Model Layer 7

Figure 5-14
Simulated Heads for Model Layer 14

active cells (e.g., where the bottoms of the cells are above the simulated water table). In [Figure 5-12](#) (elevation range 1,050 to 1,200 m), the area north and west of the NTS is saturated. Effects of recharge are noted in the Kawich, Quinn Canyon, and Groom Ranges, beneath Shoshone Mountain, in the Sheep Range, and in the Spring Mountains. To the west of Shoshone Mountain and north of Oasis Valley, the observed low hydraulic gradient is apparent. The discharge in Oasis Valley is reflected in the contour lines in this layer. Along the perimeter of Yucca Flat, the steep hydraulic gradient is apparent on the western side, but not to the north.

By Layer 7, which includes the elevation range from 700 to 900 m ([Figure 5-13](#)), many additional features are present. A steep gradient is present in the Sheep Range; this is caused by the steep rise in the LCCU from the valley west of the range to near the crest of the range over a short distance. A low gradient is present from the Amargosa Desert eastward to Indian Springs Valley, a result of the high transmissivity in LCA Zones 1, 2, and 4. Along the eastern edge of the model, the contours increase from south to north, varying from 750 m just west of Pahranaagat Valley to more than 1,400 m in the north; this is a result of the lower conductivity assigned to LCA Zone 8. The low conductivity, needed to develop the gradient so that simulated heads would be high enough in Penoyer Valley and in the areas to the west of the Pahranaagat and Sheep Ranges, is consistent with an increase in the shale content in the northeastern part of the modeled area. The effect of the zonation along the Las Vegas Valley shear zone (LCA Zone 3) is apparent in the 750-m contour line, causing it to be oriented nearly east-west, north of the Spring Mountains.

In the NTS, several features are noteworthy. A low gradient associated with the LCA exists in the southern part of the NTS, extending up into the eastern part of Yucca Flat. The steep hydraulic gradient to the north of Yucca Flat is now well-developed. The steep gradient existing on the western part of Yucca Flat and westward towards the southeastern corner of Rainier Mesa is caused by the presence of the UCCU which also creates a high vertical gradient between this layer and lower layers. The effect of recharge in Shoshone Mountain is still apparent. The high gradients to the south and southwest of the caldera complex, north of Yucca Mountain, are due to the presence of the LCCU and low-conductivity volcanic units. In the Yucca Mountain area, the high measured head of 1,031 m is not well-matched because of the steep gradient, but the high gradient is well-defined, and the water level in Well UE-29a#2 in Fortymile Canyon north of the gradient is matched well.

Dropping down into Layer 14 ([Figure 5-14](#)), the shelf caused by the UCCU is gone, and the low gradient area associated with the LCA beneath Yucca Flat is present further to the west. The high gradient into Death Valley is well-defined, and an upward gradient is present below Franklin Lake. At Yucca Mountain, a downward gradient is modeled; the 750-m contour line is further

north in Layer 14 than it is in Layer 7. However, water level data from USW-H1 indicate that an upward gradient exists (Lobmeyer et al., 1995). The eastward gradient across the proposed repository block is also not present in the modeling results. Thus, the general features of the groundwater system near Yucca Mountain are modeled, but the detailed features are not.

5.3.2 Head Residual Distributions by Zone

One of the primary goals of calibration is to minimize weighted residuals in the areas of interest and to produce as small residuals as possible in the remaining areas, given the coarseness of the geologic model and the presence of high hydraulic gradients. This was accomplished in the following manner. As explained in [Section 4.3.2](#), simulated heads were interpolated from the centroid of each model cell to the target well location within the cell for each model layer in which the well is completed. The interpolated heads in each model layer were then used to calculate a single, transmissivity-weighted average head for the layers the well penetrates. The residual was calculated as measured minus the simulated, transmissivity-weighted average head. Finally, the weighted residual was calculated by dividing the residual by the square root of the total variance for that observation.

Quantification of the calibration criteria included minimizing the weighted means and roots mean square (RMS) in each of the 15 residual zones. The weighted means and RMSs by zone are provided in [Table 5-2](#); the non-weighted values are also provided for reference. It should be noted that the RMS will be larger than the standard deviation unless the mean weighted residual is zero. [Table 5-2](#) also lists the range in measured heads observed within each residual zone. Normalized weighted and nonweighted means and RMSs can be calculated by dividing the zone parameters by the respective range in heads.

The mean weighted residual for the 792 target heads is 7.9 m. This is 0.47 percent of the range in measured heads, which indicates that, overall, the model provides an excellent approximation of regional heads. The weighted root mean square of the residuals is 51.3 m, which is approximately 3 percent of the range in measured heads. The highest mean weighted residual occurs in the Barrier zone, which includes the high hydraulic gradient associated with the LCCU. This zone was defined specifically because of the anticipated difficulty in matching heads in this area; therefore, the higher residuals are not problematic. The Sheep Range zone also has a high mean weighted residual; this value can not be considered reliable because of the zonation of the LCCU in this area to minimize convergence problems.

Table 5-2
Summary Statistics for Nonweighted and Weighted
Hydraulic-Head Residuals by Zone

Zone	Area	Abbreviation	Number of Observations	Mean Residual (m)	RMS of Residuals (m)	Mean Weighted Residual (m)	RMS of Weighted Residuals (m)	Range in Measured Heads (m)
	All		792	8.5	50.3	7.9	51.3	1687.4
1	Northern Area	NRTH	61	-6.5	38.8	5.8	42.9	202.7
2	Oasis Valley	OASI	81	43.8	82.4	38.3	72.2	533.7
3	Pahute Mesa	PM	83	-10.2	37.3	-5.8	35.7	230.7
4	Barrier	BARR	13	147.4	181.5	107.2	146.8	565.3
5	W. Yucca Flat	WYF	24	40.4	129.0	70.4	139.5	632.2
6	E. Yucca Flat	EYF	91	-1.1	21.5	1.3	22.9	101.3
7	Shoshone	SHON	6	21.3	83.1	21.7	80.5	285.8
8	Death Valley	DV	25	17.1	48.6	22.9	41.0	728.4
9	Lower Carbonate Aquifer	LCA	213	-1.0	19.7	-7.3	28.8	205.0
10	SW. of Pahrnagat Valley	PAHR	5	-11.3	12.9	-9.9	11.4	15.3
11	Spring Mountains	SPMT	23	-7.3	47.2	-1.7	53.3	278.9
12	Sheep Range	SHRG	4	61.2	67.1	49.3	47.3	39.9
13	Timber Mountain	TMBR	7	8.7	47.0	6.7	61.0	220.7
14	Amargosa Farm Area	FARM	139	6.5	10.1	6.3	9.0	58.3
15	Frenchman Flat	FF	16	0.7	4.9	0.8	5.2	20.6

Measured heads in the NRTH zone are slightly higher than calculated heads, possibly due to perched zones or the lack of detail in the geologic model. The remaining zones that are upgradient and distal from areas of interest, zones PAHR and SPMT, have satisfactory fits to measured data. Simulated heads to the southwest of the Pahrnagat Range are higher than observed heads. Head values in this area are most sensitive to the hydraulic conductivity value in the LCA(8).

Mean residuals and RMS values within the LCA and FARM zones are low, indicating a good fit to observed data within the regional carbonate aquifer. These values are also low for the DV

zone, given the range in measured heads, which indicates that the geometry of the hydraulic barrier between Death Valley and the Amargosa Desert across the Funeral Mountains is defined reasonably well.

The remaining seven zones (OV, PM, SHON, TMBR, FF, WYF, and EYF) are all within or immediately downgradient of underground nuclear testing locations. The model provides good to excellent fits for the Oasis Valley, Pahute Mesa, Timber Mountain, Frenchman Flat, and Shoshone Mountain zones. Simulated heads in the Oasis Valley (OASI) residual zone are, on average, lower than measured heads. The area where most of the mismatch occurs is on the northern side of the Grapevine Mountains and at Bullfrog Mountain, where simulated water levels are too low. Within and upgradient of the Oasis Valley discharge area within the valley, the match is considerably better. Within the TMBR zone the greatest mismatch is on the northeastern side of the caldera, at WW8 and TW-1, where simulated heads are lower than measured ones. Agreement at the remaining five locations is much better. The fit in Frenchman Flat is excellent.

Western Yucca Flat has a high mean weighted residual; it is adjoined by the eastern Yucca Flat zone, which has a small mean weighted residual. The WYF zone is structurally very complex, and high lateral and vertical hydraulic gradients are present. Because of the geologic complexity and the high gradients, heads are not easy to match in this area. The final model was specifically calibrated to produce a mean weighted residual for EYF near zero because of the importance of the flow paths from Yucca Flat southward into Frenchman Flat; however, this resulted in higher residuals in WYF and numerical instability in the high vertical gradient areas in the WYF and SHON residual zones. The instability is related to rewetting of model cells during the iterative process of solving the model equations. If higher residuals had been acceptable in EYF, the mean weighted residual in WYF would have been lower, and the solution would have been more stable in the WYF and SHON residual zones. The particle-tracking results for a particle starting at Shoshone Mountain were very sensitive to this instability, but those for other particles were not. More detailed modeling of this area should be preceded by development of greater detail in the geologic model to improve the accuracy of the hydrologic model.

5.4 Boundary Flux Rates

The model was also calibrated to match estimated discharge rates. The model-calculated flux values associated with the four external model boundaries (GHB and Well Packages) and the eight surface-water discharge boundaries (Drain Package) are provided in [Table 5-3](#). Positive values indicate flux into the model by underflow across model boundaries, while negative values indicate flux out of the model due to spring discharge/evapotranspiration or underflow.

Table 5-3
Comparison of Target and Simulated Boundary Fluxes

Underflow or Discharge Area	Target Flux Range (m ³ /d)	Target Flux Rate (m ³ /d)	Simulated Rate (m ³ /d)
Pahrnagat Valley	5,400 to 60,800	27,000	27,000
Pahrump Valley	5,000 to 7,600	5,000	1,720
Sarcobatus Flat	-1,700 to 1,700	0	0
Eagle Mountain	-850 to -3,400	-3,400	-4,929
Alkali Flat (or Peter's Playa)	-5,000 to -7,300	-6,100	-5,233
Amargosa River	-2,040 to -5,100	-2,500	-335
Ash Meadows	-67,000 to -87,300	-77,700	-77,333
Death Valley	-17,500 to -60,200	-60,100	-59,783
Franklin Lake/Alkali Flats	-14,200 to -42,600	-35,500	-37,874
Oasis Valley	-17,000 to -27,000	-25,000	-25,785
Penoyer Valley	-13,000 to -27,000	-20,300	-19,106
Indian Springs	-1,600 to -2,400	-2,400	-2,457

Overall, the calibrated model matches the target boundary fluxes very well. For example, the target for Ash Meadows discharge was -77,700 m³/d; the simulated discharge was -77,332. Similarly, the target and simulated discharges for Oasis Valley were -25,000 m³/d and -25,784 m³/d, respectively. The simulated Death Valley discharge was 318 m³/d lower than the target value of -60,100 m³/d. Matches at Franklin Lake and Penoyer Valley are not as good, but are still within 7 percent of the target values.

In the smaller discharge areas, the simulated discharge rates are close to the target flux rates, but the percentage difference is greater than in the larger discharge areas. There are four areas where the simulated flux was not within the target range. The poorest agreement is for the discharge at the Amargosa River discharge area (which apparently has never previously been measured or estimated). The simulated discharge was -334 m³/d, while the target range was -2,040 to -5,100 m³/d, and the target rate was -2,500 m³/d. However, to put these numbers in perspective, the target rate represents only 1 percent of the estimated flux of water through the system.

At Eagle Mountain, the boundary flux was estimated to range from -850 to -3,400 m³/d, with a calibration target at the upper end. The simulated flux was -4,928 m³/d. The inflow from Pahrump Valley has been estimated to be between 5,000 m³/d and 7,000 m³/d. The simulated value was 1,719 m³/d. The fourth area with the simulated flux outside the target range is Indian Springs. Its range of estimates is from -1,600 m³/d to -2,400 m³/d, with a target of -2,400 m³/d. The simulated value (-2,456 m³/d), although outside the range of estimates, is very close to the target. The sum of the magnitudes of the difference between the simulated value and the target value for these four areas is 7,031 m³/d, or 3 percent of the total flux through the system.

In summary, the match of the simulated discharges to the targets is quite good. However, there is considerable uncertainty in the estimated and target discharges for individual areas and for the modeled area overall. Because of ongoing studies by the U.S. Geological Survey, the discharge at Ash Meadows is fairly well-known, but still has an uncertainty of approximately 20,000 m³/d; discharge in remaining areas is less-well known, especially, in Death Valley. Model users should be aware of the lack of good discharge measurements, and they should interpret the results accordingly.

5.5 Particle-Tracking Results

The movement of contaminants in the groundwater system will be determined, in part, by the direction and rates of groundwater migration from contaminant sources to downgradient discharge areas. Particle tracking is a good method for evaluating the advective transport of contaminants and is easily implemented using head and flux distributions from the calibrated model. The code MODPATH, ver. 1.2 (Pollock, 1990) was used to calculate the locations of the particles along flow paths, and it was also used to incorporate information from the flow model into the subsequent transport calculations. The program uses information about the calculated fluxes through the six walls of the individual model cells and the flux removed or added through the boundary conditions to calculate velocities internal to the cells. The user starts the particles at desired locations, and the program calculates and records their location through time.

MODPATH was run using an effective porosity of 1.0 for all layers, so that it actually calculates specific discharge. The specific discharge is converted into particle velocity by determining the HSU in which a particle is traveling and using information on the effective porosity of the HSU. The pathline is based on MODFLOW results, which are based on preprocessors which perform some averaging of HSU properties present within the model layers. As a result, the particle path that is calculated does not reflect the detail of the geologic model, while the effective-porosity correction does. This sometimes causes peculiar results, such as when a particle is traveling near the top of the LCA which may be overlain by low conductivity, high effective-porosity rocks.

The particle may seem to move between the LCA and the overlying unit (e.g. VCU) whereas, in reality, the movement is due to the geometry of the interface simulated in the model, and is not representative of the pathway an actual particle would take. It is, therefore, sometimes necessary to study the detailed pathways of the particles in order to understand their rates of movement.

Figure 5-15 shows the pathlines for 14 particles released in selected testing areas. The procedure used to select the particle starting locations is described in detail in the *Tritium Transport Model Documentation Package* (IT, 1996g) and is summarized briefly as follows. All below-ground nuclear testing locations were identified, and those with working points (WP) located below the water table or within two-cavity radii above the top of the water table were retained. The three exceptions to this included test locations in Shoshone Mountain, Rainier Mesa, and the Climax Stock located on the northern boundary of Yucca Flat. These areas had tests located above two cavity-radii of the water table, but several tests were selected and assumed to originate at the water table in order to evaluate possible transport in groundwater from these locations. This did not take into account transport times through the unsaturated zone; therefore, the amount of time for contaminant migration from these three areas is underestimated.

In order to identify the fastest transport times from each of the test locations, up to three starting locations per working point were evaluated for each of the working points located within or below two cavity radii of the water table. These locations included the working point itself and two cavity radii above and below the working point. All locations with elevations below or at the water table were retained for analysis. Again, starting locations for tests originating in Shoshone Mountain, Rainier Mesa, and the Climax Stock were placed at the water table.

The compiled database consisted of a total of 415 starting points. MODPATH was then run with particles placed at each of these locations, using flux data from the calibrated model. Processing of MODPATH results incorporated the different effective porosities of the HSUs. Based on the MODPATH results, 14 particles were selected. The 14 starting locations generally included the fastest moving particles from each of the testing areas: Pahute Mesa, Yucca Flat, Frenchman Flat, Rainier Mesa, Shoshone Mountain, and Climax Stock. In Yucca Flat, particles were selected to also provide spatial coverage of the valley.

The names of the selected tests are identified in Figure 5-15, which also shows the pathlines from the originating location to the discharge point. It is very important to note that time information is not included as part of the figure. Several of the particles originate in very low conductivity units, and residence times will be large.

Figure 5-15
Particle Pathlines from Fourteen Testing Locations

Five particles were started from underground test locations on Pahute Mesa. Four of these particles (for DARWIN, PURSE, TYBO, and BULLION tests) moved southwestward to discharge locations in Oasis Valley. They began in either the TMA or TC rocks, but traveled to the discharge area primarily in the TMA. The fifth particle on Pahute Mesa (HOUSTON test) began in TC further to the east than the other four and traveled to the south along the east side of the Timber Mountain resurgent dome in TMA. Leaving the moat, it reentered TC and traveled a short distance before entering VCU and VA in northwestern Yucca Mountain. Beneath southern Crater Flat, it entered the LCA, crossed beneath the Amargosa Desert, and discharged into Death Valley through the TSDV.

The particle originating beneath Rainier Mesa, (CLEARWATER) traveled through the LCCU until entering the TMA within the Timber Mountain moat. It traveled southward, crossed the LCCU where the Belted Range Thrust raised these rocks, and moved through the LCA north of Calico Hills. It then passed through the UCCU down into the LCA (near the east side of Yucca Mountain) and remained in the LCA until reaching the Funeral Mountains. It passed through the LCCU, the TSDV, and finally discharged from the AA.

A sixth particle was started at the water table below the PILE DRIVER test in the Climax Stock at the northern end of Yucca Flat. This particle started in the intrusive, passed through a small amount of UCCU, and entered the LCA beneath northern Yucca Flat. It traveled along the upper part of the LCA, passing beneath Massachusetts Mountain which separates Yucca Flat from Frenchman Flat. Moving beneath the northwestern part of Frenchman Flat in the LCA, it moved down Rock Valley and entered the AA near Skeleton Hills. The particle continued to move southwestward to discharge at the Amargosa River discharge area.

Five particles were started in Yucca Flat. COULOMMIERS and CORDUROY originated in the VCU and LCA, respectively, and had similar flowpaths to the PILE DRIVER particle, discharging from the AA at the Amargosa River discharge area. BOURBON also started within the LCA, but migrated southward farther to the east than the previous two particles, discharging in the AA at the Franklin Lake discharge area. The final two particles, STRAIT and CUMARIN, began in the VCU on the western side of Yucca Flat. Both particles traveled in the LCA into the Amargosa Desert, but were not captured by the Amargosa River discharge area. Instead, they moved from the AA back into LCA and TSDV and discharged in Death Valley.

The particle in northern Frenchman Flat (DILUTED WATER) began in AA, passed through VCU, and then into LCA. Near the western edge, its path nearly coincided with that of the BOURBON particle, but it was shallower, discharging at the Amargosa River discharge area.

The last particle path evaluated, (Gum Drop) started at Shoshone Mountain in the UCCU, passed through the VCU, and entered LCA3. It traveled to the southeast along the base of LCA3 until it found a pathway into the LCA, which involved traveling northward a short distance before again moving southward. It moved in the upper part of the LCA beneath the UCCU, traveling through the VCU and VA a short distance until entering AA near Amargosa Valley. It continued beneath the Amargosa Desert and Funeral Range and discharged from the AA in Death Valley.

The particle-tracking results from Yucca Flat are different from earlier conceptual models which indicated that the water from Yucca Flat discharges at Ash Meadows. The numerical model does not support this conceptual model because of the inclusion of more recent, detailed information. First, the simulated flow paths appear to be sensitive to the configuration of the top of the LCA, flowing through areas where the LCA is shallower. This is a consequence of the depth-decay model for conductivity that was used in the flow model. Second, the older conceptual models were based on an interpretation that the Eleana argillite was 2,500 to 3,000 m thick beneath western Yucca Flat, which would tend to divert flow laterally around the Eleana, forcing it to the south beneath Frenchman Flat. A more recent study of these rocks by Cashman and Trexler (1994) has shown that there are two distinct depositional environments present. This new interpretation places 1,000 to 1,500 m of Eleana argillite west of a similar thickness of the Chainman shale. These two units together comprise the Upper Clastic Confining Unit. However, their position within the groundwater system allows water in the LCA to flow beneath them much further to the west than previously interpreted. The net result is that water from the eastern part of the NTS does not appear to flow to Ash Meadows, but instead discharges in the Amargosa Desert or Death Valley.

The pathline results indicate that the modeled flowpaths are greatly affected by the three-dimensional configuration of the LCA and the distribution of low-conductivity confining units. The details highlighted by the particle-tracking results (e.g., migration downwards beneath the volcanic units underling Jackass Flats) would not be apparent in a two-dimensional model or one based on a greatly simplified geologic model. The results further demonstrate the need to adequately characterize the geology within the testing areas if the details of transport are important at that scale.

5.6 Sensitivity Analyses

Sensitivity analyses were performed at the conclusion of model calibration. The objectives of the sensitivity evaluations were twofold:

- Identify those hydraulic parameters (horizontal hydraulic conductivity, vertical anisotropy, and depth-decay coefficients) to which the model is sensitive and, therefore, for which the model can provide information on the regional scale.
- Evaluate the effects on model results of changes to the underlying geologic model and other parameters integral to development of the modeling approach (e.g., recharge redistribution to low-lying alluvial fans).

The effects on model results of changes to parameters included in the latter group cannot easily be evaluated in the traditional sense, which consists of modifying parameter values by a given amount and calculating the resultant change, or sensitivity, in heads or fluxes. For example, the effects of implementing the changes to the geologic model discussed in [Section 4.4](#) of this report cannot be assessed in this manner. However, the effects on head and flux distributions due to modifications to the geologic model provide important information on the conceptual and calibrated model. This latter group is termed “special-case sensitivity analyses,” and will be discussed first. Sensitivity analyses of the hydraulic parameters are presented in [Section 5.6.3](#).

The sensitivity analyses were performed using the following steps:

- Assemble the input data sets incorporating the change being evaluated.
- Run the preprocessors and MODFLOW.
- Calculate the head residual statistics (mean weighted residual and RMS) and boundary fluxes.
- Using MODPATH and postprocessing programs, calculate particle pathlines and advective travel distance from the selected underground test locations at times of 25 years, 50 years, 100 years, and 200 years from start of test, taking into account the different effective porosities of the HSUs.

5.6.1 Special-Case Sensitivity Analyses

Special-case sensitivity analyses were conducted as part of both modeling sequences 2 and 3. A total of 12 runs testing the effects of assumptions fundamental to the flow model were performed during sequence 2. The parameters evaluated included drain conductances, recharge assumptions, and different versions of the geologic model. The results for the three geologic model evaluations are included in the current discussion; the remaining nine sensitivity runs have either been incorporated in sequence 3 or are no longer pertinent due to the change in the recharge input data

set. Eleven special-case sensitivity runs were conducted as part of the sequence 3 modeling. Five of the runs relate to assumptions in the amount and distribution of recharge; two runs evaluated the effects of increased underflow from Paharanagat Valley and Sarcobatus Flat; and the remaining four runs evaluated changes in hydraulic conductivity that were greater or otherwise different than the systematic changes discussed later.

Results from the 14 special-case sensitivity runs are presented in [Table 5-4](#), which includes the changes in mean weighted head residuals, the percentage change in the RMS of weighted residuals, and the percentage change in discharge fluxes between the base (calibrated) case and each sensitivity run. All mean residual changes greater than or equal to an absolute value of “1” are shaded in the table. Flux and RMS percentage changes greater than or equal to an absolute value of “10” are also shaded. It should be emphasized that two different base cases are being considered; sequence 2 sensitivity runs are compared to Base 2, while sequence 3 sensitivity runs are compared to Base 3. The discussion of these parameter results is arranged according to geologic model interpretations, recharge model evaluations, boundary flux evaluations, and conductivity evaluations. The water table maps for the calibrated models ([Figure 5-11](#) for sequence 3) have been reproduced on overlays (Plates 4 and 5 for Base 2 and Base 3, respectively) to facilitate comparisons between sensitivity runs and base case results.

The special-case sensitivity runs were performed by changing the factor(s) being evaluated, but otherwise leaving the conductivity parameters as they are in the calibrated model. Particle-tracking results are presented for the 11 sequence 3 sensitivity runs following the discussion of head and flux results.

5.6.1.1 Geologic Model Interpretations

Sensitivity analyses were performed for three earlier versions of the digital geologic model. The results of the three runs are compared to the base case for sequence 2 (Base 2). The three sensitivity runs are identified in [Table 5-4](#) by the term “GEOL”, followed by the version number used internally for tracking changes to the geologic model. The three runs are described in the following text.

GEOL_6

This run used geologic model `geol_6.mdl` which included the geologic interpretation prior to modification of the geologic model in Penoyer Valley, north of Yucca Mountain, and beneath Rainier Mesa (Tongue Wash).

GEOL_10

This version (geol_10.mdl) includes changes in the Penoyer Valley area and the area north of Yucca Mountain, but not beneath Rainier Mesa.

GEOL_12

This model changed the interpretation of the structure beneath Rainier Mesa, making the UCCU continuous beneath Tongue Wash.

The base case for sequence 2 (Base 2) incorporates the geologic model version geol_14.mdl. This model includes additional adjustments in the geology north of Penoyer Valley, in the Groom Range, and a minor extension of the geologic model in the Spring Mountains to correct an area where it did not extend beyond the flow model boundary. It should be emphasized that the sequence 2 model included GHB boundary conditions at Sarcobatus and Pahranaagat, whereas these were changed to constant flux boundary conditions in sequence 3. Therefore, changes to the geologic model in sequence 2 may influence flux rates across the two boundaries.

The simulated water table for run *GEOL_06* is plotted in [Figure 5-16](#). The differences between the *GEOL_06* and the Base 2 sensitivity runs are significant. The hydraulic heads in *GEOL_06* are considerably lower in the Timber Mountain, Pahute Mesa, and Western Yucca Flat residual zones than in Base 2. As a result of the lower hydraulic heads on Pahute Mesa, groundwater beneath Sarcobatus Flat flows into the model rather than out, which occurs in Base 2. In *GEOL_06*, more water moves through the area extending from Calico Hills to Bare Mountain, and the discharge in Oasis Valley is much lower than in the base case. The high gradient present in the northern part of Yucca Mountain is not simulated. The discharge at Penoyer Valley is similar in the two runs, but the heads in the northern Groom Range are considerably higher in the base case. This sensitivity run demonstrates that the geologic model used during the initial calibration sequence was not adequate to explain hydraulic head and flux distributions, and needed modification.

Sensitivity run *GEOL_10* produced a significantly better fit to hydraulic heads in Pahute Mesa, Timber Mountain, and Penoyer Valley ([Figure 5-17](#)), in addition to a greater discharge at Oasis Valley as a result of the barrier north of Yucca Mountain. The model accurately simulates the high gradient at northern Yucca Mountain. In addition to simulating the Oasis Valley discharge rates, the remaining boundary fluxes for *GEOL_10* are also very similar to those calculated for Base 2 ([Table 5-4](#)). In the Penoyer Valley area, extending the Lower Clastic Confining Unit northward from the Groom Range along the eastern side of the valley improves model goodness-of-fit to hydraulic heads and discharge rates; however, a low value for the Lower Carbonate

Figure 5-16
Elevation of the Simulated Water Table for the Sensitivity
Run Using Geologic Model Geol_6 (Episode 2)

Figure 5-17
Elevation of the Simulated Water Table for the Sensitivity
Run Using Geologic Model Geol_10 (Episode 2)

Table 5-4
Changes in Hydraulic-Head Residuals, RMS, and Boundary Fluxes for Special Case Sensitivity Scenarios
 (Page 1 of 2)

Means of Weighted Head Residuals (meters)																	
Zone	Scenario (Episode 2)				Scenario (Episode 3)												
	Base 2	Geol_6	Geol_10	Geol_12	Base 3	Rech1.5x	Rech0.75x	Rch_hd0r	Rch_hd.3r	Rch_me	SF_1700	PV_60000	VCU_ZN2	LCA3_ZN1	AA_ZN4&5	TMA_ZN6	
NRTH	13.20	10.80	-5.60	3.80	5.80	1.10	-0.60	-0.40	0.00	4.60	0.10	0.10	0.00	-0.30	0.00	-16.10	
OASI	12.30	-35.70	1.00	0.10	38.30	1.10	-0.40	-0.20	0.10	0.70	0.70	3.00	0.00	-0.90	-0.10	8.10	
PM	4.00	42.10	10.00	2.10	-5.80	1.50	-0.80	1.50	-1.70	8.10	0.70	0.00	-0.20	-3.00	-0.10	-64.00	
BARR	79.00	-3.90	-2.30	0.50	107.20	-1.20	1.90	0.00	0.20	1.60	0.20	8.80	0.00	0.80	-0.10	-0.60	
WYF	35.00	105.90	111.50	-0.70	70.40	-3.00	2.40	5.00	2.00	0.80	1.30	1.50	-43.10	-65.30	-1.50	-26.40	
EYF	-24.60	2.80	7.70	-0.10	1.30	-0.80	1.70	0.20	0.60	3.40	0.60	8.50	1.50	-5.90	-7.20	0.30	
SHON	-9.00	-51.80	5.00	-0.20	21.70	2.10	1.80	1.10	0.20	-12.70	0.30	6.50	-0.60	-21.00	-0.80	-2.80	
DV	-12.60	-0.60	0.00	-0.10	22.90	8.50	-4.30	0.00	0.10	3.50	0.00	1.10	0.00	0.10	0.00	0.90	
LCA	-5.10	-11.40	-0.30	0.00	-7.30	0.70	-0.10	-0.10	0.20	-0.10	0.10	2.60	0.00	-0.30	0.00	-1.90	
PAHR	-13.60	-2.50	-0.60	0.00	-9.90	-29.70	27.50	-0.10	-0.80	-24.70	0.00	94.80	0.00	-0.60	-1.10	0.10	
SPMT	19.50	-1.90	0.50	-1.40	-1.70	-0.10	0.40	0.00	0.10	-5.50	0.10	3.00	0.10	0.20	0.00	0.20	
SHRG	-45.70	-0.70	1.20	-1.90	49.30	-2.00	1.20	0.00	0.10	-6.20	0.00	7.00	0.00	0.30	0.00	0.00	
TMBR	9.10	156.40	41.60	1.20	6.70	2.70	-1.10	5.20	-2.30	13.80	1.10	0.40	-0.70	-9.40	0.20	-32.20	
FARM					6.30	0.50	0.10	-0.20	0.10	-2.00	0.00	3.80	0.00	0.30	0.00	1.60	
FF					0.80	-1.30	1.70	-0.10	0.20	-2.00	0.10	8.60	0.40	0.70	-0.20	0.10	

Root Mean Square of Weighted Head Residuals (meters)																	
Zone	Scenario (Episode 2)				Scenario (Episode 3)												
	Base 2	Geol_6	Geol_10	Geol_12	Base 3	Rech1.5x	Rech0.75x	Rch_hd0r	Rch_hd.3r	Rch_me	SF_1700	PV_60000	VCU_ZN2	LCA3_ZN1	AA_ZN4&5	TMA_ZN6	
NRTH	61.00	8.69	5.57	1.48	42.90	-0.23	0.00	0.93	-0.23	5.13	-0.47	0.00	0.00	0.93	0.00	70.16	
OASI	43.80	62.79	2.28	-0.23	72.20	-1.11	0.28	0.14	-0.14	-2.35	-0.42	-1.94	0.00	0.83	0.00	-16.07	
PM	35.00	66.57	8.57	-0.57	35.70	0.84	-0.28	-0.84	0.56	5.60	0.28	0.00	0.00	-1.12	-0.28	89.64	
BARR	136.90	-1.97	-0.80	-0.07	146.80	0.54	-0.82	0.07	-0.14	0.00	-0.07	-3.95	0.07	-0.34	0.07	0.14	
WYF	80.70	154.77	143.74	-0.12	139.50	0.07	-0.29	-2.72	-1.65	-25.16	-1.08	0.07	3.58	75.13	7.46	-8.75	
EYF	41.30	-16.46	-25.67	-0.24	22.90	1.31	-0.87	0.44	0.44	13.97	0.87	3.06	3.93	-3.93	0.00	0.87	
SHON	43.50	169.89	-3.91	0.23	80.50	2.86	-0.87	1.37	-0.25	1.37	0.37	-4.47	-0.12	2.24	-0.25	-1.49	
DV	48.00	2.92	1.88	0.00	41.00	-4.15	1.95	0.24	-0.24	7.07	0.00	-4.63	0.00	-0.24	0.00	-3.41	
LCA	17.20	136.05	0.00	0.00	28.80	1.04	-0.69	-0.35	0.35	1.04	0.69	4.17	-0.35	-4.51	-0.69	-17.01	
PAHR	67.50	-1.19	-0.44	-0.15	11.40	72.81	235.96	-0.88	-7.02	29.82	-0.88	826.32	-0.88	-5.26	-8.77	0.00	
SPMT	57.40	-2.96	-1.05	-0.35	53.30	-0.19	0.00	0.00	0.00	-1.69	0.00	-0.56	0.00	0.00	0.00	0.00	
SHRG	51.40	2.14	-0.58	-1.56	47.30	4.23	-2.54	0.00	-0.21	13.32	0.00	-14.59	0.00	-0.63	0.00	0.00	
TMBR	50.50	244.95	53.47	-0.59	61.00	0.16	0.33	-3.11	1.15	-3.28	0.00	0.49	0.16	0.49	0.33	20.33	
FARM					9.00	-4.44	0.00	2.22	-1.11	18.89	0.00	-23.33	0.00	-2.22	0.00	-14.44	
FF					5.20	7.69	1.92	1.92	0.00	13.46	0.00	80.77	0.00	0.00	1.92	0.00	

Table 5-4
Changes in Hydraulic-Head Residuals, RMS, and Boundary Fluxes for Special Case Sensitivity Scenarios
 (Page 2 of 2)

Boundary Fluxes (meters ³ /day)*																	
Zone	Scenario (Episode 2)				Scenario (Episode 3)												
	Base 2	Geol_6	Geol_10	Geol_12	Base 3	Rech1.5x	Rech0.75x	Rch_hd0r	Rch_hd3r	Rch_me	SF_1700	PV_60000	VCU	ZN2	LCA3	ZN1_AA	ZN4&5_TMA_ZN6
DV	-48327.00	0.95	-0.14	-0.19	-59782.87	48.14	-24.41	-0.03	0.02	29.54	0.01	0.61	0.01	0.01	0.04	0.00	0.74
OV	-15874.00	-66.36	-11.43	0.86	-25784.95	47.18	-24.30	3.52	-1.95	46.01	5.63	0.22	-0.75	-9.91	-0.14	-7.48	
Ariv	-8508.00	19.95	2.82	0.19	-334.81	43.21	-19.14	-1.52	1.28	-4.41	0.65	40.00	0.45	3.40	0.14	15.11	
AM	-69006.00	18.04	3.36	0.13	-77332.51	41.55	-20.73	-0.45	0.50	20.34	0.25	20.08	0.27	1.89	0.07	2.33	
FL	-18088.00	5.88	0.86	0.06	-37873.70	41.04	-22.16	-0.11	0.09	22.30	0.05	2.89	0.03	0.25	0.01	1.07	
AF	-5956.00	55.94	10.86	0.40	-5232.56	1.86	16.87	-4.05	5.20	-47.23	2.64	294.65	3.17	21.80	0.81	10.40	
PV	-16138.00	-0.87	-4.38	-2.21	-19105.90	45.57	-24.86	-1.59	-1.16	79.62	-0.70	0.73	-1.05	-1.17	-0.36	-7.07	
IS	-1984.00	6.70	1.01	0.05	-2456.55	46.65	-23.70	-0.04	0.11	-9.37	0.09	6.80	0.07	0.40	-0.09	0.27	
PP	185.00	-5.41	-1.08	0.00	1719.51	49.84	-24.93	-0.01	0.01	33.18	0.01	-0.54	0.01	0.03	0.00	0.02	
EM	-5982.00	3.49	0.52	0.03	-4928.82	84.89	-33.88	-0.04	0.04	49.07	0.02	1.22	0.01	0.11	0.00	0.41	

* PP and EM are GHB Fluxes, the remaining zones display Drain Fluxes

Aquifer in the northeastern part of the model is still necessary to maintain shallow heads in the valley. The heads in Western Yucca Flat are about 110 m lower, on average, than those in Base 2, since the modification at Tongue Wash is not incorporated in *GEOL_10*. Sensitivity run *GEOL_10*, while accurately calculating heads and fluxes over the majority of the study area, resulted in a depression within the potentiometric surface beneath Rainier Mesa, which is inconsistent with observed data. To address this, the UCCU was made continuous in this area, (geologic model version 12, run *GEOL_12*). The differences in regional water-table elevations and fluxes between this run (Figure 5-18) and Base 2 are minor, but the hydraulic head differences between sensitivity runs *GEOL_10* and *GEOL_12* in Western Yucca Flat are significant. The base case interpretation provides a much better agreement with regional water-level data.

The remaining special-case sensitivity runs are all compared to sequence 3 Base 3 results (Plate 5). Sequence 3 incorporates the geologic model version *geol_15.mdl*. As described previously, *geol_15.mdl* is identical to *geol_14.mdl* with the exception that the geologic model was expanded slightly in the Death Valley area to incorporate new areas included in the revised model boundary.

5.6.1.2 Recharge Model Evaluations

There were five sensitivity runs performed on the areal recharge data set. The sensitivity runs are identified in Table 5-4 by the term “RECH” or “RCH,” followed by an identifier to indicate the change implemented in the data set. The names of the five runs and the implemented change include:

<i>Rech1.5x</i>	-	Recharge rate and K_h values (horizontal hydraulic conductivity values projected to land surface) increased by a factor of 1.5 times the corresponding values included in Base 3
<i>Rech0.75x</i>	-	Recharge rate and K_h values set to 0.75 times the corresponding values included in Base 3 (25 percent decrease compared to Base 3)
<i>Rch_hd0r</i>	-	Same recharge rate as Base 3, but with no redistribution
<i>Rch_hd.3r</i>	-	Same recharge rate as Base 3, but with 30 percent redistribution versus 20 percent redistribution in Base 3
<i>Rch_me</i>	-	Maxey-Eakin recharge model, with the K_h values increased by the Maxey-Eakin to Base 3 recharge ratio

Figure 5-18
Elevation of the Simulated Water Table for the Sensitivity
Run Using Geologic Model Geol_12 (Episode 2)

The first two sensitivity runs were conducted to determine whether hydraulic heads behave in a linear fashion with respect to changes in recharge. It should be emphasized that some non-linearity is to be expected, since drain and general-head boundary conductances and the Well Package flux rates were not changed correspondingly. The next two runs were conducted to evaluate the effect of recharge redistribution on heads and fluxes. The final run was included in the sensitivity analysis to evaluate the effects of incorporating the classical Maxey-Eakin approach (1949) on model heads and fluxes.

Rech1.5x

For sensitivity run *Rech1.5x*, the changes in mean weighted residuals are minor ([Table 5-4](#)), with the exception of zones PAHR and DV. In the PAHR residual zone, the mean dropped nearly 30 m as a result of the increase in K_h s without a compensating increase in the influx from Pahrnagat Valley. In Death Valley, the heads increased about 8 m because a high gradient is needed in order to transmit the additional water without an increase in drain conductivity. If all changes were implemented (e.g., the drain conductances and the Pahrnagat Valley inflow were increased by 50 percent, etc.), the head-dependent boundary fluxes should all increase by 50 percent. By holding the PV inflow at 27,000 m³/d, the total inflow into the model was increased by approximately 44 percent rather than 50 percent. With the exceptions of Alkali Flat (Peter's Playa) and Eagle Mountain fluxes, the increases were in the range of 41 to 50 percent. The AF discharge only increased 1.9 percent, and EM increased 85 percent. The percentage changes in discharge rates simulated using the Drain Package in the Amargosa Desert (AR, AM, FL, and AF) were all less than the total inflow change, while all other changes in flux were greater.

The different behaviors are probably related to the head gradients and the resulting increase in head as a result of increasing the recharge. In the LCA and FARM residual zones, the increases in the mean residual were only 0.7 and 0.5 m, respectively, compared with increases of 1.1 m in OV and 8.5 m in DV. The small increase in the AF discharge is due to the high negative sensitivity of this discharge area to the K_h values of LCA(2), and of HSUs downgradient from the discharge area ([Section 5.6.3.2](#)). In the current sensitivity run, the K_h of LCA(2) was increased by a factor of 1.5, while the total inflow to the model was only increased by a factor of 1.44. This resulted in only a small increase in discharge at AF because of its high sensitivity to the K_h of LCA(2). The large percentage increase in discharge at Eagle Mountain (EM) resulted from the increased inflow from Pahrump (PP) due to the increase in LCCU conductivity.

Rech0.75x

The results from this run are similar, but opposite in direction to the previous run. Heads increased in the PAHR zone and decreased in DV. In most zones, the direction of the change in the mean is opposite to that of *Rech1.5x*; however, the direction of change for the SHON and FARM residual zones was the same for both runs. This is probably because the drain conductance and PAHR flux parameter values were held constant, but it may reflect minor numerical solution differences. The changes in head-dependent fluxes generally follow the opposite patterns observed for the previous run. Because the inflow from Pahrnagat Valley was not decreased when the recharge was decreased by 25 percent, the flux into the model was decreased approximately 22 percent. The discharges for the Drain-Package boundaries in the Amargosa Desert decreased by this amount or less, while the other discharge fluxes decreased more. The AF discharge actually increased by 17 percent relative to Base 3. The K_h of LCA(2) was decreased by a factor of 0.75, while the total influx to the model was decreased by a factor of 0.779, with the result being an increase in the discharge at AF because of its high negative sensitivity to changes in K_h of LCA(2).

Rch_hd0r

For sensitivity run *Rch_hd0r*, the effects on heads are minor, with less than 0.5 m change in the mean weighted residual in all zones except TMBR, WYF, PM, and SHON. These zones, with the exception of WYF, are zones where the recharge increased as a result of not redistributing the water. In WYF, it is likely that the increase in the mean weighted residual is a result of the numerical problems associated with the steep hydraulic gradient in this area, and the result may not be accurate. The changes in simulated discharge were also minor, with the discharge in OV increasing by 3.5 percent and that in the Amargosa Desert decreasing by a similar volume. Redistribution removes water from the Oasis Valley subbasin by moving some water down the Fortymile Canyon/Wash drainage into the Amargosa Desert. Without redistribution, this water remains in the subbasin.

Rch_hd.3r

In this run, the changes to heads and discharge fluxes were small, and generally opposite in direction to those observed in *Rch_hd0r*. Exceptions to this are the mean weighted residual for WYF, SHON, and EYF. These zones are where the noted numerical stability affects heads. The changes in SHON and EYF were small (0.6 and 0.2 m). The changes in the discharge fluxes were all opposite in sign from the changes in the previous run, with a decrease in discharge at OV and increases in the Amargosa Desert.

Rch_me

In this sensitivity run, the recharge model was run using the original coefficients used by Maxey and Eakin (1949). These coefficients and the corresponding precipitation ranges are listed in [Table 4-3](#). The net recharge calculated for the modeled area by this method is 272,156 m³/d, compared with 204,080 m³/d used in the base case model. In order to compare Maxey-Eakin results with those of the base case, the K_h s of all HSUs were increased by a factor of 1.3336, the ratio of the Maxey-Eakin to Base 3 recharge values. The largest effect on simulated heads was in the PAHR residual zone where the mean dropped by 25 m. This is probably due to increasing the conductivity of LCA(8) without correspondingly increasing the boundary flux at Pahrnagat. Heads increased in the NRTH, PM, and TMBR residual zones an average of 4.6 m, 8.1 m, and 13.8 m, respectively, as a result of no redistribution of recharge. In areas affected by the influx from Pahrnagat Valley (SPMT, SHRG, LCA, FF, and FARM), heads decreased. This change occurred because the overall increase in the influx to the model was only 30 percent (since the Pahrnagat Valley inflow was not changed), but the K_h s were increased by 33 percent. The discharge at Penoyer Valley increased nearly 80 percent, much more than the percentage increase in recharge, because of its proximity to the higher elevation ranges in the northern part of the model and its location upgradient of the LCCU barrier.

Discharge at Oasis Valley increased by 46 percent. Discharge fluxes in the Amargosa Desert and Death Valley discharge areas increased less than 30 percent. Those at the Amargosa River and Alkali Flat actually decreased because the effect of increasing the K_h s of all HSUs by 33 percent outweighed the increase in flux. Inflow from Pahrump increased by 33 percent because of the increase in the K_h of the LCCU; this resulted in an increase of EM discharge exceeding 33 percent. The decrease in discharge at Indian Springs (IS) resulted from the decrease in heads in the LCA residual zone. Overall, the effect of using the Maxey-Eakin model is an increase in the simulated discharge rates at almost all discharge locations, with greater increases in higher gradient areas upgradient of the LCCU barrier.

To summarize the recharge special-case sensitivity runs, when the recharge rate and K_h s are increased by the same factor, the resulting heads are similar to those of the base case, and the fluxes increase approximately proportionately to the increase in the recharge, indicating that the model behaves linearly. Except for the AF discharge (due to its sensitivity to K_h of LCA(2)), the discharge in low-gradient areas is affected less than discharge fluxes in high-gradient areas. Using the Maxey-Eakin recharge model increases the recharge amount by approximately one-third and produces simulated discharges that are higher than target discharge rates ([Table 4-2](#)). This indicates that the Maxey-Eakin model results in discharge fluxes that are larger than supported by existing data. Finally, changing the distribution of recharge within and near the NTS has little

effect on simulated heads and discharge fluxes, since the total amount of recharge within the subbasins remains the same.

5.6.1.3 Boundary Flux Evaluations

There is a large uncertainty in the boundary flux estimates for both Sarcobatus Flat and Pahranaagat Valley. Two sensitivity runs were conducted to evaluate the effects of increasing the boundary fluxes at Pahranaagat Valley and Sarcobatus Flat on head distributions, discharge rates, and particle travel distances. In run *SF_1700* (Table 5-4), the flux at Sarcobatus Flat was increased from 0 to 1,700 m³/d (the upper end of the estimated range, Table 4-2). Run *PV_60000* increased the influx at Pahranaagat Valley from 27,000 to 60,000 m³/d, again the upper end of the estimated range. These were the only changes made for the respective runs; hydraulic parameters were not changed by corresponding amounts.

SF_1700

The changes in simulated heads between *SF_1700* and Base 3 are very minor. With the exception of Oasis Valley, changes to the discharge fluxes are also minor. The discharge rate in nearby Oasis Valley increased by 5.6 percent, which is approximately 85 percent of the 1,700 m³/d increase in flux at Sarcobatus Flat.

PV_60000

In sensitivity run *PV_60000*, the mean-weighted head in the Pahranaagat Valley residual zone increased nearly 95 m; this is an artifact of not increasing the conductivity of adjoining LCA zones by an equivalent amount. The increase in the mean-weighted head residual was less than 10 m in the remaining 14 residual zones. The largest increases were in the BARR, EYF, SHRG, SHON, and FF zones. With the increased flux across Pahranaagat Valley, discharges increased considerably at Ash Meadows (AM - nearly 47 percent of the increase in Pahranaagat Valley influx) and Alkali Flat (AF - also nearly 47 percent). Flux changes elsewhere were minor.

5.6.1.4 Conductivity Evaluations

Four special-case sensitivity analyses were conducted on specific hydraulic parameters. The run names shown in Table 5-4 were selected to identify the hydrostratigraphic unit evaluated in each model simulation and the hydraulic conductivity zone within each HSU that was changed. For example, run *VCU_ZN2* changed the hydraulic properties of Zone 2 in the Volcanic Confining Unit. The names of the four sensitivity runs and the figures that identify the zone locations for the corresponding HSUs include: *VCU_ZN2* (Figure 4-7); *LCA3_ZN1* (LCA3 has only one zone); *AA_ZN4&5* (Figure 4-3); and *TMA_ZN6* (Figure 4-4). The following discussion summarizes the results for each of the four sensitivity runs.

Table 5-5
Distances Traveled by Particles for Base 3 and
Percentage Changes for Special Case Sensitivity Scenarios
(Page 1 of 4)

Run Name	Test Name	Starting Location	<u><i>Distance Traveled (meters)</i></u>			
			25 years	50 years	100 years	200 years
BASE 3	BOURBON	B	10108	17405	28763	43145
	BULLION	WP	6493	38598	38598	38598
	CLEARWATER	WT	1042	1206	1546	2336
	CORDUROY	WP	11694	19159	29843	73520
	COULOMMIERS	B	950	2468	8000	15473
	CUMARIN	B	6292	11611	20112	65774
	DARWIN	B	4947	32171	32171	32171
	DILUTED WATER	B	10	20	40	81
	HOUSTON	B	5098	38979	42344	44573
	PILE DRIVER	WT	8954	12721	15446	42881
	PURSE	WP	6683	34019	34019	34019
	STRAIT	B	806	4070	11809	19211
	TYBO	WP	30918	30918	30918	30918
			<u><i>Percent Change</i></u>			
			25 years	50 years	100 years	200 years
RECH1.5X	BOURBON	B	39.1	34.1	-5.8	-25.1
	BULLION	WP	345.0	0.2	0.2	0.2
	CLEARWATER	WT	-0.7	7.0	19.2	780.2
	CORDUROY	WP	36.9	31.7	56.4	16.4
	COULOMMIERS	B	68.9	145.1	45.4	203.7
	CUMARIN	B	50.8	47.9	120.1	2.0
	DARWIN	B	389.0	-0.1	-0.1	-0.1
	DILUTED WATER	B	40.0	45.0	45.0	42.0
	HOUSTON	B	456.2	4.7	1.8	0.4
	PILE DRIVER	WT	28.9	12.0	117.6	36.1
	PURSE	WP	240.2	-0.3	-0.3	-0.3
	STRAIT	B	192.4	101.7	55.2	165.1
	TYBO	WP	0.0	0.0	0.0	0.0
RECH0.75X	BOURBON	B	-20.5	-20.5	-19.7	-2.2
	BULLION	WP	-30.5	-14.3	-0.1	-0.1
	CLEARWATER	WT	-25.9	-6.6	-10.9	-17.4
	CORDUROY	WP	-22.2	-17.8	-16.2	-32.3
	COULOMMIERS	B	-29.2	-36.5	-32.4	-27.2
	CUMARIN	B	-25.7	-19.9	-19.1	-43.0
	DARWIN	B	-8.9	-25.2	0.2	0.2
	DILUTED WATER	B	-20.0	-20.0	-20.0	-21.0
	HOUSTON	B	-38.6	-25.6	-3.8	-2.2
	PILE DRIVER	WT	-25.8	-15.0	-8.1	-23.7
	PURSE	WP	-6.3	-18.6	0.2	0.2
	STRAIT	B	-24.2	-44.1	-32.9	-4.5
	TYBO	WP	0.0	0.0	0.0	0.0

Table 5-5
Distances Traveled by Particles for Base 3 and
Percentage Changes for Special Case Sensitivity Scenarios
(Page 2 of 4)

Run Name	Test Name	Starting Location	<i><u>Percent Change</u></i>			
			25 years	50 years	100 years	200 years
RCH_HD0R	BOURBON	B	-0.7	-0.6	0.0	2.9
	BULLION	WP	-2.3	-1.0	-1.0	-1.0
	CLEARWATER	WT	-9.0	-5.7	-0.8	6.7
	CORDUROY	WP	-0.8	-0.6	-0.6	-0.2
	COULOMMIERS	B	-0.5	-1.3	-0.4	-2.7
	CUMARIN	B	-0.5	-0.3	-2.2	-0.3
	DARWIN	B	0.1	-0.3	-0.3	-0.3
	DILUTED WATER	B	0.0	0.0	0.0	0.0
	HOUSTON	B	2.6	15.7	12.8	9.4
	PILE DRIVER	WT	-1.1	0.9	0.3	0.1
	PURSE	WP	0.3	-0.1	-0.1	-0.1
	STRAIT	B	-1.0	-0.4	-1.6	-1.2
	TYBO	WP	-0.2	-0.2	-0.2	-0.2
RCH_HD.3R	BOURBON	B	0.4	0.4	0.1	-1.6
	BULLION	WP	0.2	0.6	0.6	0.6
	CLEARWATER	WT	-5.3	-3.2	-4.1	-5.2
	CORDUROY	WP	0.4	0.3	0.3	0.1
	COULOMMIERS	B	1.2	1.2	0.3	2.8
	CUMARIN	B	0.5	0.3	1.8	0.2
	DARWIN	B	-0.2	0.7	0.7	0.7
	DILUTED WATER	B	0.0	0.0	2.5	0.0
	HOUSTON	B	-4.2	1.1	-1.2	-3.1
	PILE DRIVER	WT	0.3	1.6	1.0	0.4
	PURSE	WP	-0.2	0.1	0.1	0.1
	STRAIT	B	0.4	0.2	0.8	0.7
	TYBO	WP	0.1	0.1	0.1	0.1
RCH_ME	BOURBON	B	40	34	-14	-40
	BULLION	WP	90.9	-1.0	-1.0	-1.0
	CLEARWATER	WT	-1.5	5.9	18.2	862.6
	CORDUROY	WP	37.8	31.2	49.7	15.2
	COULOMMIERS	B	69.8	117.3	44.5	199.4
	CUMARIN	B	22.6	20.6	38.7	-0.7
	DARWIN	B	326.0	-0.8	-0.8	-0.8
	DILUTED WATER	B	30.0	30.0	30.0	29.6
	HOUSTON	B	183.7	17.8	10.3	7.0
	PILE DRIVER	WT	29.5	13.1	149.8	34.2
	PURSE	WP	253.7	-0.5	-0.5	-0.5
	STRAIT	B	193.3	101.7	26.2	120.1
	TYBO	WP	-0.5	-0.5	-0.5	-0.5

Table 5-5
Distances Traveled by Particles for Base 3 and
Percentage Changes for Special Case Sensitivity Scenarios
(Page 3 of 4)

Run Name	Test Name	Starting Location	<i>Percent Change</i>			
			25 years	50 years	100 years	200 years
SF_1700	BOURBON	B	0.1	0.1	0.0	-1.0
	BULLION	WP	-0.8	0.2	0.2	0.2
	CLEARWATER	WT	-8.7	-7.1	-5.3	-3.3
	CORDUROY	WP	0.1	0.1	0.1	-0.1
	COULOMMIERS	B	0.6	0.4	0.1	1.8
	CUMARIN	B	0.3	0.2	1.4	0.0
	DARWIN	B	-0.3	1.4	1.4	1.4
	DILUTED WATER	B	0.0	0.0	2.5	0.0
	HOUSTON	B	-1.0	0.4	0.3	-2.1
	PILE DRIVER	WT	-0.1	1.5	0.8	0.3
	PURSE	WP	-0.2	1.3	1.3	1.3
	STRAIT	B	0.0	0.0	0.1	0.1
	TYBO	WP	0.0	0.0	0.0	0.0
PV_60000	BOURBON	B	-2.5	-1.7	21.4	75.5
	BULLION	WP	0.0	0.0	0.0	0.0
	CLEARWATER	WT	-1.1	-0.7	-0.8	-0.9
	CORDUROY	WP	-2.0	-1.8	-2.3	6.5
	COULOMMIERS	B	-2.1	-4.1	-3.0	-16.1
	CUMARIN	B	-14.4	-5.0	-29.5	-57.3
	DARWIN	B	0.0	0.0	0.0	0.0
	DILUTED WATER	B	20.0	20.0	20.0	17.3
	HOUSTON	B	-0.1	0.1	0.1	0.5
	PILE DRIVER	WT	-3.1	0.5	0.4	19.4
	PURSE	WP	0.0	0.0	0.0	0.0
	STRAIT	B	-1.7	-2.8	-8.9	14.1
	TYBO	WP	0.0	0.0	0.0	0.0
VCU_ZN2	BOURBON	B	1.0	2.6	-11.2	-32.8
	BULLION	WP	0.3	0.1	0.1	0.1
	CLEARWATER	WT	0.3	0.3	0.5	0.9
	CORDUROY	WP	0.7	0.8	4.4	-3.1
	COULOMMIERS	B	3.1	2.6	0.6	12.8
	CUMARIN	B	2.7	4.9	25.9	-17.6
	DARWIN	B	0.0	0.1	0.1	0.1
	DILUTED WATER	B	10.0	15.0	12.5	12.3
	HOUSTON	B	0.4	0.9	0.6	-2.1
	PILE DRIVER	WT	-0.1	2.2	9.2	-3.8
	PURSE	WP	0.0	0.1	0.1	0.1
	STRAIT	B	0.5	0.2	1.8	27.2
	TYBO	WP	0.0	0.0	0.0	0.0

Table 5-5
Distances Traveled by Particles for Base 3 and
Percentage Changes for Special Case Sensitivity Scenarios
(Page 4 of 4)

Run Name	Test Name	Starting Location	<i>Percent Change</i>			
			25 years	50 years	100 years	200 years
LCA3_ZN1	BOURBON	B	0.7	0.9	-4.1	-23.6
	BULLION	WP	2.9	-0.5	1.5	1.5
	CLEARWATER	WT	7.6	9.0	9.0	9.8
	CORDUROY	WP	0.3	0.4	1.0	-3.1
	COULOMMIERS	B	-3.3	-2.1	3.2	51.9
	CUMARIN	B	-12.5	-4.5	-7.1	0.6
	DARWIN	B	-1.3	2.4	2.4	2.4
	DILUTED WATER	B	0.0	0.0	2.5	0.0
	HOUSTON	B	4.2	-19.1	-17.8	-13.2
	PILE DRIVER	WT	-0.2	-2.6	-2.0	-0.6
	PURSE	WP	-1.0	1.1	1.1	1.1
	STRAIT	B	-0.4	-0.2	2.7	10.3
	TYBO	WP	0.7	0.7	0.7	0.7
AA_ZN4&5	BOURBON	B	0.0	0.7	-8.6	-23.8
	BULLION	WP	0.0	0.0	0.0	0.0
	CLEARWATER	WT	-0.8	-0.8	-0.8	-0.9
	CORDUROY	WP	0.3	0.2	0.9	-2.0
	COULOMMIERS	B	7.1	5.1	-2.2	-18.1
	CUMARIN	B	3.7	1.3	14.7	0.9
	DARWIN	B	0.0	0.0	0.0	0.0
	DILUTED WATER	B	630.0	630.0	620.0	591.4
	HOUSTON	B	0.3	0.1	0.1	-0.1
	PILE DRIVER	WT	0.2	3.5	16.8	0.7
	PURSE	WP	0.0	0.0	0.0	0.0
	STRAIT	B	0.6	0.1	0.3	21.9
	TYBO	WP	0.0	0.0	0.0	0.0
TMA_ZN6	BOURBON	B	-2.6	-2.5	-0.1	19.8
	BULLION	WP	-35.4	-3.1	1.4	5.4
	CLEARWATER	WT	-4.4	-1.7	1.9	6.8
	CORDUROY	WP	-2.9	-2.3	-2.4	-3.2
	COULOMMIERS	B	-3.5	-5.5	-1.7	-9.5
	CUMARIN	B	-2.4	-1.7	-10.9	0.1
	DARWIN	B	-9.9	5.9	6.3	6.3
	DILUTED WATER	B	0.0	0.0	0.0	-1.2
	HOUSTON	B	-18.1	-58.4	-11.4	-0.9
	PILE DRIVER	WT	-3.3	-1.1	-1.2	-0.7
	PURSE	WP	17.1	4.1	4.1	4.1
	STRAIT	B	-3.3	-1.4	-6.0	-1.6
	TYBO	WP	-1.9	-0.5	2.3	8.4

VCU_ZN2

In Frenchman Flat, recently interpreted aeromagnetic data suggest that the volcanic rocks are not as continuous as incorporated in the geologic model. This may cause greater hydrologic communication between the AA and the underlying LCA. In this sensitivity run, a small section of the VCU was replaced with parameter values corresponding to the LCA. The effect on heads is minor except in the WYF zone. This change is believed to be due to numerical instability in this area. The change on fluxes was very minor.

LCA3_ZN1

The K_h for LCA3 is significantly lower than for the other carbonate rocks in the model. In run *LCA3_ZN1*, the K_h was increased from 0.05 to 1.0 m/d (0.2 to 3.3 ft/d). The mean-weighted residuals decreased significantly in Western Yucca Flat (-43.1 m), Shoshone Mountain (-21.0 m), and Timber Mountain (-9.4 m), indicating that the low K_h value for LCA3 is necessary to maintain higher heads in these zones. The low conductivity value probably indicates that the LCA3 is not as continuous as represented in the geologic model. The major changes in fluxes were decreases in the discharge at Oasis Valley (nearly 10 percent) and Alkali Flat (22 percent increase). These changes indicate that the reduction in head in the above residual zones moved the location of the water-table divide westward, diverting water from the Oasis Valley system to the Ash Meadows system.

AA_ZN4&5

The values of K_h for the higher conductivity zones of the AA were determined from the calibration and were primarily constrained by the gradient and discharge rates in the Amargosa Desert. In this sensitivity run, the values of K_h for AA(4) (Frenchman Flat) and AA(5) (Yucca Flat) were increased from 11 to 100 m/d. Resulting changes in head were minor except in EYF where the mean weighted residual fell by 7.2 m. The effects on boundary fluxes were very minor.

TMA_ZN6

A conductivity zone was defined at the Black Mountain caldera to determine whether use of lower conductivity values in this area would develop the potentiometric trough present in Area 20 of the NTS. In Base 3, this trough is present. In the current sensitivity run, the values of the K_h s of the volcanics in this zone were increased to those of adjacent HSUs. The effect on heads was significant. Heads in this part of the model decreased by tens of meters (PM, -64 m; TMBR, -32 m; WYF, -26 m; NRTH, -16 m). The simulated water table for this simulation ([Figure 5-19](#)) lacks the potentiometric trough, indicating that lower conductivities near Black Mountain may be an explanation for the trough. With the reduction of head in the north, discharge at Penoyer Valley decreased. This reduction increased the amount flowing beneath the Timpahute Range,

Figure 5-19
Elevation of the Simulated Water Table for the Sensitivity Run
Using Increased TMA(6) Horizontal Hydraulic Conductivity (Episode 3)

resulting in increases in discharge at AF and other areas in the Amargosa Desert. The discharge rate at Oasis Valley also decreased, indicating that there was a redistribution of recharge from the Oasis Valley subbasin into the Ash Meadows and Alkali Flat (Franklin Lake)-Furnace Creek Ranch subbasin. This is apparently due to a slight westward movement of the groundwater divide that is present in the Kawich Range north of Pahute Mesa.

5.6.2 Particle-Tracking Results for Special-Case Sensitivities

A sensitivity analysis was also performed on the effect of the differing modeling assumptions on the distance of particle transport for the Base 3 model. Information is provided in [Table 5-5](#) on the distances traveled in 25 years, 50 years, 100 years, and 200 years for 13 of the 14 particles for the 11 sensitivity runs. The analysis is not presented for the Gum Drop particle because of the numerical instability problems affecting the WYF and SHON residual zones and the resulting erratic particle-tracking results. This discussion will focus on the 25-year travel distance for particles originating on western Pahute Mesa and the 100-year travel distances for the remaining particles. The 100-year travel distance is of interest because transport simulations indicate that concentrations that are high enough to cause concern typically occur in less than 100 years. However, four of the particles originating on western Pahute Mesa reached the discharge area in less than 50 years (BULLION, DARWIN, PURSE, TYBO), with one of the particles (TYBO) discharging in less than 10 years. Therefore, the 25-year travel distances for the western Pahute Mesa particles are used in the sensitivity analysis. These distances are the estimated distance that a conservative particle would move. Tritium and other contaminants will move shorter distances because of attenuation processes.

[Table 5-5](#) also indicates the starting locations for each of the tests. The starting points are at one of four possible locations: the working point; the water table (WT), applicable only for those tests in Rainier Mesa and the Climax Stock (where the working point is located more than two cavity radii above the water table); at the top (T) of a sphere with a radius twice that of the cavity, centered on the working point; or at the bottom (B) of a sphere with a radius twice that of the cavity, centered on the working point. In no case was the travel rate greatest at two cavity radii above the water table; therefore, “T” is not used as a starting point location.

[Table 5-5](#) presents particle distances traveled for Base 3, and the percentage change in travel distance between the Base 3 and sensitivity runs for each of the 11 special-case scenarios. For Base 3, when a particle discharged at an earlier time than the time period displayed in the column header, the travel distance to the point of discharge is recorded in the column (and the travel distance remains constant in subsequent columns for that particle). This occurred for four of the particles: those originating at BULLION, DARWIN, PURSE, and TYBO. Unless the point of

discharge changes considerably between the base run and the sensitivity run, the percentage change will be small for all times after which the particle has discharged.

In several cases, a relatively small change in the model produced a large change in the travel distance. This generally indicates that the particle velocity increases as the particle moves downgradient, and that the model change caused the particle to enter the higher velocity zone earlier. A good example is the 25-year travel distance for DARWIN for the *Rech1.5x* and *Rech0.75x* cases. When the recharge and conductivities were increased by a factor of 1.5, the 25-year travel distance increased by nearly 400 percent. Conversely, when a factor of 0.75 was used, it decreased by only 9 percent.

Rech1.5x

Increasing recharge and conductivities by a factor of 1.5 had significant impacts on the travel distances. For most particles, the 50-percent increase caused a large increase in travel distance. Doubling or tripling the travel distance at specified times was common. It is interesting to note that the percent change in distance can vary widely at different times, resulting from movement of particles through HSUs of different conductivities and effective porosities. Thus, those particles which were less sensitive to changes after one time period may have significantly greater sensitivities at other times. For example, the HOUSTON particle shows a very large increase in the 25-year travel distance over Base 3, but only small increases at longer times. This particle enters the VCU sometime between 25 and 50 years. The VCU has a higher effective porosity than the upgradient volcanic units, and the resultant velocity and change in travel distance with respect to Base 3 is small. The BOURBON particle has an interesting behavior. Its travel distance increases for 25 and 50 years, but decreases at 100 and 200 years, relative to the Base 3 case. The increase in recharge may have changed the path of the particle into an HSU with either lower conductivity or higher effective porosity. Evaluating the causes of the changes in velocities requires evaluating the pathway in detail and determining how the pathway changes with changes in the model.

Rech0.75x

Travel distances are less sensitive to a reduction in recharge and conductivities than to increases in these parameters. This is, in part, because there can not be a reduction in travel distance greater than 100 percent. However, in no case did the travel distance decrease by 50 percent or more; however, for increases in these parameters doubling of travel distance was common. Typically, the reduction in travel distance was approximately the same as reduction in recharge.

Rch_hd0r and Rch_hd.3r

These sensitivity runs involved changes to the amount of recharge redistributed from upland regions to downgradient drainages; the overall rate of recharge remained the same as for Base 3. Recharge redistribution has only minor effects on particle movement.

Rch_me

This run evaluates the impact of using the Maxey-Eakin recharge model which results in approximately one-third more recharge to the model (especially at higher elevations), less recharge at lower elevations, and no redistribution of recharge along streams in the NTS and nearby areas. For particles starting on Pahute Mesa, the approximately 33 percent increase in recharge increases 25-year travel distances from 91 (BULLION) to 326 (DARWIN) percent. These results are similar to those in the *Rech1.5x* run, although the percentage increase is smaller for all particles except PURSE. This is probably related to the greater increase in average heads for the TMBR residual zone than for the PM zone. The PURSE particle, starting further from Timber Mountain than the other particles, would be less affected by the reduction in gradient. The 100-year travel distances for particles starting in Yucca Flat increase by a smaller amount and, in some cases, actually decrease. The PILE DRIVER particle travels 150 percent further, while the travel distances for other particles increase by less than 50 percent. The greater sensitivity for PILE DRIVER likely results from its starting location at the northern end of Yucca Flat. The quicker that it can move from the low-flux area of Yucca Flat into the area where flow from the east occurs, the further the particle will move. Other particles experience this effect at earlier times.

SF_1700

Increasing the influx from Sarcobatus Flat from 0 to 1,700 m³/d had minimal impact on travel distances. Twenty-five year travel distances for Pahute Mesa particles decreased, but only by a small amount. The 100-year travel distance for the CLEARWATER particle decreased about 5 percent, and those of DILUTED WATER and CUMARIN increased 2.5 and 1.4 percent, respectively.

PV_60000

Increasing the influx from Pahranaagat Valley from 27,000 to 60,000 m³/d affected Yucca Flat and Frenchman Flat particles in a mixed manner, but had little effect on other particles. The 100-year travel distances for BOURBON and DILUTED WATER particles increased, while those for CUMARIN and STRAIT declined, by 5 percent or more. BOURBON and DILUTED WATER particle paths are the two easternmost in Yucca and Frenchman Flats, while CUMARIN and STRAIT particles are the two westernmost paths. The increase in influx would be expected to

result in more westerly paths for these particles. The decrease in travel distance for CUMARIN and STRAIT may be caused by their moving into the AA earlier and the reduction in velocity associated with the increase in effective porosity.

VCU_ZN2

This sensitivity run evaluated the impact of a different interpretation of the continuity of the VCU beneath Frenchman Flat. The DILUTED WATER particle was likely to show an effect because of its proximity to the area where the VCU was replaced by LCA, and it did. Interestingly, Yucca Flat particles were also affected. The travel distances of the DILUTED WATER particle increased from 10 to 15 percent, depending on the time. The 100-year travel distance of CUMARIN increased nearly 26 percent, although its 200-year travel distance decreased 18 percent. The 100-year travel distance for PILE DRIVER increased 9 percent. The explanation is not obvious, but may be a function of the location of the path of the particle relative to the VCU/LCA contact. These particles move in and out of these two HSUs. A slight downward movement of the path could decrease the amount of time the particles spent in the VCU. These effects are probably artifacts of the model; however, the increases in travel distance for DILUTED WATER are more reliable, and the overall change in travel distance remains small.

LCA3_ZN1

This run evaluated the effects of increasing the conductivity of LCA3. The resulting decrease in hydraulic head in WYF and SHON residual zones supports the hypothesis that the LCA3 must have a low net hydraulic conductivity, indicating that the unit is not as continuous as represented in the geologic model. When higher values of K_h are used, the effects include a slight increase in the 25-year travel distance for the HOUSTON particle, but lower travel distances at longer times, possibly because of an earlier move into the VCU. The movement of the CLEARWATER particle was also faster.

AA_ZN4&5

In this run, the K_h of AA(4) and AA(5) (Yucca Flat and Frenchman Flat, respectively) were increased from 11 to 100 m/d (an 800 percent increase). The travel distance of DILUTED WATER (which travels entirely in AA(5) for hundreds of years) increased approximately 600 percent, but was less than 1 km at 200 years. Particles in Yucca Flat were also affected, but to a much smaller degree. The 100-year travel distances for CUMARIN and PILE DRIVER increased approximately 15 percent. The 100-year travel distance for STRAIT was essentially unchanged, but its 200-year distance was 22 percent higher than Base 3. None of the latter three particles travels through AA(4) or AA(5). The impact on the particle travel is probably related to the path length through the VCU, and is difficult to interpret or predict.

TMA_ZN6

This run removes the reduced conductivity zone incorporated in the model that is associated with the Black Mountain caldera. Because this zone now has the same conductivities as adjacent volcanic HSUs, the area across which the flux moves is greater, and the resulting flow rates in the Pahute Mesa testing area are decreased. This is supported by particle-tracking results for three of the four western Pahute Mesa particles (BULLION, DARWIN, and TYBO). However, the 25-year travel distance for the PURSE particle increased by 17 percent. The increase in the travel distance for the PURSE particle probably results from its proximity to the Black Mountain zone, and the likely inclusion of the lower Base 3 conductivity values in the calculated transmissivity value for the model cell in which the PURSE particle originates. Changes in travel distances also occurred for several Yucca Flat particles, probably related to a minor shift in the path relative to the VCU/LCA contact.

Overall, the largest effects on travel distances were related to the recharge rate and the corresponding values of K_h used in the model. Increases in these parameters caused significant increases in travel distances. We consider the discharge values obtained in the Base 3 model to be a better representation of the discharges occurring from the groundwater system than either the *Rech1.5x* or *Rch_me* cases based on currently available data, but cannot rule out that discharge rates may be higher than those incorporated in the Base 3 model. For example, the current estimates for discharge at Oasis Valley range from 17,000 to 27,000 m³/d. The *Rech1.5x* and *Rch_me* runs both result in simulated discharges of approximately 38,000 m³/d, which are significantly higher than current estimates.

Assumptions regarding the redistribution of recharge appear to have minimal impact of particle-tracking calculations within the saturated zone. Increasing the inflow at Sarcobatus Flat caused minor effects on travel distances. However, increasing the inflow from Pahranaagat Valley caused the particles from Yucca and Frenchman Flats to move further to the west. Decreasing the flux across Pahranaagat was not investigated, but this might allow particles to discharge at Ash Meadows.

Changing the values of hydraulic conductivity in the Black Mountain area caused significant changes in travel distance for particles starting on Pahute Mesa, but had minimal effect elsewhere. In Frenchman Flat, movement of the DILUTED WATER particle is affected more by the hydraulic conductivity of the valley-fill materials than by the continuity of the VCU beneath the basin; in all cases evaluated, however, its travel distance was limited.

5.6.3 Sensitivity Analyses of Hydraulic Parameters

The sensitivity of model heads and fluxes to hydraulic parameters were evaluated by systematically changing individual hydraulic parameter values from those in Base 3. All horizontal hydraulic conductivity values were increased by 100 percent and decreased by 50 percent over Base 3 values, and the depth-decay coefficients (λ , **8**) were increased and reduced by 10 percent over Base 3 values. Sensitivity testing during sequence 2 indicated a general insensitivity to the anisotropy value, K_v , so those cases were not run for the present model. There are 58 different K_h parameters and 58 individual **8** parameters, resulting in 116 sensitivity runs with increased parameter values and an equal number of sensitivity runs with decreased values. A FORTRAN program was written to sequentially vary the parameter values, and batch files were used to control execution of all programs required for the remaining three steps of the sensitivity analyses.

The convention used in naming the sensitivity run provides information on the parameter type (K_h and **8**), the HSU identifier, and the HSU zone number, if applicable (see [Section 4.7](#) for identification of zoned HSUs). For example, $K_{h_LCA}(3)$ is the horizontal hydraulic conductivity parameter for Zone 3 of the LCA. It should be recalled that changing K_h and **8** affect both the transmissivity and V_{cont} in the model.

The mean weighted residual and RMS of the head residuals for each of the fifteen residual zones ([Figure 4-1](#)) were recorded for each run, as were the boundary fluxes for the ten different head-dependent flux areas. These data were then used to calculate the changes in these values between the base case and the sensitivity runs. [Table H-1 \(Appendix H\)](#) presents the changes in the mean weighted residual (between the sensitivity run and the base case) per residual zone as a function of the 100 percent increase and 50 percent decrease in the K_h parameter values and the 10 percent increase and decrease in the **8** parameter values. Changes with absolute values greater than or equal to one meter are shaded. A positive change indicates a general increase in water levels within the zone. [Table H-2](#) presents the *percentage* change in the RMS of the weighted head residuals per zone for the same percentage changes in the parameter values listed above. A positive change indicates an increase in the RMS; shading indicates a change with an absolute value greater than or equal to 10 percent. The percentage changes in boundary flux rates between the calibrated model and the sensitivity runs are provided in [Table H-3](#). Positive values indicate an increase in the recharge or discharge flux.

The following discussion will first evaluate the effects of parameter changes on head sensitivities within each of the individual 15 zones, followed by a discussion on the effects of the sensitivity runs on fluxes. This is intended to provide insight into the parameters that have the greatest

control on model head and flux results. Finally, the sensitivity of pathlines and travel distances to changes in the parameters will be discussed.

5.6.3.1 Head Sensitivities Within Residual Zones

This section presents the mean head sensitivities, or responses, to either increasing the K_h parameters by a factor of 2, or decreasing the **8** values by 10 percent. Both of these changes result in higher transmissivities, and therefore have similar effects on simulated heads or boundary fluxes. Following each parameter discussed in the text is a sign in parentheses; the sign indicates the direction of change in the mean head or flux value with respect to a change in either the K_h or **8** value. If the sign is positive, the head or flux is said to have a positive sensitivity to the modeling parameter (e.g., an increase in the modeling parameter causes an increase in the mean head or flux for that sensitivity run). Conversely, if a decrease in the parameter causes an increase in the mean head or flux, or an increase in the parameter causes a decrease in the mean head or flux, then the head or flux is said to have a negative sensitivity to the parameter. The parameters are listed in order of decreasing magnitude of the sensitivity, based on either an increase in K_h or decrease in **8**. These changes were used because they both result in higher transmissivities, and thus have similar effects on simulated heads or boundary fluxes. Changes in the opposite direction could result in a higher magnitude of sensitivity.

Many of the results discussed in the following text indicate that increases in conductivity values for certain HSUs decrease heads in residual zones in the vicinity or upgradient of those HSUs. This is because downgradient discharge areas (e.g., Death Valley, Amargosa Desert, and Ash Meadows) control heads at the terminal points in the model. If upgradient conductivities are increased and the recharge flux is held constant, then upgradient hydraulic gradients will have to decrease to maintain mass balance, and the corresponding hydraulic heads will decrease. Although the tables contain results from varying the depth-decay parameters, they will not generally be discussed. Observations concerning an increase in K_h are generally valid for a decrease in **8**, as both changes increase HSU transmissivities.

Residual Zones

Northern Area (NRTH)

The conductivity parameters having the greatest impact on heads in the northern part of the model area are the K_h s of AA(1) (-), VU(1)(-), TC(1)(-), LCA(5)(-), and TMA(1)(-). The **8**s of these parameters also affected heads, with a decrease in **8** lowering heads. Changes in three other parameters (LCCU(1), LCA(7), and LCA(8)) also resulted in a greater than 1-m magnitude change in the mean weighted residual. In most cases, the change in the mean was less than

5 meters. The conductivity parameters with the greatest effect on simulated heads are those that are in the northern half of the modeled area and those that control the gradient between the recharge areas in the north and the discharge areas. Decreasing the value of K_h for AA(1) would have raised heads in the NRTH zone and decreased the RMS, but would have resulted in a poorer fit in the PAHR, SHRG, and FARM zones.

Oasis Valley (OASI)

The simulated heads in the Oasis Valley area are most sensitive to changes in the K_h s of LCCU(3)(-), VA(3)(-), VCU(1)(+), and AA(6)(-), and to the δ s of these same zones. The rocks with negative sensitivities to changes in K_h are present within the residual zone. Increasing the transmissivities of these zones reduces gradients and hydraulic heads in the zone. The VCU(1) is part of the barrier between Timber Mountain and Yucca Mountain. Increasing the transmissivity of these rocks lowers heads in the Timber Mountain area as well as in the Oasis Valley discharge area, as indicated by a reduction in the discharge rate. The increase in the average head within the residual zone resulted from an increase of heads in eastern Crater Flat due to the increased flux crossing the LCU barrier to the north.

Pahute Mesa (PM)

The simulated heads on Pahute Mesa are most sensitive to changes in the K_h s of TC(1)(-), TMA(1)(-), TMA(4)(-), VU(3)(-), and TMA(3)(-), and to their respective δ s. All the sensitivities of these K_h parameters are negative, as would be expected for rocks within or a short distance downgradient from the zone. The simulated heads were less sensitive to changes in the properties of deeper rocks beneath Pahute Mesa, presumably because of their lower hydraulic conductivity and their more limited areal extent. Heads were also sensitive to the K_h of VU(1)(-). Increasing this parameter appears to cause a relative redistribution of flowpaths in the north from the western part of the model to the eastern part, resulting in greater flux to Death Valley, slightly increased heads in the eastern residual zones, and increased discharge fluxes at the Ash Meadows and Amargosa Desert discharge areas. This suggests a slight movement of the groundwater divide beneath the Kawich Range westward, which decreases discharge to Oasis Valley.

Barrier (BARR)

This zone represents the high gradient area northeast of the NTS. The simulated heads in this zone are affected most by changes in the K_h s of LCA(1)(-), AA(2)(-), LCA(4)(-), and LCA(2)(-), and in their δ s. The sensitivity to changes in LCA(1), LCA(4), and LCA(2) is due to their positions between the BARR zone and the major discharge areas and the reduction in horizontal gradient caused by increasing the K_h of these HSUs. The effect of increasing K_h of AA(2), the alluvial zone located in Ash Meadows and nearby discharge areas, is to decrease the vertical

gradient needed for the water to flow from the underlying LCA to drain cells located in areas dominated by AA(2). This reduces the head in the LCA, causing a decline in heads in the BARR zone, as well as in most of the model.

Western Yucca Flat (WYF)

The simulated heads in western Yucca Flat behave erratically. This behavior is associated with the process used to simulate rewetting of the cells in this area. A high vertical gradient occurs across the UCCU, and the success of the model in rewetting cells that dry up during the iterative model process appears to determine the value of the residuals. In sequence 2, the model was specifically calibrated to result in approximately equally weighted residuals in WYF and EYF. This resulted in higher simulated heads throughout Yucca Flat, which minimized the numerical instability associated with rewetting cells in WYF. During sequence 3, the heads in eastern Yucca Flat were more accurately simulated than in sequence 2 because of the importance of gradients beneath and flow paths from this area. This resulted in a good fit to EYF heads, but resulted in the inconsistent results noted above.

Eastern Yucca Flat (EYF)

The simulated heads in eastern Yucca Flat were most sensitive to the K_h s of LCA(1)(-), AA(2)(-), LCA(4)(-), and LCA(2)(-), and their **8**s. These HSUs are within or downgradient from the EYF zone. Interestingly, the heads are not very sensitive to the properties of the volcanic rocks (HSUs VA(1) and VCU(1)), or of AA(4). This is because of the low flux in Yucca Flat. There were low, positive sensitivities to the properties of the rocks that control underflow into Yucca Flat, such as LCCU(1), UCCU, and several volcanic HSUs, and to parameters that affect hydraulic heads north of Yucca Flat, such as LCA(5) and LCA(8).

Shoshone (SHON)

Simulated water levels near Shoshone Mountain, CP Basin, and Calico Hills are most affected by the K_h s of LCA3(-), AA(2)(-), VCU(1)(-), UCCU(-), LCA(1)(-), and LCA(2)(-), and to the **8**s of VA(1)(+) and VCU(1)(+). These HSUs either affect the head in the LCA in this area or the heads in units overlying the UCCU. It appears that decreasing the value for K_h of LCA3 would provide the greatest improvement in hydraulic heads in this area; however, the simulated value was already two orders-of-magnitude lower than for other carbonate rocks in this area, and further reduction did not seem prudent.

Death Valley (DV)

The simulated heads in Death Valley are most affected by the K_h s of LCA(9)(+), AA(2)(-), LCA(4)(+), LCCU(3)(+), and TSDV(2)(-). The parameters with negative sensitivities affect the ease with which water can move to the drain cells in Death Valley, and therefore also affects the gradients. Increasing K_h of LCA(9), while decreasing the gradient across the southeastern end of the Funeral Mountains, increases the discharge to Death Valley and thus increases gradients and heads in the DV zone. Increasing LCA(4) reduces the discharge in Ash Meadows and Alkali Flat, while increasing LCCU(3) decreases the discharge at Oasis Valley; both result in an increased discharge flux at Death Valley.

Lower Carbonate Aquifer (LCA)

The lower carbonate zone comprises the Amargosa Desert (excluding the Amargosa farm area), Jackass Flat, and a large area east of the NTS underlain by the LCA. The K_h parameters with the greatest effect on simulated heads are VA(1)(-), VCU(1)(+), AA(2)(-), VA(3)(-), LCA(9)(-), and LCA(4)(-). The greater effect caused by VA(1) and VCU(1) relative to the properties of the LCA results from the higher simulated gradient in western Jackass Flat and at Yucca Mountain in the volcanic rocks overlying the LCA. Increasing the K_h of VA(1) lowers simulated heads in this area because a lower gradient is needed to transmit the water moving through this area. On the other hand, increasing the K_h of VCU(1) allows more water to move from the Timber Mountain area and increases the gradient in the VA within the LCA residual zone. The effect observed for AA(2) was discussed above (BARR zone). The properties of the LCA are less important in controlling heads because of the higher K_h values used for these rocks and the resulting low gradient. Reducing the gradient further by increasing the K_h of LCA(1), for example, has little effect on simulated heads.

SW. of Pahrnagat Valley (PAHR)

This zone covers the eastern part of the model and extends from the northern part of the Sheep Range northward to the boundary with Pahrnagat Valley. It includes only five measurements of hydraulic head from the northern end of the zone. Simulated heads in this zone are quite sensitive to the K_h of LCA(8)(-) and LCCU(2)(-), and moderately sensitive to K_h of LCA(1)(-). LCA(8) is an HSU that overlaps the PAHR residual zone. It has a lower K_h than the LCA to the west because of the need to simulate a higher gradient in this area to match the PAHR zone heads and the gradient believed to exist in Desert Valley. LCCU(2) represents the shallow LCCU present in the Sheep Range; increasing the conductivity of this zone decreases heads west of Pahrnagat Valley. The 8 values that affect the heads the greatest are those for LCA(8)(+) and LCCU(2)(+).

Spring Mountains (SPMT)

The simulated heads for the Spring Mountain zone are most sensitive to the K_h s of LCA(3)(-), AA(1)(-), LCA(6)(-), LCA(1)(-), and LCCU(2)(-). LCA(3) is the zone along the Las Vegas Valley shear zone; a low conductivity for this zone was needed to develop the gradient observed across the shear zone. The sensitivity to the K_h of AA(1) may be related to the averaging of properties that occurs when the geologic model is mapped into the flow model and the short north-south dimension of AA(3). Heads in the SPMT zone are not very sensitive to the K_h of AA(3), at least to a doubling of its value. LCA(6) is the LCA zone that is approximately coincident with SPMT, and that largely determines the gradient in the SPMT zone.

Sheep Range (SHRG)

Simulated heads near the Sheep Range are sensitive to the K_h s of LCA(1)(-), LCCU(2)(-), and LCA(3)(-), and to their values of **8** (positive sensitivity). The sensitivity to LCA(1) results from the large size of the LCA zone, and the constraints placed on upgradient heads in the zone due to the head-dependent boundary conditions in the discharge areas. The sensitivity of heads to the K_h s of the LCCU(2) and LCA(3) results from their relatively low conductivity and their location relative to the recharge in the Sheep Range and Spring Mountains.

Timber Mountain (TMBR)

Heads in the Timber Mountain area are sensitive to the K_h s of VCU(1)(-), VU(3)(-), TMA(3)(-), TMA(4)(-), VA(1)(+), TMA(1)(-), and LCCU(1)(-). The properties of VCU(1), VU(3), and LCCU(1) affect the gradients downgradient from the Timber Mountain area and, thus, the heads near Timber Mountain. The properties of TMA affect the gradient within the TMBR zone and affect heads at the northern edge of the zone. The K_h of VA(1) is the only one in the above list with a positive sensitivity. Increasing this parameter apparently increases the movement of water through the Timber Mountain area, resulting in an increase in gradient. The **8** parameters with the greatest influence are VCU(1)(+), TMA(1)(+), TMA(3)(+), TMA(4)(+), and TMA(2)(+).

Amargosa Farm Area (FARM)

The Amargosa Farm area was designated as a separate zone from the LCA to remove the influence of the high number of wells in this area from the LCA residual statistics. Heads are most sensitive to the K_h s of LCA(9)(-), AA(2)(-), LCCU(3)(-), LCA(4)(-), LCA(2)(-), and VCU(1)(+), though the sensitivities are relatively low in all cases. The K_h s of LCA(9) and LCCU(3) affect the gradient into Death Valley and affect simulated water levels in the Amargosa Desert. The sensitivity to the K_h of AA(2) was discussed above (BARR). The FARM residual zone is within the area covered by LCA(4), so that the heads in the farm area are lowered when the K_h of LCA(4) is increased. Increasing the K_h of LCA(2) decreases the flow through Jackass

Flat and the farm area, so that a lower gradient results in the southern Amargosa Desert. Lastly, the positive sensitivity to increases in K_h of VCU(1) is due to the resulting increase in flow across the barrier north of Yucca Mountain. Heads have a positive sensitivity to the K_h of LCA(8). Increasing this parameter lowers heads at Penoyer Valley resulting in lower discharge rates. The additional water moves toward the downgradient part of the system, resulting in higher gradients and higher heads.

Frenchman Flat (FF)

The mean weighted residuals in Frenchman Flat are most sensitive to K_h s of AA(2)(-), LCA(4)(-), LCA(2)(-), LCA(1)(-), and AA(6)(-), and to the δ s of LCA(1)(+), LCA(2)(+), LCA(4)(+), and AA(2)(+). These HSUs are all present downgradient from Frenchman Flat and affect the gradient between Frenchman and the discharge area. Heads have a positive sensitivity to K_h of LCA(8)(+) and LCA(5)(+). Increasing their values decreases the discharge at Penoyer Valley and allows more water to flow through the LCA, which increases the gradient within the LCA.

5.6.3.2 Sensitivities of Boundary Fluxes

Table H-3 provides the percentage change in boundary fluxes due to changing the hydraulic conductivity parameters by factors of 2 and 0.5, and the depth-decay coefficients by factors of plus and minus 10 percent. A positive increase indicates an increase in the absolute value of the flux. The fluxes for Pahranaagat Valley and Pahrump Valley are positive, meaning into the modeled area; all others are negative (discharge from the modeled area).

Discharge Areas

Death Valley (DVal)

The most significant parameters affecting the discharge from Death Valley are the K_h s for LCA(9)(+), LCCU(3)(+), LCA(4)(+), and TSDV(2)(+). A significant part of the water passes through LCA(9), LCCU(3), and TSDV(2) to reach the Death Valley discharge area, so that increasing their hydraulic conductivity clearly allows more water to discharge in this area. Also, increasing LCCU(3) allows more water to pass through the LCCU barrier at Beatty, making more water available to flow to Death Valley. Increasing the K_h of LCA(4) decreases the discharge in Alkali Flat (northeast of Ash Meadows) and Ash Meadows by increasing the flow beneath Jackass Flats, allowing more water to discharge in southern Amargosa Desert and Death Valley.

Oasis Valley (OV)

The discharge rate at Oasis Valley is most sensitive to the K_h of VCU(1)(-); it is much less sensitive to K_h s of VU(3)(-), LCCU(1)(-), and LCCU(3)(-). These units are part of the barrier

that extends from the Belted Range southwestward to Bullfrog Mountain. Increasing the conductivity of these units increases movement across the barrier and lowers heads upgradient of it. VU(3) also affects gradients north of Beatty and the simulated discharge.

Amargosa River (Ariv)

Because of the low discharge into the Amargosa River, a small change in the discharge flux appears as a large percentage change. The K_h parameters that caused more than a 20 percent change when doubled are LCA(9)(-), AA(6)(-), LCCU(3)(-), LCA(4)(+), AA(2)(+), and TSDV(2)(-). Increasing LCA(9), LCCU(3), and TSDV(2) decreases the gradient between the Amargosa Desert and Death Valley and reduces heads at the Amargosa River discharge area. In fact, doubling LCA(9) drops heads below the specified drain elevation, causing discharge to cease. Increasing the K_h of LCA(4) allows more flow from the east through Rock Valley and Jackass Flat, causes a reduction in discharge at Ash Meadows and Alkali Flat, and increases discharge at the Amargosa River and Franklin Lake discharge areas. The Amargosa River discharge area overlies AA(2) so that making AA(2) more permeable results in an increase in discharge rate.

Ash Meadows (AM)

The discharge at Ash Meadows is most sensitive to changes in LCA(9)(-), AA(6)(-), LCCU(3)(-), and LCA(2)(+). As with Amargosa River, increasing LCA(9) and LCCU(3) increases flow into Death Valley and lowers heads in the Amargosa Desert. AA(6) affects the gradient above Franklin Lake and the heads in the Ash Meadows discharge area. Increasing LCA(2) diverts flow from Rock Valley and Jackass Flat and increases the Ash Meadows discharge.

Franklin Lake (FL)

The discharge at Franklin Lake is sensitive to the K_h s of AA(6)(+), AA(1)(-), AA(2)(+), and LCA(9)(-). The drain cells for Franklin Lake coincide with both AA(6) and AA(2) so that increases in the conductivities of these HSUs would be expected to increase the discharge. AA(6) is present along Furnace Creek Wash between Death Valley and the Franklin Lake discharge area. Increasing its conductivity will divert some of the water from Franklin Lake to Death Valley and lower water levels at Franklin Lake.

Alkali Flat (AF)

The simulated discharge at Alkali Flat is sensitive to many conductivity parameters. These include LCA(4)(-), AA(2)(-), and AA(6)(-). Doubling any of these decreased the discharge to zero. Increasing LCA(2)(-) and LCA(9)(-) also caused significant reduction in discharge. Decreasing the conductivities of some of these same parameters by 50 percent more than doubled the

simulated discharge at Alkali Flat. This behavior indicates that the simulated water level is slightly above the drain elevation assigned to these boundary cells. Parameters with positive sensitivities include VU(1)(+), LCA(5)(+), and LCCU(1)(+). Increasing the K_h of the first two decreased the discharge at Penoyer Valley and diverted that water toward Ash Meadows, resulting in higher discharge at Alkali Flat. The positive sensitivity to LCCU(1) (and also VCU(1)(+)) is probably related to the general increase in flow across the barrier extending from the Groom Range to Beatty.

Penoyer Valley (PV)

With only one exception (K_h of AA(4)(+)), increasing any of the K_h parameters resulted in a decrease in discharge at Penoyer Valley. This reflects the location of the discharge area near the upgradient end of the modeled groundwater system. The K_h parameters that have the greatest effect on simulated discharge at Penoyer Valley are LCA(8)(-), LCA(5)(-), VU(1)(-), and AA(1)(-). LCA(8) was defined to simulate a higher gradient area near Desert Valley, and has a large effect on simulated water levels at the Penoyer Valley discharge area which is located at the upgradient end of this zone. The positive sensitivity calculated for AA(4) may not be indicative of the behavior of the system, but of computational or round-off error; the increase in discharge was only 0.01 percent.

Indian Springs (IS)

Discharge at Indian Springs is most sensitive to the K_h of LCA(3)(-), AA(1)(-), LCCU(2)(-), LCA(1)(-), and AA(3)(-). These HSUs are all involved in the movement of water from the Spring Mountains into the major part of the flow system. LCA(3) is the zone defined along the Las Vegas Valley shear zone. It is important in establishing the gradient observed in this area and in raising heads high enough for simulated discharge to occur at Indian Springs. Doubling the K_h of this zone reduced the discharge nearly to zero. The discharge is less than one-fourth as sensitive to the remaining parameters.

Pahrump Valley (PP)

The modeled inflow from Pahrump Valley is low because of the low conductivity of LCCU(1). Doubling the K_h of LCCU(1) increased the underflow by approximately 60 percent, indicating the control the LCCU has on this flux rate. The flux is also sensitive to the K_h of AA(6)(+); this unit overlies the LCCU along the model boundary.

Eagle Mountain (EM)

The discharge past Eagle Mountain is most sensitive to changes in K_h s of AA(6)(+), AA(1)(+), and LCA(4)(+). The discharge has a positive sensitivity to the K_h s of AA(6) and LCA(4) because

these HSUs are present at the boundary and are used to calculate the GHB conductances for these boundary cells. AA(1) is present between an area of recharge (Greenwater Range) and the boundary cells. Increasing the K_h of AA(1) diverts water that would otherwise move to Death Valley at lower values of K_h .

5.6.3.3 Particle-Tracking Results for Hydraulic Parameter Sensitivities

Because a major goal of the regional flow modeling effort was to provide information to facilitate analysis of contaminant transport from the weapons testing areas, it is important to analyze the effects of the hydraulic parameter sensitivity changes on transport distances and direction. This was done by running MODPATH 116 times using MODFLOW head and flux data from the 116 separate sensitivity runs. The runs included the 100 percent increase in horizontal hydraulic conductivities and the 10 percent decrease in the depth-decay coefficients. For each of the runs, the transport distances at times of 25 years, 50 years, 100 years, and 200 years from start of test for 13 of the 14 particles were compiled. Results from Gum Drop were not used because of the numerical sensitivity of the model in the Shoshone Mountain area and the resulting impacts on particle tracking results. These data, and the corresponding distance for Base 3, are listed alphabetically by testing location in [Table I-1](#) of [Appendix I](#).

The information contained in [Appendix I](#) is unwieldy without some form of data reduction. To facilitate evaluation of the information, the travel distances were tabulated, and the percent change in distance between Base 3 and the sensitivity runs were calculated. All parameters with percent differences greater than or equal to plus or minus 10 percent of Base 3 values have been grouped by testing location and regional area and are listed in [Table 5-6](#). Positive sensitivities are listed first from largest to smallest positive value. Parameters that fall within this category result in longer transport distances than particles associated with the base case. Negative sensitivities are listed second from largest negative value to smallest negative value. Parameters that fall within this category result in shorter transport distances than travel distances for the Base 3 run.

The 25-year (western Pahute Mesa) and 100-year (others) transport distances for the 116 sensitivity runs, plus the base case, are plotted for the 13 testing locations in [Figure 5-20](#). The Base 3 particle pathlines ([Figure 5-15](#)) are also shown. The stars represent the Base 3 locations after 25 or 100 years. The particles starting on western Pahute Mesa are calculated to move quickly off the NTS. Those from other testing areas remain on the NTS for a much longer time period, though the path for BOURBON approaches the eastern boundary. CLEARWATER and DILUTED WATER travel only short distances.

Table 5-6

Conductivity Parameters that Caused More Than a 10 Percent Change in the 25- or 100-Year Travel Distance

<i>Parameters with Positive Sensitivity*:</i>													
<i>Test Name</i> <i>Area</i>	Darwin Pahute Mesa	Purse Pahute Mesa	Bullion Pahute Mesa	Tybo Pahute Mesa	Houston Pahute Mesa	Clearwater Rainier Mesa	Pile Driver Climax Stock	Bourbon Yucca Flat	oulommier Yucca Flat	Corduroy Yucca Flat	Cumarin Yucca Flat	Strait Yucca Flat	Diluted Water Frenchman Flat
	KH-TMA(1) KH-TMA(4) KH-TMA(3)	KH-TMA(1)	KH-TC(1) KH-TMA(4)		KH-TC(1) KH-TMA(4) KH-TC(4) KH-TMA(3)		KH-VU(1) KH-LCCU(1) KH-BCU(1) KH-LCA(1) KH-VA(3) KH-TSDV(2)		KH-VU(1)	KH-VU(1)	KH-VU(1) LD-LCA(1) KH-AA(1) KH-LCCU(1) KH-LCA(2) KH-BCU(1)	KH-VU(1) LD-LCA(1) KH-AA(1)	KH-AA(5) LD-LCA(1)
<i>Parameters with Negative Sensitivity*:</i>													
<i>Test Name</i> <i>Area</i>	Darwin Pahute Mesa	Purse Pahute Mesa	Bullion Pahute Mesa	Tybo Pahute Mesa	Houston Pahute Mesa	Clearwater Rainier Mesa	Pile Driver Climax Stock	Bourbon Yucca Flat	oulommier Yucca Flat	Corduroy Yucca Flat	Cumarin Yucca Flat	Strait Yucca Flat	Diluted Water Frenchman Flat
	LD-TMA(4) LD-TMA(1)	LD-TMA(1)	LD-TC(1) KH-TMA(1)		LD-TC(1) KH-BAQ(1) KH-TMA(1)		LD-VU(1) LD-LCA(1) LD-LCCU(1) LD-BCU(1)	KH-VU(1)			LD-VU(1) KH-LCA(8) LD-LCCU(1) LD-TMA(1) LD-AA(1)	LD-VU(1)	KH-LCA(1) LD-AA(5)

*Sensitivities decrease from top to bottom in each list.

Notes - For Pahute Mesa particles, the sensitivities were evaluated for the 25-year travel distance. For other particles, the 100-year travel distance was used.

The TYBO particle has discharged in less than 25 years and does not show a sensitivity at 25 years.

Figure 5-20
Locations of Particles After 25 Years (Pahute Mesa Shots) and 100 Years (All Others),
for the Base Case and the Hydraulic Parameter Sensitivity Runs

The calculated travel distances are for particles moving at the rate that the groundwater moves. However, since retardation of contaminants will occur as a result of sorption and ion exchange reactions, precipitation reactions, diffusion into lower conductivity materials, and radioactive decay, the contaminants will move more slowly. Assuming that diffusion of tritiated water from the fractures into the rock matrix occurs, even tritium can be significantly retarded. Therefore, the distance calculated for the movement of the particles at 25 or 100 years should not be considered a reliable indicator of the rates of movement of contaminants. The effects of retardation on contaminant migration is evaluated as part of the transport modeling (IT, 1996g).

Estimated travel distances appear to be affected by the modeling approach that resulted in the use of averaged hydraulic properties in the MODFLOW model, in comparison to the detailed geologic data (e.g., effective porosity data) included in the MODPATH velocity calculations. This discrepancy appears to have a greater effect on travel-time calculations for particles traveling near the top of the LCA, near the LCA-VCU contact.

The four particles starting on western Pahute Mesa traveled to the discharge area through only TMA or TC. For each of the particles, the travel distance (at 25 years) was most sensitive to the K_h and/or θ of the HSU in which the particle started. For example, the DARWIN particle started in TMA(1). Doubling K_h of TMA(1) resulted in a 228 percent increase in the 25-year travel distance. The starting HSUs for the other particles are TMA(1) (PURSE), TC(1) (BULLION), and TMA(1) (TYBO). Generally, the 25-year travel distances are secondly most sensitive to the hydrologic properties of the HSUs immediately downgradient from the originating HSU. This is not true for DARWIN, however, since increasing the K_h of the next HSU along the flowpath (TC(1)) by a factor of two decreased its 25-year travel distance by 6 percent because this change also resulted in a reduced the flux at the starting location.

The travel distance of the HOUSTON particle has a negative sensitivity to the K_h of BAQ(1) even though the particle does not move through this HSU. The reason is unclear, but increasing the K_h of BAQ(1) may cause the particle to have a longer travel path through the VCU, which has a lower effective porosity than the TMA or TC.

The 100-year travel distance for CLEARWATER is not very sensitive to any of the parameter changes evaluated. Even though the particle starts in LCCU(1), doubling its K_h produced less than a 2-percent increase in the travel distance, perhaps because it resulted in a longer path through the LCCU. The parameter with the greatest positive sensitivity is the K_h of BAQ(1).

For the particles starting in Yucca Flat (BOURBON, CORDUROY, COULOMMIERS, CUMARIN, and STRAIT), the 100-year travel time is quite sensitive to the K_h of VU(1), although not in a consistent manner. For most particles, doubling VU(1) increases the underflow through the barrier north of Yucca Flat and results in increases in the 100-year travel distance by about 20 to 35 percent. The response for the BOURBON particle was different. Its 25- and 50-year travel distances increased as expected, but the 100- and 200-year distances were decreased. Examination of the files containing information on the particle paths for Base 3 and the VU(1) sensitivity case showed that increasing the conductivity of VU(1) causes the BOURBON particle to travel further in the VCU than in Base 3. The VCU has a higher effective porosity and lower hydraulic conductivity than the LCA does, which slows the particle considerably. Evaluation of the specific discharge in conjunction with the particle velocity would be needed to determine whether the particle path has changed so that the particle is actually moving in the VCU or if this is an effect of the vertical averaging of conductivities. In summary, the increased underflow from the north when the K_h of VCU is increased causes more rapid movement of most, and perhaps all, particles in Yucca Flat.

Another feature of the Yucca Flat particles is that when the **8** of LCA(1) is increased, indicating greater reduction of conductivity with increasing depth, the travel distances increase. This change in **8** effectively decreases the thickness of the LCA and forces flow into a thinner interval at the top of the LCA, resulting in a net increase in velocity and travel distance.

The travel distance for the CUMARIN particle is sensitive to a larger number of parameters than the other particles; the reason for this is not clear. In Base 3, the particle frequently moves between the LCA and VCU due to the artifact in assigning effective porosity values to HSUs within the hydrologic model, as previously mentioned. The movement of the CUMARIN particle between the LCA and VCU is not representative of the actual pathway of the particle, since it would tend to migrate within the LCA below the LCA/VCU contact. It is, therefore, possible that the large number of sensitivities listed in [Table 5-6](#) represent those parameters that affect the path length of the particle within the VCU, and are also an artifact of the model and not representative of actual sensitivities.

The 100-year travel distance for the Frenchman Flat particle, DILUTED WATER (which is only 40 m for Base 3) is increased when the conductivity of AA(5), the originating HSU, is increased or its **8** value is decreased. The travel distance is less sensitive to the K_h of VU(1) than are particles within Yucca Flat, indicating that underflow across the barrier north of Yucca Flat is not as important to Frenchman Flat particles as the flux of water coming from the east. Because the DILUTED WATER particle does not travel far from its original location in 100 years, it remains

within the AA. Increasing the LCA transmissivity reduces the gradient in the AA in northern Frenchman Flat, and reduces the particle velocity by approximately 45 percent.

Perhaps the most important aspect to note in [Figure 5-7](#) is that, despite the large changes in parameter values, nearly all particles representing the sensitivity runs plot on the pathlines calculated for Base 3. For these particles, the assumption used in the transport modeling (that the HSUs through which the particle passes for the base case can be used for the Monte Carlo runs) is reasonable. The HOUSTON particle, however, varies from its base-case pathline. This probably results from its proximity to the eastern boundary of the Oasis Valley groundwater subbasin; changing the model parameters changes the location of the simulated subbasin boundary. The approximate east-west alignment of the points for HOUSTON coincides with the contact between the TC and VCU at the southern edge at the Timber Mountain caldera.

The conductivity parameters that have the greatest effect on travel distance are not necessarily the ones that have the greatest effect on location. This is well-illustrated with the HOUSTON particle. The easternmost point is for the sensitivity run where the K_h of VCU(1) was doubled. The VCU is part of the barrier at the northern end of Yucca Mountain. Increasing its conductivity allows more water to flow through this area and moves the HOUSTON pathline eastward from the base case. The 25-year travel distance was increased 5.6 percent, less than the criterion used in development of [Table 5-6](#). The western-most points are for doubling the K_h s of VA(1) and TBA(1). The 25-year travel distances were decreased 1.6 and 8.5 percent, respectively, indicating that the paths were slightly straighter. For those particles that lie along the base-case pathline, the correspondence between the parameters which affect travel distance and the plotted particle location is much closer. For example, the southern point for BULLION is the particle location for the sensitivity case where the K_h of TC(1) was doubled. This resulted in nearly a 200 percent increase in the 25-year travel distance or a tripling of the distance traveled.

5.7 Summary of Results

The calibration process resulted in a regional flow model of the NTS and vicinity that met most of the model calibration criteria for weighted head residuals ([Table 4-1](#)). The goodness-of-fit measures for the overall model are quite good. The mean-weighted residual is 7.9 m which is 0.047 percent of the overall range in measured heads. The overall RMS is 51.3 m or slightly over 3 percent of the range in target heads.

The mean weighted head residual calibration criteria were not met for 4 of the 15 residual zones. Tight criteria had been set for both the OV (15 m) and LCA (5 m) residual zones; these criteria would result in residuals that are 2.8 and 2.4 percent of the range in measured heads in these

zones, respectively. The mean weighted residuals for these zones, expressed as a percentage of the range in measured heads, are 7.1 and 3.6 percent, which still represent a good fit. The criteria were also missed for SHON (21.7 m compared with a criterion of 20 m) and WYF (70.4 m compared with 45 m). This was due both to the high vertical gradients in these areas and to the deliberate decision to reduce the mean weighted residual for EYF to close to zero (1.3 m).

In four areas that are important for regional and local-scale contaminant transport modeling, the match between observed and simulated heads is very good. For PM and TMBR, the magnitudes of the mean weighted residuals are 5.8 m (2.5 percent) and 0.8 m (3.5 percent). For EYF and FF, the magnitudes of the mean weighted residuals are 1.3 m (1.3 percent) and 0.8 m (3.5 percent), respectively. The remaining six residual zones (NORTH, BARR, DV, PAHR, SPMT, and FARM) also had good to excellent matches between observed and calculated heads, and the resulting mean weighted residuals were generally much lower than the calibration targets ([Table 4-1](#)).

The calibration process also emphasized matching simulated discharge rates to target rates ([Table 5-3](#)), although there is considerable uncertainty in the overall mass balance for the system and the discharge rates at individual areas. The target ranges were met for six of the ten head-dependent boundaries. The target flux rate and simulated fluxes at each of the remaining four boundaries were 5,000 m³/d or less, so that they represent minor inflow into or outflow from the model. The sum of the absolute values of the deviations from the target values for these four areas is 7,031 m³/d, or only 3 percent of the simulated flux (approximately 233,000 m³/d) through the system. For the two discharge areas with greatest flux, (Ash Meadows and Death Valley), the simulated discharge was within 0.5 percent of the target value. The deviations for Oasis Valley and Franklin Lake are 3.1 and 6.6 percent of their target fluxes.

The salient features in the interpreted water table map are present in the model. These include:

- The high gradient surrounding the northern part of Yucca Flat
- The higher heads in the western part of Yucca Flat overlying the UCCU
- The high gradient north of and within northern Yucca Mountain
- The potentiometric trough in Area 20 on Pahute Mesa
- The very low gradient throughout most of the area underlain by the LCA
- The moderate gradient between Three Lakes, Pahrangat, and Penoyer Valleys
- The high gradient between the Amargosa Desert and Death Valley

- The moderate gradient across Timber Mountain and the higher gradient in Pahute Mesa
- Effects of recharge in the Spring Mountains, and the Sheep, Kawich, and Quinn Canyon Ranges

Particle tracking was conducted to evaluate flow paths and advective movement of contaminants downgradient from testing locations without consideration of retardation mechanisms. Particles were selected for the analysis both to provide coverage of all weapons testing areas and to include the most rapidly moving particles. Particles starting on western Pahute Mesa moved quickly downgradient, discharging in Oasis Valley. The particle originating on eastern Pahute Mesa continued downgradient to the Death Valley discharge area. Particles starting in Yucca Flat moved downward into the LCA, then south and southwestward to discharge in the Amargosa Desert (but not Ash Meadows) or Death Valley. Their initial movements were sensitive to parameters that affect underflow into Yucca Flat. The particles in Frenchman Flat and Rainier Mesa did not move far from their starting locations within the 200-year time period evaluated.

During the second calibration sequence, sensitivity analyses were performed by changing basic assumptions in the model, such as the geologic models. Evaluation of the geologic models indicated that a barrier extending from the Calico Hills westward to Bare Mountain is needed to simulate the observed high gradient and match the discharge rates in Oasis Valley. Without this barrier, particles from Pahute Mesa move southward rather than to Oasis Valley. The sensitivity analysis also indicates that simulating the UCCU as a continuous unit beneath Rainier Mesa provides a better match to observed water levels near Rainier Mesa and in western Yucca Flat.

For the Base 3 model, there were five sensitivity runs performed with different recharge assumptions. When both the recharge and the K_h values were changed by the same factor, simulated water levels were close to those for the Base 3 case with the exception of heads near Pahranaagat Valley and in Death Valley. These areas differed from the base case because the Pahranaagat boundary flux and the conductances in the Death Valley drain cells were not increased proportionately to the increase in recharge. The discharge fluxes changed approximately by the same percent as the increase in recharge. Particle travel distance commonly increased significantly when the recharge factor was greater than unity. This suggests that the specific discharges increase downgradient, which will be the case when recharge is distributed more widely than discharge. The flow lines must converge to the discharge areas, with a consequent increase in the specific discharge.

Use of the Maxey-Eakin recharge model produced similar effects. The 25-year travel distances for particles starting on western Pahute Mesa increased significantly as a consequence of

increasing both recharge and hydraulic conductivities. The 100-year travel distances for other particles also increased but the percentage increases were much smaller than for the Pahute Mesa particles. When the redistribution parameters were varied, effects were minimal on heads, fluxes, and particle movement.

Individually changing most of the hydraulic-conductivity parameters produced only small effects in the water levels and boundary fluxes because of the limited spatial distribution of the HSUs. The model was generally more sensitive to changes in K_h than K_v or **8**. An increase in K_h produces a similar change as a decrease in **8** for the same HSU because each produces an increase in the transmissivity.

In general, the travel distances did not change significantly when doubling or halving the K_h and K_v values or when increasing or decreasing the **8** values by ten percent. Commonly, the travel distance was most sensitive to the K_h of the HSU in which the particle started; doubling the K_h typically produced a 10 to 40 percent increase in travel distance. In some distances, however, the travel distance increased 2 or 3 times the Base 3 distance. When the conductivity parameters were varied, the paths changed slightly, but the particles remained close to the pathlines calculated for the calibrated model.

6.0 Summary

This report documents the development, calibration, and results of a regional three-dimensional, steady-state flow model of the NTS and surrounding areas. The model is designed to provide a basis for predicting the movement of contaminants from the weapons testing areas on a regional scale, constrained by estimates of the amount of water moving through the groundwater system. It is also intended to provide a means for evaluating the uncertainty in these predictions by allowing the easy modification of hydrologic parameters. The model can also be used to supply boundary conditions for more detailed models of the weapons testing areas that are consistent with regional mass-balance information.

The model is based on a complex geologic model of an even more complex geologic framework. It incorporated extensive hydrologic data and uses water levels from more than 900 sampling points. It was constructed to more accurately simulate the hydrology of the areas of concern, which include the weapons testing areas and downgradient regions, than areas that are distant from the NTS. The modeling procedure was developed specifically to facilitate quality assurance checks by minimizing data entry errors and allowing reproducibility of results.

The groundwater system was modeled using MODFLOW. The model grid consists of 68 columns by 76 rows and 20 layers. The large number of layers was necessary to accurately simulate the geologic complexity of the thinner, hydrologically significant HSUs, primarily located in Pahute Mesa and Yucca Flat, and to increase numerical accuracy. The nonuniform grid is more finely spaced in the vicinity and downgradient of the NTS and is rotated 5 degrees clockwise to orient it with the average fracture direction in the primary testing areas of concern, Pahute Mesa and Yucca Flat. General head boundary cells were used to simulate underflow across model boundaries in the southern part of the model where flux estimates are based solely on estimates of transmissivity and information of hydraulic gradients. A constant-flux boundary condition was used at Pahranaagat Valley where geochemical data provide additional constraints on inflow rates. Drain cells were utilized to simulate discharge due to springs and evapotranspiration.

Distribution of recharge was based on a modification of the Maxey-Eakin (ME) approach. The ME coefficients imply that recharge does not occur when the annual precipitation is less than 23.1 cm. In the recharge model used for the flow model, the lower threshold was reduced to 16 cm, and coefficients lower than the ME coefficients were used. The net recharge to the model was approximately 204,000 m³/d, compared with approximately 270,000 m³/d for the ME recharge

model. In addition, 20 percent of the recharge water in the vicinity of the NTS was redistributed downstream to simulate infiltration along stream channels and on alluvial fans. The ME recharge model was evaluated in later sensitivity runs.

This report primarily addresses the results from the last of three calibration sequences. Both heads and fluxes were used as target criteria during model calibration. The target heads consisted of 798 sampling locations within the active cells of the model domain. Fifteen residual zones were defined for which the mean and roots mean square (RMSs) of the weighted head residuals were calculated for comparison with previously determined calibration criteria. This approach allows flexibility in establishing calibration criteria to reflect the geohydrologic complexity and available data for different areas, and it is more sensitive to mismatches than applying calibration criteria on a model-wide basis.

The overall model has a mean-weighted residual of 7.9 m and an RMS of 51.3 m. The range in measured heads is nearly 1,690 m, so the above values represent 0.4 and 3.0 percent of the range, respectively. The individual head calibration criteria were met in eleven of the fifteen zones. In two of the remaining four residual zones (Lower Carbonate Aquifer [LCA] and Oasis Valley [OV]), the criteria were very tight. The achieved mean weighted residuals for the calibrated model for these zones were 3.6 and 7.1 percent of the range in measured heads within the respective zones. For the other two zones (WYF and SHON), the criteria could have been met, but would have resulted in higher residuals in EYF. Because it was felt that minimizing EYF residuals was essential due to the importance of flow paths from Yucca Flat into Frenchman Flat, the EYF residual was minimized at the expense of higher residuals within SHON and WYF.

Estimates of the boundary fluxes in 12 areas were also used to set additional calibration goals. Discharge and recharge flux estimates within the model area are highly uncertain, and target flux ranges were established for each of the 12 areas to try and incorporate this uncertainty. The calibration goal was for the simulated fluxes to be within the range of estimates, but the calibration was performed to minimize the deviation between the simulated flux and a value considered to be the “best estimate” of the flux. The match to these target values is very good. For the largest two discharge areas (Ash Meadows and Death Valley), the simulated values are within 0.5 percent of their respective target values. The mismatch at Oasis Valley was only 3.1 percent. For four of the smaller discharge areas, the simulated values were outside the respective target ranges. However, the sum of the absolute value of the deviations from the target values for these areas was slightly over 7,000 m³/d, or about 3 percent of the total flux through the system.

As part of the application of the model, particle-tracking calculations using MODPATH were performed. Additional postprocessing of the MODPATH results was done to include the different effective porosities of the HSUs through which the particle traveled. Particle locations were based on the locations of underground tests. From over 400 locations, which included tests where the working point of the tests was less than two cavity radii above the water table, 14 particles were selected. These were chosen so that each testing area (Pahute Mesa, Rainier Mesa, Yucca Flat, Climax Stock, Shoshone Mountain, and Frenchman Flat) was represented. Further, particles with rapid estimated movement in each testing area were selected. Results indicate that particles originating in the western Pahute Mesa testing area discharge in Oasis Valley. The particle originating on eastern Pahute Mesa traveled east of Oasis Valley, passing beneath Crater Flat and the Amargosa Desert to discharge in Death Valley. Particles originating in the eastern testing areas (Yucca Flat and Frenchman Flat) discharge in Death Valley or the Amargosa Desert, but not at Ash Meadows. The geologic model contains no effective barrier to prevent water from leaving Yucca or Frenchman Flats and traveling southwestward beneath Rock Valley and eastern Jackass Flats. Without a large volume of water coming into and leaving Yucca Flat to overwhelm water from the eastern part of the flow system, there is no reason to expect water from Yucca Flat or Frenchman Flat to discharge at Ash Meadows.

The calibrated model accurately simulates several observed hydrologic features present on the NTS. The high gradient between Emigrant Valley and Yucca Flat is present, as is the high gradient north of the Yucca Mountain area. The higher heads in the western part of Yucca Flat above the Upper Clastic Confining Unit (UCCU) are present. A moderately low gradient across Timber Mountain, increasing to the north beneath Pahute Mesa, is well-simulated. The potentiometric trough located in Area 20 on Pahute Mesa is also present.

Extensive sensitivity analyses were performed on both water level and boundary flux responses and on particle-tracking results. The sensitivity analysis was performed in two separate steps. The first step involved changing basic assumptions of the model such as using different versions of the digital geologic model and recharge models. The second step was a systematic variation of the hydraulic-conductivity parameters; the horizontal hydraulic conductivity and depth-decay coefficients were both increased and decreased by specified amounts.

The sensitivity analysis of the different geologic models confirmed that a barrier to flow in the area of Calico Hills westward to Bare Mountain is needed to match estimated discharge rates at Oasis Valley and observed gradients in this area. This barrier is based on structural relationships associated with the Belted Range Thrust and alteration of volcanic rocks in the Claim Canyon Caldera segment and northern Yucca Mountain. This interpretation is consistent with geologic

and hydrologic information in the area. In addition, an interpretation that the UCCU is continuous beneath Rainier Mesa is consistent with hydraulic-head observations in ER-12-1 and provides better agreement with head data elsewhere. The changes in the geologic model near Penoyer Valley resulted in an improvement in the hydrologic model, but lower hydraulic conductivities for LCA rocks in the northern part of the model were still needed to match water levels and estimated fluxes in that part of the model.

Sensitivity analyses were performed for several different recharge models. The results from the recharge sensitivity models include the following:

- C When the recharge rates and hydraulic conductivities are increased or decreased by the same factor, the model behaves in an approximately linear fashion. The slightly nonlinear behavior is attributable to not changing the other boundary conditions (drain conductances and underflow) by an equivalent amount.
- C Travel distances for particles on western Pahute Mesa increase several-fold when the recharge rates and hydraulic conductances are increased; increases for particles from other testing areas are moderate.
- C Use of the Maxey-Eakin recharge model and similarly increasing HSU hydraulic conductivities by the Maxey-Eakin-to-base case recharge ratio produce effects similar to those described above. However, the distribution of the recharge differs. With the Maxey-Eakin approach, there was a greater percentage increase in the discharge at Penoyer Valley than when the base-case recharge rates and conductivities were increased by a common factor .
- C Redistribution of recharge to downstream areas on and near the NTS has little effect on water levels, discharge rates, or particle movement.

Other sensitivity analyses were performed to evaluate the effects of uncertainty in the specified flux boundary conditions and in changes to hydraulic conductivity values other than those that were evaluated as part of the systematic analysis described below. Findings from these “special-case” sensitivities include:

- C The transport distance in Frenchman Flat is sensitive to the conductivity of the AA in Frenchman Flat, but the travel distances are likely to be short for reasonable values of K_h .
- C Removing the low-conductivity zonation in the vicinity of Black Mountain (Black Mountain volcanics were assigned the same conductivity values as adjacent HSUs) also removed the potentiometric trough near Area 20 on Pahute Mesa. This indicates that the low conductivity zone is one possible explanation for the presence of the trough.

A systematic sensitivity analysis was performed on the horizontal hydraulic conductivity and lambda values of the 58 different HSUs as well as on the sensitivities to changes in boundary fluxes. The majority of results indicated that increasing the conductivity value for a given HSU decreased heads in residual zones in the vicinity or upgradient of that HSU. This is because downgradient discharge areas control heads at the terminal point in the model; if upgradient conductivities increase and the recharge remains the same, then resultant heads must decrease to maintain mass balance. Travel distances of particles are generally most sensitive to changes in the hydraulic properties of the HSU in which they start. The increase in travel distance, expressed on a percentage basis, is usually less than the percentage change in the hydraulic conductivity for the starting HSU. In some instances, however, the percentage change in travel distances may be several times greater than the change in hydraulic conductivity. Sensitivity results also indicated the following:

- C Lower LCA conductivity values are necessary in the northern part of the model to maintain necessary heads and fluxes.
- C Particles originating on western Pahute Mesa move quickly downgradient from their respective starting locations, discharging to the south and southwest at Oasis Valley.
- C Particles within Yucca Flat discharge in either the Amargosa Desert or Death Valley, but not at Ash Meadows.
- C Particles originating on Rainier Mesa or within Frenchman Flat do not migrate far from their starting locations within the 200-year time period evaluated.
- C Particle travel distance commonly increased significantly when recharge was increased, suggesting that specific discharges increase downgradient.
- C Despite the large changes in hydraulic parameter values, nearly all particles evaluated plot on the pathlines calculated for the base case simulation.

In summary, the NTS regional groundwater flow model incorporates a significant amount of detail at the regional scale and provides excellent agreement to observed head and flux data. The model will be able to provide initial estimates of boundary fluxes for local-scale transport modeling; however, the constraints placed by the regional model on hydrologically significant parameters specific to each local-scale model should be evaluated prior to local-scale transport modeling. Additionally, the effects of the uncertainty in the regional model discharge fluxes on the uncertainty in the boundary fluxes for local-scale models should also be evaluated.

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Appendix A

Listing of Pre- and Post-Processing Programs

Because of the complexity of the modeled area, as captured in the geologic model, and because of the large amounts of data that needed to be handled, the modeling effort was very dependent not only on the modeling codes themselves, but on many support programs. These varied from programs that processed the geologic model information to others that displayed components of the model and modeling results. These codes, which include both pre- and postprocessors, are described in this appendix. The names of programs are indicated by use of capital letters. The last two positions in the prefix are reserved for the version number of the code. Computer files are normally in lower case letters, unless there is a need to emphasize a portion of the name. The DOS convention of “*” is used to indicate any valid name or part of a name.

PREPROCESSORS

Preprocessors are programs that are used to assemble modeling data sets. Specifically for the NTS modeling task, the preprocessors range from programs that combine the geologic model with hydrologic property information for almost every run of the model, to programs for developing data sets that are infrequently changed.

MAPINFO

MapInfo is a GIS package developed by the *MapInfo* Corporation which displays information that has spatial properties associated with it. GIS regions can be defined which have specific locations and shapes. These regions can have many different data items associated with them. *MapInfo* imports and exports information on the spatial properties of the regions in a *.mif file, while the associated data is placed in a *.mid file. A *.mif file was constructed using a FORTRAN program that took information on grid spacing, orientation, and origin coordinates and constructed individual regions for each of the model cells within a layer. This *.mif file was then used to graphically assemble information as needed. For example, the ibound arrays for MODFLOW which identify the active and inactive model cells were constructed using *MapInfo*.

Similarly, *MapInfo* was used to display information from the geologic model by HSU. *MapInfo* is not able to display three-dimensional data, only two-dimensional. However, multiple layers can be stacked to determine their spatial relationships, which provides a useful tool for performing QA on data sets. Also, *MapInfo* was used for graphically designating zonations within an HSU so that the hydrologic properties of an HSU could be changed laterally. An example is the separation of HSU 07, the regional LCA, into several zones with different hydraulic properties.

ARAYMC01

ARAYMC01 is used to convert between *.mid files and input files for the modeling codes. When the *.mid data file is exported from *MapInfo*, it consists of a series of records with comma-

delimited parameters. Each record is associated with a region defined in the *.mif spatial file. However, processing the information in the *.mid file can break the association with the *.mif file. Therefore, parameters are defined in the *.mid file that record the layer, row, and column represented by the data record. The program ARAYMC01 reads the information in the *.mid file, and creates either a two-dimensional array for a single variable or a multi-column list of desired variables. The output format can be specified.

TMSMOD06

The geologic model is constructed on a 2-km by 2-km grid oriented north-south and east-west. The flow model is rotated 5 degrees clockwise from north, covers only a portion of the geologic model grid, and has a variable grid spacing. The rotation was performed to align the columns of the model with the average strike of faults for Yucca Flat and Pahute Mesa so that the effects on anisotropy can be evaluated. A method was needed to process the geologic information into the flow model. This work is done by three programs, TMSMOD06, VCONT04, and BCFMAK03. TMSMOD06 and VCONT04 combine information from a file (cond.mdl) describing hydrologic properties of the different HSUs, another file (m_elev.in) providing the elevations of the tops of the hydrologic model layers, with the geologic model (geol_*.mdl). The properties of an HSU can be varied spatially by defining zones which are read from a file zones*.in.

TMSMOD06 calculates the thickness of each of the twenty HSUs within each of the model layers. These thicknesses are multiplied by $10^{-\lambda d}$ to simulate the decrease in hydraulic conductivity with depth below land surface. Lambda (λ) is a “decay” rate initially estimated from data assembled during the Hydrologic Parameter Analysis task and represents the decrease in the logarithm of hydraulic conductivity with increasing depth (d) below land surface.

After the thickness is calculated, it is multiplied by the hydraulic conductivity for the HSU to give the transmissivity of the HSU within each model layer. The transmissivities of the individual HSUs within a layer are then summed with those of other HSUs in the layer, to produce an array which is the transmissivity of the model layer. This array is written to a file h##.tms. These arrays are 114 columns by 140 rows, coincident with the geologic model.

VCONT04

This program is very similar in structure and operation to TMSMOD06, but calculates the array vcont needed by MODFLOW. The array represents the resistance to flow between model layers. VCONT04 calculates the parameter based on the thickness of HSUs within model layers, the horizontal hydraulic conductivity of the HSU, and the ratio of vertical to horizontal conductivity (anisotropy). Because vcont represents the conductance between the center of a model cell and

the center of the model cell immediately below, it is calculated from the properties of rocks present in the bottom half of one cell and the top half of the cell below. The vertical conductivity is adjusted for depth below land surface with the same exponential function used for the transmissivity in TMSMOD06. The input files used by TMSMOD06 are also used by VCONT04. The output array files are named h##.vct.

BCFMAK03

The output arrays from TMSMOD06 and VCONT04 are based on the geologic grid. These need to be converted for use by MODFLOW, specifically the Block-Centered Flow (BCF) package. BCFMAK03 performs this conversion. It translates and rotates the hydrologic grid relative to the TMSMOD06 and VCONT04 grids and interpolates values for the center of the model cells from the four grid points which surround the cell center. The interpolation is performed using bilinear interpolation rather than using a distance-weighted average or other gridding scheme commonly used for randomly spaced data because it is both more accurate and computationally efficient. BCFMAK03 reads the information needed to calculate the locations of the grid points and the model cells from the file “grids.dat”, and the file name to process from the file “val.flr” that can contain as many file names as need to be processed. The names of the output files are identical to those of the input files, but with the letter “g” added to the front of the name.

RCHHM16

The recharge code develops an estimate of the rate of recharge based on the estimate of annual precipitation and application of Maxey-Eakin (ME)- like parameters. In the vicinity of the NTS, water can be routed from the higher elevation areas (where the rates of precipitation and ME recharge are greater) to lower elevation areas based on locations of stream channels and basin-fill deposits. In other areas, the recharge is applied at the model cell in which the precipitation occurs. This code requires several input files: precipitation data on an approximately 1-km by 1-km grid, the ME-like parameter values, the locations of points where stream recharge will occur, and the proportions of upland recharge volume to be applied along channels.

POSTPROCESSORS

ROTUNI03

The output from MODFLOW is provided in two files. The first is the main output file. While this is readable, it is difficult to compare the results with measured values and to evaluate the general configuration of the flow field. Contour maps of heads, with posted values of measured heads, are a much faster and reliable form of presentation. The postprocessing of the head data is done by ROTUNI03 and SURFER.

ROTUNI03 is a variation of a GeoTrans postprocessor called UNIWORK. It reads head information from a binary or ASCII file written by MODFLOW and creates a SURFER grid file. The model grid can be rotated with respect to the coordinate system used by SURFER, which makes plotting the contours on base maps possible. The program requires the head output file (rot_uni.hds), information on the model grid and the SURFER grid (rot_uni.in), and writes the SURFER grid file to rot_uni.grd. Bilinear interpolation is used to calculate the values for the SURFER grid, so that additional gridding is not needed.

NTSPLT04.BAT

NTSPLT04.BAT is a DOS batch file which:

- Prints the file cond.mdl to preserve a hard copy of the hydraulic parameters. The file also contains a log of each of the runs, describing why changes were made to the data sets during the calibration process;
 - Prints the file drn.out, ghb.out, and wel.out created by DRNBUD03, GHBBUD03 and WELBUD01 (see following);
 - Copies the MODFLOW head output file base.hds to a file 996***.hds for preservation;
 - Copies previously constructed files (nts_l*.in) into rot_uni.in;
 - Runs ROTUNI03 22 times, once for the water table map, once for each of the 20 model layers; and once for the map that provides water table levels above land surface;
 - Invokes SURFER's TOPO to contour the gridded head information and to post observed water levels for the 20 model layer maps;
- C Creates 22 maps from TOPO; and
- C Creates a plot from GRAPHER of observed minus simulated heads.

SURFER

SURFER is a plotting package produced by Golden Software. The DOS version was used so that plotting could be quickly performed by the modeler. The packages used were TOPO and PLOT.

B2AHDS01

This program reads the binary head file created by MODFLOW and creates a *.mid file for importing into *MapInfo*. The *.mid file contains the head information for each of the 20 model layers.

SLGMID01

Because of the three-dimensional complexity contained in the geologic model, it is difficult to visualize the distribution of hydraulic properties without a graphical tool. *MapInfo* can create thematic maps, which makes the distributions readily apparent. SLGMID01 reads the g*.tms and g*.vct files used by MODFLOW and produces *.mid files for importation into *MapInfo*. Because the values of transmissivity and vcont can range over orders of magnitude, the program produces *.mid files of both the value and the logarithm (base 10) of the value for greater ease in viewing the data files.

DRNBUD03, GHBBUD03, and WELBUD01

These programs read the files written by MODFLOW (modified as described above) which contain the information on the flux rates calculated by MODFLOW at the drain, GHB, and well boundaries. They sum the fluxes for all boundary cells in a particular area (such as Ash Meadows or Oasis Valley), and write the results to files drn.out, ghb.out, and wel.out for printing.

TARGHD06

Information on water levels was provided in a data table fldstat6.txt from the ERMA database. This table provided information on well location, measurement interval, water level, and uncertainty and variability of the hydraulic head. In order to be useful in the modeling, these data must be processed so that they represent a head in a model cell which has coordinates in three dimensions. The program TARGHD06 processes the location of each well, including its open interval, determines which model cell(s) the well represents, and determines the HSUs the well taps (based on the geologic model) for comparison with the HSU information provided in the database.

MAKTAR02

This program is a companion program to TARGHD06. It takes output from TARGHD06, and transmissivity information for each model cell from the gh*.tms files, and calculates a weighting factor that represents the transmissivity of a model layer (or portion thereof) relative to all model layers tapped by the well. This proportion is used to help calculate the weighting factor to be multiplied by the residual (observed minus calculated hydraulic head). The weighted residual is used to guide model calibration.

RESIDL03

This program calculates and summarizes the residuals of hydraulic head for each model layer. It also calculates summary statistics on the residuals for each layer and the entire model: mean residual head, root mean square residual, mean weighted residual, and root mean square weighted residual.

RESIDZ06

A different approach to calculating head residuals is used in this code. It reads an array based on the flow model grid that defines residual zones. This program calculates the following summary statistics for each zone, and for the overall model: means of the unweighted and weighted residuals, root mean square of the unweighted and weighted residuals, and the preceding statistics normalized by dividing by the range in measured heads in the zone. The residuals are weighted by the inverse of the estimated standard deviation of the measured head. The simulated head at a measurement point is calculated by interpolating from the simulated head at the corresponding MODFLOW cell center. If the observation is a multi-layer observation, the head for the well is the transmissivity-weighted average of the heads in the model layers intercepted by the well.

MODELING CODES

MODFLOW

Flow simulations were performed with MODFLOW (McDonald and Harbaugh, 1988), using the rewetting package BCF2 (McDonald et al., 1991), and the preconditioned conjugate gradient solver (PCG2, Hill, 1990). MODFLOW was modified slightly to allow more efficient input of data from BCFMAK03. Normally, input files must be read from different FORTRAN unit numbers which are either attached and opened by statements added to the main program or by a file utility program. However, this requires that the files remain open for the entire run, making that unit number unavailable. There are 20 gh*.tms and 19 gh*.vct files that must be read. Because the BCF input arrays were being recreated with each run, it would be very tedious and error-prone to manually edit the input file arrays. The subroutine BCF1RP was modified to read the file name from the BCF file, open unit 99 to that file, read the transmissivity and/or vcont data, and close the file. The data were printed to the output file and compared with the input files to make sure the information was read correctly.

The code was also modified slightly to write the discharges from the drain, general-head boundary, and well cells to separate files for easier processing with the programs DRNBUD03, GHBBUD03, and WELBUD01. The calibration involved matching both observed heads and measured or estimated discharge rates, so that the discharges from the boundary cells are needed.

The final change involved changing the variables V, SS, and P in the PCG2 package to double precision, as described by Hill (1990), to increase the numerical accuracy in the solver.

MODPATH

MODPATH (Version 1.2) is a program written by David Pollock of the U.S. Geological Survey. It calculates the positions of particles at different times, based on results from MODFLOW. Particles can be released at desired locations within the model. The program requires several input files from MODFLOW, containing information on layer geometry and boundary conditions, and an output file from MODFLOW with information on cell-by-cell flux rates in three dimensions. The output files can be used for plotting the locations of particles as they move through the flow system. An additional application for the particle tracking results is to provide the Darcy velocity information needed to perform the 1-D transport modeling.

Appendix B

Target Head Data

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	top	bottom	top	bottom
9415590	656251	4155149	65	8	1158.2	100	5	5	1158.2	1157.2
9419625	647248	4033680	65	69	893.1	100	7	7	893.1	892.1
360951116072201	578904	4002311	44	76	744.1	3.3	7	7	741.0	740.4
361158116240501	553821	4006034	27	76	584	10.3	11	11	256.0	249.9
361158116240502	553821	4006034	27	76	579.9	10.4	9	9	570.0	566.9
361204116060301	580840	4006427	45	76	759.3	10.3	7	8	761.7	619.0
361210116225701	555516	4006414	28	76	607.2	10.3	12	12	213.3	207.2
361210116225702	555516	4006414	28	76	607.6	10.3	9	9	594.3	591.3
361216116053701	581486	4006803	46	76	762.7	3.3	7	8	755.9	606.3
361248116113801	572463	4007709	39	76	742.3	3.4	7	7	738.8	738.5
361406116110601	573242	4010119	40	76	743	3.4	7	7	743.4	736.7
361406116173900	556166	4010177	29	76	605.5	100	8	9	606.5	595.5
361413116221201	556616	4010211	29	76	605.8	1	8	8	606.0	603.1
361413116221202	556616	4010211	29	76	606.3	1	8	8	606.5	603.6
361413116221203	556616	4010211	29	76	606.7	1	8	8	607.4	600.2
361415116002001	579906	4010270	44	75	802.6	100	7	9	802.5	593.7
361415116222101	556390	4010271	29	76	607.2	1	8	8	607.3	601.4
361415116222102	556390	4010271	29	76	607.2	1.2	8	8	609.2	605.1
361415116222103	556390	4010271	29	76	607.7	1	8	9	607.8	598.9
361415116230200	555367	4010265	28	76	608.9	1	8	9	608.9	592.3
361417116224001	555916	4010330	28	76	606.3	1	8	9	606.5	597.4
361451116170800	556984	4011169	29	76	607.1	100	8	8	602.5	602.2
361457116183400	554638	4011123	27	76	608	100	8	8	608.0	606.4
361516116220101	556877	4012154	29	75	608.4	100	8	8	608.7	607.4
361516116220102	556877	4012154	29	75	608.3	100	8	8	608.7	600.9
361527116171300	556877	4012154	29	75	608.3	100	8	8	608.8	603.8
361533116111901	572895	4012797	39	75	743.2	1.6	7	7	743.5	740.7
361553116212101	557868	4013301	29	75	610.2	100	8	8	611.3	605.0
361553116212102	557868	4013301	29	75	610.4	100	8	8	610.9	609.8
361605116212701	557716	4013669	29	75	611.6	3.3	8	8	611.9	609.9
361605116212702	557716	4013700	29	75	611.4	1	8	8	611.7	608.1
361607115353801	626309	4014456	62	74	1984.7	38.3	1	1	1985.2	1963.9
361610116223701	555968	4013812	28	75	607.6	1	8	8	607.9	604.4
361627116221202	556589	4014340	29	75	613	100	8	8	613.5	606.6

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	top	bottom	top	bottom
361640116315501	542041	4014658	19	75	613.3	100	8	8	613.4	610.5
361745116215502	556997	4016746	29	75	617.6	100	8	8	617.6	616.0
361808116273501	548513	4017403	23	75	628.9	1.1	8	8	629.1	627.0
361817116244701	552701	4017705	26	75	621.1	1	9	9	573.5	561.3
361835116220301	556813	4018224	28	75	619.7	10.4	8	8	620.0	611.2
361835116224501	555740	4018278	28	75	619.5	100	8	8	619.5	618.8
361840116184001	560376	4018617	31	75	647.1	10.3	8	8	647.4	644.1
361840116184002	560301	4018740	31	75	651.9	10.3	8	8	652.0	614.8
361840116184003	560400	4018772	31	75	650	10.3	8	8	650.1	644.7
361840116184004	560400	4018772	31	75	649.7	10.3	8	8	649.9	613.6
361840116184005	560475	4018772	31	75	648.3	10.3	8	8	648.6	621.5
361840116184006	560525	4018772	31	75	646.2	10.3	8	8	646.5	602.9
361840116184007	560525	4018772	31	75	646.7	10.4	8	8	647.2	646.2
361845116193707	560426	4018618	31	75	651	10.3	8	8	651.2	650.8
361903116093001	576290	4009807	42	76	748	3.4	7	7	748.6	714.7
361954116181201	563029	4020855	32	74	648.2	1	12	12	116.6	113.5
361954116181202	563029	4020855	32	74	692	1.7	8	8	668.9	667.9
362014116133901	569555	4021644	37	74	716.2	1	11	11	268.7	265.6
362014116134902	569555	4021644	37	74	715.9	1	7	11	716.0	259.2
362033116255202	551055	4021885	24	74	628.1	100	8	9	628.2	528.2
362113116160101	565806	4022909	34	74	694.8	10.4	11	11	344.1	341.1
362113116160102	565806	4022909	34	74	694.9	10.5	8	8	663.8	662.9
362120116162201	565253	4023429	34	74	693.4	100	8	8	693.4	692.4
362140116261001	550595	4023947	24	74	625.1	10.3	13	13	51.8	48.8
362142116154701	566120	4024113	34	74	701	100	7	8	701.0	700.0
362145116161301	565472	4024201	34	74	693.4	100	8	8	693.4	692.4
362153116171502	563925	4024436	33	74	672.6	10.3	8	8	649.8	620.9
362154116162001	563925	4024436	33	74	674.2	100	8	9	651.6	594.6
362230116162001	565162	4025554	34	73	682.8	100	8	8	682.8	681.8
362230116392901	530677	4025394	11	74	649.1	1	8	8	649.3	633.5
362238115462801	609937	4026284	58	73	1827.3	100	1	1	1827.3	1826.3
362250116175001	563040	4026185	32	73	671.9	100	8	9	671.9	571.9
362250116175301	562965	4026185	32	73	671.2	1.6	8	8	662.0	642.5
362250116265101	549560	4026098	23	74	641.5	10.3	12	12	161.6	158.5

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	top	bottom	top	bottom
362250116265102	549560	4026098	23	74	642.2	10.3	8	8	634.0	633.1
362252116425301	525592	4026055	7	74	634	100	8	8	634.0	633.0
362303116174502	563161	4026587	32	73	674.7	10.3	8	9	674.9	574.9
362314116160101	564057	4026809	33	73	687.3	100	8	8	671.2	641.3
362343116160802	565569	4027837	34	73	716.3	100	7	7	716.3	715.3
362343116160803	565569	4027837	34	73	716.3	100	7	7	716.3	715.3
362343116160805	565569	4027837	34	73	716.3	100	7	7	716.3	715.3
362354116174001	563275	4028159	32	73	701	100	7	8	701.0	700.0
362358116163301	565016	4028480	33	73	702.9	10.3	8	9	671.8	549.9
362400116161701	565391	4028298	34	73	696.2	10.5	8	8	690.4	616.7
362401116181101	562501	4028369	32	73	685.8	100	8	8	685.8	684.8
362401116181102	562501	4028369	32	73	684.3	100	8	8	684.3	683.3
362401116181103	562501	4028369	32	73	685.8	100	8	8	685.8	684.8
362402116172201	563721	4028409	32	73	688.2	100	9	10	563.9	404.2
362405116161305	564828	4027000	33	73	701	100	7	8	701.0	700.0
362406116154001	566286	4028521	34	73	706.2	10.3	8	9	678.2	556.3
362407116162401	565366	4028267	34	73	716.3	100	7	7	716.3	715.3
362408116154001	566137	4028519	34	73	705.2	10.3	7	9	705.9	513.9
362409116155601	565640	4028269	34	73	699.7	10.6	8	8	685.2	612.1
362410116160901	565962	4028518	34	73	705.7	10.3	8	9	660.2	587.0
362410116161002	565414	4028514	34	73	707.1	100	7	7	707.1	706.1
362415116270501	549197	4028715	23	73	650.7	100	8	9	650.7	550.7
362417116163600	564838	4028972	33	73	707.3	1	8	9	670.9	568.8
362425116164901	564538	4029124	33	73	696.5	100	8	8	696.5	642.2
362425116181001	562493	4029386	32	73	678.1	10.3	8	9	660.2	599.9
362432116165701	564337	4029338	33	73	699.6	1	8	9	664.1	554.1
362443116263602	549914	4029582	23	73	650.8	100	8	9	650.8	550.8
362444116251001	552054	4029872	25	73	642.8	100	8	9	643.6	542.9
362457115223301	645623	4031095	65	70	844.9	100	7	7	839.7	827.5
362502116192301	560592	4030574	30	73	669	100	8	8	669.0	668.0
362505116223001	555777	4035749	27	71	661.7	10.3	8	8	661.4	635.5
362508115225302	645119	4031425	65	70	847.9	1	7	7	848.4	748.4
362521116160801	565546	4030857	34	72	715.8	10.3	7	8	715.9	678.8
362525115225401	645085	4031949	65	70	850.8	100	7	7	851.7	848.5

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	top	bottom	top	bottom
362525116274301	548238	4030866	22	73	665.2	1	11	11	343.8	342.9
362525116274302	548238	4030866	22	73	659.6	10.5	8	8	658.4	657.5
362525116274501	548188	4030866	22	73	662.2	100	8	8	662.2	662.0
362526116181801	562308	4030987	31	72	690.1	100	8	9	690.1	590.1
362529116155801	565793	4031105	34	72	718.4	100	7	8	718.4	618.4
362529116160501	565544	4031042	34	72	718.8	10.3	7	8	719.0	660.8
362529116171100	563875	4031122	32	72	717.9	1	7	8	718.1	671.7
362531115224401	645331	4032138	65	70	838.5	100	7	7	831.5	807.1
362532116172700	563576	4031181	32	72	718.3	1	7	8	718.7	618.7
362532116181501	562381	4031172	31	72	716.3	100	7	7	716.3	715.3
362535116244801	552594	4031200	25	73	670.6	100	8	8	670.6	669.6
362554116184101	561729	4031846	31	72	701	100	7	8	701.0	700.0
362554116204001	558766	4031825	29	72	662.6	100	8	8	646.2	627.9
362555116205301	558442	4031854	29	72	655.1	1	8	8	615.4	603.2
362557116181301	562425	4031943	31	72	723.9	100	7	7	723.9	722.9
362620115212601	647248	4033680	65	69	894.6	100	7	7	894.6	893.6
362624115212701	647221	4033803	65	69	885.9	3.3	7	7	886.2	847.4
362627116213501	557635	4033296	28	72	659	100	8	9	616.0	509.3
362648116201401	559402	4033493	29	72	673.7	10.3	8	9	647.7	537.9
362648116274601	548149	4033423	22	72	676	100	8	8	652.5	642.8
362650116311501	542946	4033457	18	72	671.4	100	8	9	671.4	589.7
362702116322201	541276	4033819	17	72	671.2	1.5	8	9	671.8	597.6
362705116300901	544587	4033928	19	72	673.7	100	8	8	673.7	673.0
362705116315001	542072	4033915	18	72	673.3	100	8	9	673.4	573.4
362705116322301	541251	4033911	17	72	675.3	100	8	9	675.3	575.3
362715116322301	541250	4034219	17	72	673.3	4.9	8	9	675.3	593.6
362723116184101	561709	4034588	31	72	731.5	100	7	7	731.5	730.5
362725116305901	543339	4034538	19	72	673	2.4	8	9	674.2	562.1
362726116314401	542219	4034563	18	72	672.2	100	8	9	672.1	591.9
362727116322201	541273	4034589	17	72	670.9	100	8	8	670.9	646.1
362728116501101	514664	4034534	4	73	121.9	100	12	12	121.9	120.9
362736116285701	546374	4034892	21	72	674.7	1.6	12	13	100.9	97.8
362736116285702	546374	4034892	21	72	675.4	1.8	8	8	662.3	661.4
362740116112601	573454	4035142	39	71	715.8	1.6	7	7	716.1	714.2

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	top	bottom	top	bottom
362745116204001	558742	4035245	29	71	680.3	100	8	8	680.4	621.2
362750115244001	643541	4036454	65	68	890.7	1	7	7	868.7	820.0
362751116192701	560431	4035811	30	71	704.1	100	7	7	704.1	703.1
362755116202001	559238	4035557	29	71	682.1	10.3	8	9	682.1	582.1
362757116202401	559138	4035617	29	71	679.1	100	8	9	655.6	533.4
362757116202402	559138	4035617	29	71	680.6	100	8	9	680.6	533.4
362809116213101	557468	4035976	28	71	664.8	10.7	8	9	659.0	497.4
362811116202401	559135	4036049	29	71	679.3	12.2	8	9	666.9	533.7
362830115270501	638942	4037550	64	68	904.5	10.3	6	7	904.8	877.9
362835116192101	560422	4037136	30	71	693.4	100	8	8	693.4	692.4
362835116264101	549748	4036729	23	71	673.9	10.3	8	9	674.2	564.5
362848116195901	559749	4037193	29	71	670.6	100	8	8	670.6	669.6
362848116264201	549622	4037129	23	71	673.3	1	8	9	672.0	569.6
362848116291101	545587	4037815	20	71	683.6	100	8	9	683.5	579.1
362848116301501	544418	4037717	19	71	685.5	100	8	8	685.5	638.5
362850116202601	559077	4037250	29	71	680.9	10.9	8	10	669.7	470.9
362852116281401	547428	4037795	21	71	686.6	3.3	8	8	686.7	682.7
362852116294901	545064	4037813	20	71	687.6	100	8	8	687.6	682.4
362856116284201	546732	4037760	21	71	685.8	3.4	8	8	686.1	681.2
362858116091501	575405	4036946	40	70	719.5	100	7	8	717.6	687.1
362858116091502	575772	4037627	40	70	719.4	100	7	7	719.4	704.8
362858116195301	559972	4037410	29	71	689.4	1	8	8	659.9	628.8
362858116195302	560046	4037473	30	71	691.1	10.3	8	9	678.8	589.8
362902116304701	543622	4037528	19	71	674.8	100	8	8	674.9	634.0
362905116092301	575571	4037841	40	70	719.3	100	7	8	702.3	688.9
362905116274001	548275	4037645	22	71	673.5	100	8	9	673.5	573.5
362917116294601	544812	4038520	19	71	688.6	100	8	9	688.6	548.6
362917116304701	543620	4037990	19	71	683.5	100	8	9	683.5	583.5
362921116280401	547474	4038596	21	71	678	1.7	8	8	678.8	672.6
362921116302501	544165	4038548	19	71	688.2	100	8	8	688.2	675.1
362923116291101	545508	4038647	20	71	684.3	3.3	8	8	684.3	637.0
362924116203001	559020	4038359	29	70	685.8	100	8	8	685.8	684.8
362925116253301	551429	4038649	24	71	675.9	4.7	8	8	679.7	644.6
362929116085701	576211	4038586	40	70	719.2	1	7	8	719.7	664.3

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	top	bottom	top	bottom
362930116295901	544812	4038397	19	71	676.2	100	8	9	676.2	576.2
362938116270001	549264	4038668	22	71	672.8	3.4	8	8	664.7	603.8
362939116265401	549414	4038699	22	71	667.7	100	8	9	667.7	567.7
362946116254101	551226	4039388	24	70	677	100	8	8	677.0	640.4
362946116270301	548666	4038911	22	71	677.7	4	8	9	678.5	529.1
362946116302201	544236	4039257	19	71	688.4	3.5	8	8	682.7	639.4
362946116302301	544213	4038887	19	71	688.9	100	8	8	687.9	669.0
362946116302302	544213	4038887	19	71	686.7	100	8	8	686.7	638.9
362947116252001	551751	4038960	24	70	673.8	2.2	8	8	662.0	630.0
362957116254901	551027	4039263	23	70	673.7	100	8	9	673.8	573.8
363002116304801	543588	4039377	18	71	680.6	100	8	9	680.6	580.6
363002116310701	543116	4039374	18	71	681.2	10.3	8	8	681.8	629.7
363005116291001	546026	4039482	20	70	683.1	100	8	8	683.0	676.0
363009116291101	545674	4040219	20	70	686.1	100	8	8	686.1	683.4
363009116302701	544110	4039595	19	70	686.7	1	8	8	680.4	668.5
363011116280401	547663	4040230	21	70	681.3	4	8	8	682.1	677.6
363017116253001	551494	4040221	24	70	676	3.6	8	8	673.9	640.3
363017116253002	551496	4039882	24	70	684.3	100	8	8	666.0	641.6
363020116290001	546272	4039945	20	70	681.5	100	8	8	681.5	676.6
363026116160401	565574	4040255	33	70	686.6	10.3	8	9	686.9	586.9
363026116160402	565574	4040255	33	70	680.8	10.3	8	9	681.2	581.2
363026116275601	547863	4040139	21	70	677.4	100	8	8	655.0	628.2
363027116270001	549256	4040177	22	70	677.3	100	8	9	635.2	522.5
363028116270201	549206	4040208	22	70	677.3	3.3	8	9	653.5	595.6
363030116104501	573458	4040473	38	69	714.1	10.3	7	8	714.4	691.3
363030116280001	547763	4040261	21	70	685.5	100	8	8	685.5	680.9
363039116303501	543906	4040518	19	70	686.2	10.3	8	9	687.8	587.8
363045115280201	637258	4041684	63	66	894.4	1.6	7	7	884.2	875.1
363046116281401	547409	4041184	21	70	686.1	1.7	8	8	678.5	631.5
363046116285701	546340	4041116	20	70	687.2	10.4	8	8	687.6	681.8
363050116105001	573379	4041058	38	69	714.8	100	7	8	714.1	691.3
363053116271001	549003	4040977	22	70	677	100	8	9	677.0	577.0
363053116272001	548754	4040976	22	70	681.6	3.3	8	8	674.2	617.5
363054116270401	549152	4041009	22	70	678.8	100	8	8	674.5	615.1

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	top	bottom	top	bottom
363058116270501	549126	4041132	22	70	682	1.6	8	9	658.3	593.7
363109116252601	551586	4041485	24	70	677.7	10.3	8	8	674.6	647.1
363109116253101	551458	4042070	24	69	687.6	100	8	8	683.0	645.5
363111116275601	547855	4041525	21	70	688.3	1.7	8	8	681.5	620.6
363111116290201	546214	4041516	20	70	692.5	100	8	8	692.5	682.8
363111116300001	544769	4041878	19	70	687.9	100	8	8	688.0	662.5
363115116242001	553227	4041680	25	69	704	100	7	8	704.0	604.0
363117116303601	543875	4041689	19	70	688.7	3.3	8	8	692.2	648.0
363120116300001	544770	4041786	19	70	687	1	8	8	688.6	659.3
363121116112301	572550	4042006	38	68	714.7	100	7	8	715.8	699.4
363129116241701	553299	4042112	25	69	677.2	10.3	8	8	677.2	652.2
363129116242501	553100	4042111	25	69	674.9	1.7	8	8	666.9	651.6
363129116252901	551508	4042101	24	69	677.3	4.1	8	8	659.9	652.2
363132116285201	546459	4042165	20	70	685.3	100	8	9	685.3	585.3
363133116250101	552204	4042228	24	69	675.3	100	8	8	675.3	664.4
363134116292001	545762	4042223	20	70	684.9	1.6	8	8	679.1	655.0
363135115281401	636935	4043220	63	65	890.5	1.6	7	7	884.6	869.3
363136116271501	548745	4042609	22	69	687.5	10.5	8	8	681.8	626.1
363138116142701	568243	4042495	35	68	701.2	100	7	7	701.3	713.8
363138116252101	551555	4042625	24	69	692.2	1.4	8	8	692.8	625.2
363138116290201	546335	4042164	20	70	688.6	1.4	8	8	689.1	683.0
363138116310101	542875	4042701	18	69	688.8	100	8	8	688.8	654.7
363138116323801	540836	4042629	16	70	688	2.4	8	8	690.7	651.2
363140116275301	547926	4042173	21	69	687.9	1.1	8	8	683.4	655.0
363145116310601	543125	4042548	18	69	689.5	10.3	8	8	690.7	649.2
363148116251001	551977	4042689	24	69	676.1	1.9	8	8	675.2	656.9
363155116323301	540960	4042846	17	69	689.5	100	8	8	675.4	635.8
363157116221201	556303	4042870	27	69	693.9	1.8	8	8	694.4	693.1
363200116304401	543966	4043353	18	69	689.1	10.3	8	8	690.2	668.8
363200116323301	540959	4043000	17	69	693.7	100	8	8	690.4	649.2
363203116295801	544810	4043604	19	69	689.1	2.3	8	8	657.8	634.0
363205115335601	628415	4044013	62	65	941.3	100	6	7	902.3	867.8
363205116271801	548789	4043564	22	69	687.9	3.9	8	8	685.2	630.4
363209116314001	542275	4043283	17	69	678.1	1	8	8	679.0	640.7

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	top	bottom	top	bottom
363210116313801	542325	4043314	17	69	689.9	1.6	8	8	690.8	651.6
363211116294601	545110	4043359	19	69	689.5	10.3	8	8	690.4	660.8
363212115240301	643159	4044462	64	64	882.2	3.3	7	7	856.5	847.4
363212116270401	549286	4043567	22	69	688.5	3.3	8	8	689.8	647.1
363213116133700	569204	4043581	35	68	719.7	10.3	7	9	719.8	530.6
363213116133800	569180	4043581	35	68	719.5	1	9	9	543.2	526.5
363213116133901	569155	4043580	35	68	719.4	10.3	7	9	719.4	479.1
363213116134001	569130	4043580	35	68	719.9	10.3	7	9	720.1	530.3
363214116284801	546552	4043459	20	69	688.2	6.1	8	8	664.5	656.8
363217116320001	541352	4044049	17	69	692.6	5.6	8	9	661.7	565.7
363223116292201	545701	4044441	20	68	690.2	100	8	8	690.2	626.6
363223116295501	544284	4044310	19	69	687.9	1.5	8	8	688.2	627.3
363223116303801	543937	4044154	18	69	690.7	10.3	8	9	675.7	590.1
363223116345901	537325	4043692	14	69	693.9	1.3	8	8	677.1	635.7
363225116260901	549954	4044156	22	68	688.1	1.6	8	8	685.2	610.2
363225116282401	546771	4044323	20	68	687.6	100	8	9	673.7	596.2
363225116310901	543042	4044211	18	69	689.8	100	8	8	689.8	627.3
363230116260501	550602	4043975	23	68	686.5	100	8	9	686.5	586.5
363231115322201	630741	4044850	62	64	907.7	1	6	7	941.3	898.9
363237116292901	545528	4044163	19	69	690.4	3.3	8	8	683.6	626.6
363238115464601	609254	4044766	58	65	1014.7	1	6	7	1007.9	850.6
363243116354101	536278	4044304	13	69	687.8	100	8	9	687.8	587.8
363244116320701	541323	4044912	17	68	690.1	100	8	8	688.2	618.1
363248116302801	544060	4044494	18	68	685.9	100	8	9	685.8	585.8
363248116303101	543981	4045325	18	68	692.8	10.3	8	9	693.0	575.5
363250116251301	551888	4045000	24	68	700	1.7	8	9	695.8	580.0
363252116265001	549476	4045170	22	68	691.3	1.6	8	8	684.3	623.3
363252116292501	545524	4044964	19	68	691.4	10.3	8	9	684.0	577.3
363254116295501	544729	4044960	19	68	690	10.4	8	9	692.2	501.7
363255115515801	601490	4045195	56	66	1010	1	6	6	1010.7	961.6
363256116282101	547214	4045158	21	68	687.4	1.6	8	8	693.1	635.2
363310116294001	545250	4045178	19	68	691.5	1	8	8	692.9	618.2
363316116362401	535205	4045316	13	68	688.9	1.7	8	8	688.8	666.0
363317116293001	545494	4045980	19	68	691	100	8	8	691.0	650.7

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	(meters ²) variance	top	bottom	top	bottom
363332115244001	642250	4046789	64	63	842.3	3.3	7	7	842.5	799.2
363332116323501	540523	4045832	16	68	692.1	2.5	8	8	693.1	659.5
363338116303101	543977	4046034	18	68	691.3	19.6	8	8	691.9	634.0
363340116332901	539971	4046816	16	67	694.1	10.3	8	8	679.1	635.2
363340116362801	535101	4046425	12	68	692.9	1.6	8	8	677.5	604.4
363342116325101	540792	4046820	16	67	693.9	10.3	8	8	695.1	678.5
363342116335701	539151	4046843	15	67	696.5	100	8	8	696.5	647.7
363342116345401	537039	4046710	14	68	690.7	2.5	8	8	685.5	636.8
363344116304501	543925	4046496	18	67	691.2	1.6	8	8	693.8	651.1
363346116322801	541612	4046700	17	67	694.2	10.3	8	8	695.2	635.8
363348116254901	550985	4046381	23	67	695	1	8	8	698.0	624.8
363348116292701	545118	4046595	19	67	691	2	8	9	684.2	598.9
363350116252101	552101	4046881	24	67	699.5	2.5	7	8	700.5	658.4
363354115400601	619168	4047240	60	64	970.2	100	6	6	970.2	969.2
363355116254901	550984	4046597	23	67	691.3	2.4	8	8	680.6	602.9
363356115400501	619192	4047302	60	64	969.3	100	6	6	969.3	968.3
363356115400601	619167	4047271	60	64	969.3	100	6	6	969.3	968.3
363402116344201	537735	4046744	14	68	689.6	100	8	9	689.7	589.7
363405116321501	541385	4047562	17	67	705.6	11.2	7	8	701.1	648.7
363407115215301	646332	4048060	65	62	865.8	3.3	7	7	866.0	844.9
363407116243501	552394	4047684	24	66	709	100	7	8	709.0	625.5
363407116273301	548397	4046951	21	67	701.3	100	8	8	676.9	646.5
363407116342501	537731	4047668	14	67	691.4	10.9	8	8	691.3	617.5
363409116233701	551352	4047431	23	67	713.2	100	7	8	713.2	694.9
363410116261101	550434	4047056	23	67	691.2	100	8	9	679.1	539.5
363411116264701	549536	4047667	22	67	689.5	100	8	8	689.5	694.0
363411116272901	548496	4047075	21	67	688.9	100	8	8	678.1	647.7
363415116275101	547945	4047781	21	67	696.2	100	8	8	696.2	650.5
363417116271801	548470	4047260	21	67	690.1	4.3	8	8	692.0	682.8
363422115433701	613911	4048032	59	64	984.6	3.3	6	6	969.9	964.7
363428116234701	554010	4047632	25	66	719.3	1	7	8	710.4	673.2
363428116240301	553613	4047629	25	66	720.1	10.4	7	8	700.1	663.2
363428116281201	547424	4047593	21	67	690.4	100	8	9	690.4	590.4
363429116233401	554333	4047665	25	66	715.7	100	7	8	715.7	615.7

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	top	bottom	top	bottom
363429116315901	541782	4047595	17	67	690.8	3.4	8	8	675.5	637.7
363430115400501	619177	4048350	60	63	940.9	100	6	6	940.9	931.2
363434116354001	536659	4048403	13	67	692.4	1	8	8	693.2	650.9
363436116333201	540038	4048449	16	67	693	10.8	8	8	670.5	640.1
363436116342301	538199	4048441	14	67	706.9	10.9	7	8	708.9	664.5
363436116345901	537305	4048375	14	67	726	100	7	8	726.0	630.0
363437116010801	587784	4048188	47	65	735.8	1	8	8	697.4	675.7
363438116324601	540612	4048082	16	67	696.6	3.5	8	8	682.2	630.4
363440116282401	547124	4047961	20	67	686.4	100	8	8	686.4	642.8
363442116363301	534971	4047965	12	67	689.1	100	8	8	683.0	664.7
363447115404601	618076	4048858	60	63	934.1	1.7	6	7	914.4	827.5
363452115404401	618199	4049014	60	63	938.9	2.3	7	7	875.7	779.1
363452115405101	617976	4048919	60	63	933.3	10.6	7	7	890.0	771.1
363454116314201	542198	4048891	17	66	693.4	1.6	8	8	669.1	605.1
363456116335501	538893	4048998	15	66	707.4	1.7	8	8	678.8	649.9
363500115400001	619799	4046540	60	64	958.9	100	6	7	957.1	807.8
363503116284001	546722	4048668	20	66	693.6	3.5	8	8	691.9	679.7
363503116351501	536906	4048620	13	67	690.9	1.8	8	8	685.2	679.1
363508115391701	620354	4049537	60	63	932.5	1	6	6	932.8	925.2
363511116335101	538993	4048876	15	66	690.8	100	8	9	690.8	590.8
363514115475001	607603	4049553	57	63	835.8	1	7	8	831.5	636.7
363519116322001	541522	4049935	16	66	693.7	10.3	8	8	676.0	615.1
363521116352501	536655	4049174	13	66	691	1.9	8	8	691.6	653.5
363523116353701	536354	4050004	13	66	693.7	1.7	8	8	692.2	655.6
363527115510901	602653	4049893	56	63	832.3	100	7	8	832.4	691.3
363527116292501	545600	4049401	19	66	697.8	2.3	8	8	698.7	637.3
363529115391301	620444	4050186	60	62	930	1	6	6	929.5	920.3
363529115392101	620246	4050183	60	62	930	1	6	6	930.3	922.9
363530116021401	586127	4049804	46	64	721.7	100	7	10	717.5	366.0
363540116240801	553474	4049847	24	65	721.9	3.3	7	8	725.1	676.3
363549116305001	543484	4050068	18	66	695.9	10.3	8	9	695.0	582.8
363621116263201	549683	4052320	22	64	704.4	100	8	8	682.8	646.2
363709116264601	549533	4052566	22	64	704	100	7	8	704.0	604.0
363711116263701	549750	4053646	22	64	707.7	3.5	7	8	709.2	632.1

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	top	bottom	top	bottom
363742116263201	549867	4054910	22	63	706.7	2.2	8	8	679.7	621.8
363750115394099	619709	4054522	60	61	737.8	100	6	7	936.0	836.0
363815116175901	562608	4054685	30	63	725.1	1	7	8	707.5	687.7
363830116241401	552822	4054927	24	63	705.4	1	8	9	694.6	567.5
363835116234001	554136	4055244	25	63	705.4	1	8	8	689.4	658.9
363836116234001	553812	4055457	24	63	702.8	8.5	7	8	702.0	648.3
363840116233501	554011	4055335	24	63	701.6	100	8	8	695.6	656.9
363840116234001	554135	4055398	25	63	705.6	100	7	8	705.6	690.4
363840116235000	553887	4055396	24	63	704.1	100	7	8	704.1	659.9
363907116235701	553708	4056227	24	62	718.4	100	7	8	718.4	676.3
363910115300099	634076	4057201	63	59	843	100	6	7	934.5	834.5
364141116351401	527996	4060511	7	61	718.9	1	9	9	517.5	514.5
364141116351402	527996	4060511	7	61	722.5	21.9	7	7	707.2	706.3
364215116362701	534411	4062693	11	60	716	100	7	8	787.9	687.9
364243116432401	524714	4062750	6	61	730.1	10.3	11	11	298.7	256.1
364246116445701	522406	4062836	5	61	743.2	10.3	7	11	743.3	256.1
364247116442301	523250	4062869	5	61	736.6	10.3	11	11	243.9	240.8
364457116231201	550737	4067333	22	58	729.7	100	7	8	729.7	683.0
364514116482901	517138	4067384	4	59	873.4	10.3	7	7	873.5	752.9
364534116065902	578874	4068347	40	57	729.3	1	11	11	302.6	226.4
364550116472701	518673	4068497	4	59	799.6	100	7	9	799.6	566.9
364552116413301	527449	4068582	6	59	737.9	10.3	7	7	738.0	721.1
364554116232401	554447	4068773	24	58	727.7	1	7	8	711.7	642.8
364557116410901	528043	4068738	7	59	751.5	1	7	7	751.6	746.9
364557116411101	527994	4068738	7	59	751.3	1	7	7	751.4	746.7
364557116411201	527969	4068738	7	59	763.9	100	7	8	763.9	674.5
364557116411401	527919	4068738	7	59	752	1	7	7	752.1	747.0
364557116411501	527895	4068738	7	59	746.1	100	7	7	717.8	714.8
364557116411801	527820	4068737	7	59	751.8	1	7	7	751.9	746.9
364557116413701	527349	4068736	6	59	738.3	100	7	7	738.3	732.8
364557116434501	524176	4068726	5	59	755.9	10.5	7	7	743.1	737.0
364559116521901	511433	4068761	3	59	1001.4	100	6	6	1001.4	1001.2
364600116412001	527770	4068830	7	59	754	1	7	7	754.2	749.9
364600116413001	527523	4068736	6	59	751.3	100	7	8	709.2	672.7

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	top	bottom	top	bottom
364601116414101	527250	4068859	6	59	744.4	100	7	7	744.5	738.4
364603116410801	528067	4068923	7	58	757.3	1	7	7	757.4	754.7
364603116412101	527745	4068922	7	58	760.3	1	7	7	760.5	756.9
364607116410701	528092	4069046	7	58	759.7	1	7	7	759.9	756.8
364615116412401	527670	4069291	6	58	761.2	1	7	7	761.2	756.5
364615116412402	527670	4069291	6	58	755.8	100	7	7	707.9	704.5
364635115572901	592986	4070369	49	55	725.8	100	7	8	730.6	675.4
364649116280201	547546	4070427	19	57	730.5	1	8	8	681.7	678.1
364656116261601	550172	4070657	21	57	729.4	1	8	8	689.4	685.8
364706116170601	563802	4071057	30	56	732.2	1	7	8	721.1	653.8
364708115574401	592476	4071750	49	54	727.7	1.1	8	9	668.7	573.3
364732116330701	539979	4071713	14	57	779.4	1	8	12	685.8	201.2
364757116245801	552094	4072549	22	56	729.5	1	8	8	690.8	687.1
364758116331701	539728	4072513	14	57	789.4	100	7	8	789.5	689.5
364804115580801	591990	4073101	49	53	734.2	100	7	8	734.7	668.1
364805115580801	591990	4073132	49	53	734.2	1	7	8	729.1	668.2
364814116485401	516507	4072929	3	57	791.1	100	7	9	791.2	499.9
364822116262601	549908	4073306	21	56	729.6	1	7	7	708.6	704.7
364825116290501	545968	4073376	18	56	775.9	1	7	7	724.4	720.8
364828116234001	554021	4073516	23	55	728.2	1	7	13	707.4	1.5
364830115512601	601943	4074016	55	52	728.7	1	7	9	729.4	500.2
364844115541301	597800	4074399	52	52	727.3	100	7	7	727.3	700.5
364905116280101	547547	4074617	19	55	730.4	1	8	14	688.6	-53.0
364915115574101	592635	4075296	49	52	733.8	1	7	10	729.1	434.4
364916116265601	549155	4074966	20	55	730.5	1	8	8	697.6	693.9
364922115580101	592138	4075476	49	52	733.9	1	8	8	638.5	602.6
364923115575701	592236	4075538	49	52	733.8	1.1	7	8	735.1	669.6
364928115580101	592136	4075691	49	52	715.6	1	7	9	718.0	559.2
364933116285701	546155	4075473	18	54	775.7	1	7	7	719.3	715.6
364938116252102	551505	4075657	22	54	752.3	1	14	16	-182.7	-691.1
364942116280001	547565	4075758	19	54	731.4	1.1	7	8	729.1	690.7
364942116280002	547565	4075758	19	54	732.6	1	7	8	732.8	632.8
364942116280003	547565	4075758	19	54	754.3	1	7	8	759.1	659.1
364942116280004	547565	4075758	19	54	731.1	1	7	8	731.5	631.5

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	top	bottom	top	bottom
364942116280005	547565	4075758	19	54	772.2	1	7	8	772.7	672.7
364945116235001	553734	4075825	23	54	729	1	7	8	729.3	678.9
364947116254300	550958	4075931	21	54	730.1	100	7	12	714.6	219.2
364947116254301	550959	4075870	21	54	729.3	100	7	12	716.2	217.8
365011115584701	590982	4077004	48	51	734.3	1	7	12	734.5	162.7
365023116271801	548599	4077027	20	53	730.6	1	8	8	683.2	679.5
365032116243501	552634	4077328	22	53	730	1	8	8	682.9	679.3
365032116265401	549192	4077308	20	53	729.8	1	7	7	715.1	709.0
365032116265402	549192	4077308	20	53	730	1	7	8	730.1	630.1
365032116265403	549192	4077308	20	53	730.1	1	7	8	730.3	630.3
365049116285501	546192	4077815	18	53	775.1	100	7	13	775.1	81.9
365049116285502	546192	4077815	18	53	775.8	1	7	8	776.0	676.0
365049116285503	546192	4077815	18	53	777.8	1	7	8	778.1	678.1
365049116285504	546192	4077815	18	53	775.5	1	7	8	775.5	675.5
365049116285505	546192	4077815	18	53	775.3	1	7	8	775.3	675.3
365105115565801	593663	4078698	49	49	733.7	1	7	8	733.7	633.7
365105116262401	549929	4078329	20	52	731	1	7	10	731.2	436.9
365108116262301	549953	4078421	20	52	730.3	1	13	13	1.3	-15.1
365108116262302	549953	4078421	20	52	728.3	1	7	8	728.5	628.5
365108116262303	549953	4078421	20	52	730.5	1	7	8	730.7	630.7
365114116270401	548936	4078600	20	52	730.1	1	7	10	720.9	354.2
365116116233801	554037	4078693	23	52	728.9	1	7	8	729.2	668.5
365122116275501	547672	4078840	19	52	774.8	1	7	8	771.8	697.1
365122116275502	547672	4078840	19	52	775.2	1	7	8	775.5	675.5
365122116275503	547672	4078840	19	52	775.1	1	7	8	775.5	675.5
365140116260301	550442	4079410	21	52	730.6	1	8	8	695.2	691.6
365147116185301	561088	4079696	28	51	748.3	100	7	8	748.3	614.5
365152115565701	593672	4080146	49	49	733.5	1	7	8	733.5	633.5
365157116271201	548731	4079924	20	51	730.9	1	7	16	731.2	-525.8
365157116271202	548731	4079924	20	51	784.9	1	7	8	785.0	685.0
365157116271203	548731	4079924	20	51	731.1	1	7	8	736.2	636.2
365157116271204	548731	4079924	20	51	730.1	1	7	8	730.6	630.6
365157116271205	548731	4079924	20	51	730.4	1	7	8	730.7	630.7
365201115581601	591713	4080402	48	48	733.5	1	7	8	733.5	633.5

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	(meters ²) variance	top	bottom	top	bottom
365213115564401	593987	4080797	50	48	734.9	100	7	8	734.8	670.8
365239116020901	585932	4081513	44	48	848	100	7	7	900.0	850.0
365239116253401	551149	4081233	21	50	738.3	1	7	8	700.7	697.0
365259115571601	593179	4082206	49	47	736.2	1.2	7	8	737.3	654.4
365322116273501	548146	4082540	19	50	1030.7	1.4	6	15	1031.9	-276.7
365326116520201	511835	4082535	2	52	1081.3	100	5	6	1081.2	1042.4
365340116264601	549356	4083102	20	49	1034.1	1	6	6	946.6	942.6
365412116013901	586646	4084386	44	46	844.4	1	7	8	774.2	655.0
365418116012601	586966	4084574	45	46	843.3	1.1	7	8	810.6	646.9
365437116384401	531575	4084775	8	49	1174	100	4	5	1219.2	1119.2
365445116383901	531701	4085021	8	49	1194.8	1	5	6	1180.5	1030.5
365500116003901	588115	4085881	45	45	724.6	1	7	8	725.1	674.8
365502115134101	657846	4086952	66	40	940.5	10.3	6	7	940.7	865.6
365503116444101	522743	4085547	5	49	1027.2	100	6	6	1027.2	1026.2
365506115142499	656776	4087057	66	40	925.2	100	6	7	990.9	890.9
365508116003501	588212	4086128	45	45	725.6	1.1	7	8	716.3	683.3
365508116003502	588212	4086128	45	45	724.7	100	7	8	719.6	676.6
365517116365801	534193	4086018	10	48	990	100	5	5	1193.0	1093.0
365520116370301	534073	4086108	9	48	1009.2	1	6	7	954.3	710.4
365527116475301	517990	4086275	3	49	1161.3	100	5	6	1097.3	957.0
365550116091101	575433	4087299	37	45	819.1	1	7	7	826.9	751.9
365636116430801	524169	4088416	5	47	1085.1	100	5	5	1085.1	1084.1
365709116481101	517538	4089417	3	47	1238.4	100	4	5	1231.4	1082.1
365711115115101	660493	4090978	67	37	929.1	100	6	7	929.2	849.8
365711115115201	660468	4090978	67	37	929.4	1.6	6	7	929.6	849.8
365731116425501	525352	4090114	5	46	1085.1	100	5	5	1085.1	1084.1
365740116043501	582224	4090754	41	42	745	100	7	8	759.5	678.4
365749116431101	524954	4090668	5	46	1085.1	100	5	5	1085.1	1084.1
365804116432101	524706	4091129	5	45	1083.6	100	5	5	1083.6	1082.6
365810116425101	524778	4091869	5	45	1097.3	100	5	5	1097.3	1096.3
365821116343701	537742	4073213	13	56	810.4	100	7	14	754.9	-244.8
365849116002101	587796	4092811	45	40	739.1	1	7	8	739.4	692.8
365856116453701	522030	4093217	4	44	1249.7	100	4	4	1249.7	1248.7
365905116012001	587023	4093420	44	40	739.7	1	9	14	562.6	-83.3

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	top	bottom	top	bottom
365905116012002	587023	4093420	44	40	739.4	1	9	9	562.6	501.6
365905116033201	583760	4093387	42	40	741.2	100	9	13	555.3	15.5
365930115075499	666267	4095376	67	34	930.2	100	6	7	978.7	878.7
365943116032901	583822	4094559	42	40	730.1	1.1	7	8	739.3	671.8
370002116430101	524573	4094210	5	43	1127.8	100	5	5	1127.8	1126.8
370003116424501	526128	4094801	5	43	1188.7	100	5	5	1188.7	1187.7
370005116040301	582975	4095228	41	39	743.1	1	9	12	567.3	194.2
370017116014201	586457	4095633	44	39	735.4	1.1	7	7	736.3	704.6
370020116003701	588062	4095742	45	39	738.4	1	7	7	738.9	718.2
370053116002901	588249	4096761	45	38	736.9	1	7	7	737.2	718.0
370116115561301	594564	4097539	49	37	729.2	100	9	9	578.0	488.1
370116115561302	594564	4097539	49	37	729.1	100	8	8	670.6	639.5
370142116021100	585729	4099200	43	36	732.1	100	7	8	732.1	693.7
370142116021101	585729	4099200	43	36	729.7	1.3	7	8	730.9	651.0
370154116430201	525156	4097787	5	41	1204	100	4	4	1204.0	1203.0
370208116092401	575008	4098945	36	37	1174.6	100	5	6	1174.6	1033.4
370208116092402	575008	4098945	36	37	1306	1	6	6	1023.7	967.0
370214116021002	585724	4099233	43	36	731.2	100	10	10	432.8	418.1
370214116452701	521843	4098424	4	41	1213.1	100	4	4	1213.1	1212.1
370218116033101	583726	4099334	42	36	745.9	1	7	9	746.1	522.1
370246116064901	578826	4100150	38	36	1112.1	100	5	5	1112.1	1089.4
370253116055201	580232	4100379	39	36	886.7	1	7	7	889.1	708.9
370254116064201	578997	4100398	38	36	1105.9	1	5	6	1106.3	920.1
370254116070601	578404	4100393	38	36	1145.6	1	5	6	1146.1	1019.9
370254116082002	576576	4100376	37	36	1199.8	1	5	8	1139.5	661.5
370301116065301	578723	4100612	38	36	1146	100	5	6	1146.0	1048.1
370301116185801	560812	4100465	26	37	1280	100	3	4	1417.0	1317.0
370301116185802	560812	4100465	26	37	1280	100	3	4	1417.0	1317.0
370311115591901	589959	4101032	46	35	728.8	100	7	8	728.7	677.5
370320116012001	586913	4101709	44	35	729	1	10	11	359.7	299.4
370321115594201	589363	4101334	45	35	748.2	1	7	8	748.2	670.8
370321115594202	589363	4101334	45	35	743.7	1	7	9	723.0	530.9
370326116021101	585681	4101450	43	35	731.5	1.1	7	8	732.2	623.6
370334116012100	586938	4101709	44	35	727.6	1	10	11	359.7	300.0

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	top	bottom	top	bottom
370337116033001	583726	4101769	42	35	770.4	1	7	9	770.7	501.3
370337116033002	583726	4101769	42	35	739.5	1	9	10	494.6	451.6
370338116011801	586986	4101833	44	35	732.8	100	8	9	632.2	492.0
370339116011901	586961	4101863	44	35	732.5	100	7	9	732.6	492.3
370348116024301	584884	4102120	42	34	771.1	1	7	7	771.2	767.3
370353116000601	588760	4102314	45	34	750.7	1	7	9	751.3	594.5
370353116020201	585895	4102284	43	34	730.4	1	7	9	717.2	552.3
370353116021401	585598	4102312	43	34	724.1	100	11	12	243.4	154.1
370355116013001	586684	4102354	43	34	732	1.1	7	9	727.5	545.2
370406116095600	574307	4102760	35	35	1198.5	100	5	5	1198.5	1174.7
370411116025901	584482	4102824	42	34	770.1	1	7	7	770.5	724.2
370411116025905	584482	4102824	42	34	774.8	1.1	7	8	783.6	601.4
370411116025912	584482	4102824	42	34	771.3	1	7	7	750.8	744.4
370412115593601	589494	4102907	45	34	729.6	1	6	8	962.1	641.5
370412116095101	574307	4102760	35	35	1198.2	100	5	9	1078.7	513.3
370418116044501	582229	4103326	40	34	740.5	100	7	8	725.4	671.1
370419116101700	574131	4103159	35	34	1236.9	1	4	5	1204.4	1068.8
370425116095801	574131	4103159	35	34	1237.2	1	4	5	1204.4	1061.5
370428116043001	582229	4103326	40	34	740	1	7	8	740.7	671.1
370434116040702	582795	4103517	41	34	763.2	2.8	7	9	765.2	560.9
370435116040701	582795	4103547	41	34	766.4	1.1	7	7	766.8	762.2
370436116000201	588844	4103640	45	33	774.2	1	7	7	775.1	745.0
370444116001801	588447	4103882	45	33	757.4	1	7	8	757.4	603.2
370447116030501	584322	4103932	42	33	764.3	100	7	7	764.3	764.3
370451116024102	584914	4104062	42	33	820.9	1	7	7	821.5	735.9
370454116003201	588098	4104187	44	33	754.2	1.4	7	8	754.2	677.7
370501116041301	582664	4104347	41	33	760.9	1.3	7	10	792.2	393.5
370509116040301	582785	4104595	41	33	763.5	1	6	6	1005.0	969.0
370513116025101	584512	4104736	42	33	756.1	1	7	9	764.1	559.9
370514116000601	588733	4104810	45	32	761.9	1	7	7	763.4	742.6
370514116024101	584907	4104770	42	33	800.2	100	7	7	800.2	799.9
370520116025701	584510	4104951	42	33	740.5	100	7	7	740.5	874.9
370547116041101	582675	4105765	41	32	795.6	100	7	7	796.4	737.3
370547116041102	582675	4105765	41	32	777.5	100	7	10	748.8	415.1

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	top	bottom	top	bottom
370547116041104	582675	4105765	41	32	794.5	100	7	8	807.8	668.1
370556116000901	588646	4106103	45	32	731.5	1	7	8	734.3	659.6
370556116025401	584573	4106061	42	32	775.3	100	7	7	775.3	744.5
370601116030102	584398	4106214	42	32	773.6	1	10	11	386.8	343.5
370601116030103	584398	4106214	42	32	772.9	1	7	9	774.3	489.2
370605116012401	586791	4106361	43	32	825.4	1	7	7	825.8	818.8
370608116043102	582175	4106408	40	32	784.8	1.1	7	9	785.5	550.2
370616116090801	575335	4106590	36	32	1318.1	1	3	4	1377.4	1295.0
370626116015601	585995	4107000	43	31	727.4	100	9	10	553.8	474.2
370631116551801	506964	4106719	2	36	1204.2	3.3	4	5	1204.2	1104.2
370645116031901	583940	4107565	41	31	793.5	1	7	7	794.0	724.3
370648116473001	518513	4107260	3	35	1202.4	3.3	4	5	1203.0	1195.7
370700116474001	518266	4107630	3	35	1220.4	100	4	5	1220.4	1120.4
370704116474201	518785	4107384	3	35	1236.1	100	4	5	1236.1	1136.1
370712116073901	577516	4108336	37	31	805.1	100	7	7	805.1	796.5
370720116041601	582523	4108630	40	30	748.8	1	7	7	749.1	741.2
370723116033101	583633	4108733	41	30	763.1	1	7	7	763.6	703.0
370726116040302	582842	4108818	41	30	746.7	100	7	9	746.7	576.0
370728116042001	582422	4108875	40	30	754.2	1.1	7	7	755.8	743.3
370736116050301	581359	4109112	40	30	763.8	1.1	7	10	778.1	452.3
370737116035901	582938	4109158	41	30	741.1	100	7	9	741.1	526.3
370741116194501	559593	4109084	25	31	1306.3	100	6	7	1007.4	792.8
370753116502701	514142	4109255	2	34	1203.1	1.6	4	5	1203.1	1103.1
370758116040601	582758	4109803	40	29	748.2	1.3	7	9	749.5	592.5
370802116050301	581351	4109913	39	29	748.4	1	7	7	749.0	705.1
370806116264001	549324	4109757	18	31	1271.9	1	5	12	1191.5	162.8
370815116032701	583716	4110337	41	29	787.9	1.6	7	7	788.7	778.6
370819116022901	585170	4110475	42	29	740.3	1	7	8	740.7	668.8
370823116050001	581419	4110561	39	29	745.7	1	7	8	746.1	606.8
370831116080701	576803	4110764	36	29	1010.9	1	6	7	1026.0	835.8
370836116035001	583142	4110978	41	29	740.7	100	7	8	740.6	641.6
370840116510101	513301	4110702	2	33	1203.2	1.1	4	5	1203.8	1183.9
370846116030851	584175	4111297	41	28	750.8	1.2	7	11	745.0	315.2
370904116040301	582812	4111838	40	28	740.4	1	7	8	805.4	678.9

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	top	bottom	top	bottom
370909116041901	582416	4111988	40	28	734.1	100	7	8	734.1	618.9
370909116041951	582416	4111988	40	28	739.3	1	7	8	741.4	652.4
370910116045901	581429	4112009	39	28	740.2	100	7	9	740.2	593.2
370917116023701	584930	4112260	42	28	735	2.2	7	8	738.3	626.8
370929116132304	568992	4112484	31	28	1271.6	100	7	7	748.5	739.1
370929116132306	568992	4112484	31	28	1276.8	100	7	9	748.5	594.3
370929116132307	568992	4112484	31	28	1437.1	1	4	5	1294.1	1135.6
370929116132308	568992	4112484	31	28	1437.3	1	4	5	1294.1	1135.6
370929116132309	568992	4112484	31	28	1277	1	7	9	748.5	594.3
370929116132311	568992	4112484	31	28	1429.6	1	4	5	1294.1	1135.6
370953116030801	584154	4113361	41	27	734.5	1	8	8	697.8	604.5
370956116172101	563115	4113270	27	28	1407.6	1	3	13	1354.8	62.5
370958116051501	581020	4113485	39	27	759.9	1.6	7	7	778.8	739.2
370958116051503	581020	4113485	39	27	760.2	1.9	7	9	703.8	589.8
370958116051508	581020	4113485	39	27	735.8	100	9	9	585.3	479.8
370958116051511	581020	4113485	39	27	736.5	100	9	11	585.3	319.5
370958116051512	581020	4113485	39	27	736.2	1.1	9	11	539.5	322.5
371014116051601	580991	4113977	39	27	785.8	1	7	7	788.2	721.6
371014116051602	580991	4113977	39	27	785.8	1	7	8	786.0	615.2
371043116142101	567540	4114754	30	27	1325.9	100	7	7	893.0	786.0
371052116125201	569736	4115048	31	27	1416.6	1.4	3	4	1418.0	1339.0
371106116110401	572395	4115502	33	26	1302.4	100	4	7	1257.8	724.9
371108116045301	581542	4115647	39	26	735.2	1.1	7	8	736.2	668.7
371109116024702	584648	4115709	41	25	762.2	1.1	7	7	763.2	739.7
371123116025201	584521	4116139	41	25	759.6	1.2	7	8	761.1	646.5
371123116025202	584521	4116139	41	25	763.9	1.8	7	7	766.3	718.2
371131116021501	585455	4116426	42	25	992.5	4.4	6	6	967.2	920.9
371154116024601	584659	4117095	41	25	996.7	1.2	6	8	997.5	666.4
371154116024602	584659	4117095	41	25	994.9	1	7	7	781.9	754.5
371155116031401	583969	4117119	41	25	757.3	1.1	7	8	757.9	662.0
371155116031402	583969	4117119	41	25	772.6	1.1	7	7	750.4	723.0
371243115050601	670702	4119604	68	18	968.9	1.7	6	6	969.2	955.9
371313116274201	547765	4119240	17	25	1284.5	1	4	4	1284.7	1257.9
371315116282701	546656	4119295	16	25	1276.9	1.1	4	5	1278.0	1114.0

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	top	bottom	top	bottom
371321116292301	545271	4119474	15	25	1278.1	100	13	13	39.0	0.0
371329116220301	556117	4119784	22	24	1350	100	4	14	1271.1	-65.5
371332116254101	550744	4119843	19	25	1303.8	1	4	4	1319.4	1301.9
371339116221601	555794	4120090	22	24	1424.6	1	3	3	1425.1	1409.1
371341116222901	555474	4120150	22	24	1429	1.7	3	3	1429.4	1409.3
371349116222001	555694	4120398	22	24	1423.3	1.1	3	3	1423.9	1408.2
371350116264701	549114	4120388	17	24	1329.7	1	3	4	1367.1	1321.6
371352116281801	546871	4120436	16	24	1267.1	100	4	11	1267.1	285.6
371353116282501	546699	4120466	16	24	1275.3	100	9	10	530.6	451.4
371359116252301	551182	4120677	19	24	1336.8	1.2	4	4	1338.4	1330.1
371401116220601	556036	4120770	22	24	1392	100	3	3	1392.0	1387.1
371401116252001	551256	4120739	19	24	1319.5	1	4	5	1319.7	1171.7
371410116221301	555862	4121046	22	24	1369.8	1.1	3	4	1370.1	1232.9
371416116282201	546769	4121175	16	24	1317.3	100	4	4	1317.3	1258.5
371421116333701	539007	4121290	11	24	1331.3	1	4	4	1331.6	1272.8
371421116333702	539007	4121290	11	24	1330.3	1	4	7	1325.8	854.6
371421116333703	539007	4121290	11	24	1329.8	1	5	5	1189.9	1121.3
371421116333704	539007	4121290	11	24	1330.5	1	4	4	1330.7	1266.7
371425116210101	551153	4121478	19	24	1324.7	1	8	8	649.9	613.3
371425116251901	551276	4121479	19	24	1318.8	100	4	6	1273.7	963.4
371425116251902	551276	4121479	19	24	1349.4	1	4	5	1273.7	1105.4
371433116251301	551153	4121478	19	24	1349.1	1.1	8	8	690.7	665.4
371434116251601	551348	4121757	19	23	1343.7	1	4	7	1255.2	784.6
371434116255101	550486	4121752	18	23	1328.7	100	4	4	1328.7	1323.7
371439115480001	606437	4122429	55	20	1079.3	100	5	6	1079.3	1019.9
371440115483401	605599	4122449	54	20	1204.1	100	5	5	1182.6	1149.4
371444116263001	549523	4122054	18	23	1338.1	1	3	4	1354.0	1302.2
371452116284901	546097	4122281	15	23	1273.9	1.2	5	9	1160.4	536.7
371452116292101	545309	4122277	15	23	1278.5	1	4	4	1279.2	1260.3
371452116293903	544866	4122274	15	23	1280.9	3.3	4	5	1281.1	1184.1
371452116303301	543535	4122267	14	23	1284.4	1.6	4	4	1284.7	1232.6
371459116204801	557921	4122601	23	22	1396.3	100	4	15	1201.8	-341.7
371505116254501	550628	4122708	18	23	1344.6	1	4	6	1279.2	975.3
371505116254502	550628	4122708	18	23	1351.5	1	3	6	1351.6	975.3

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	(meters ²) variance	top	bottom	top	bottom
371505116594101	500472	4122555	1	26	1213.8	3.3	4	5	1211.3	1181.1
371509116223601	555283	4122860	21	22	1358.5	1.6	3	4	1360.1	1321.0
371509116223602	555283	4122860	21	22	1358.8	1	3	4	1359.1	1331.0
371512116193101	559840	4122984	24	22	1495	1	3	3	1495.4	1425.9
371513116193001	559864	4123015	24	22	1497.8	1.1	3	3	1498.1	1380.8
371517116594001	500496	4122925	1	26	1215	100	4	5	1215.0	1115.0
371519116223301	555355	4123169	21	22	1369	100	3	4	1368.9	1331.8
371521116252001	551241	4123205	19	22	1354	1.1	3	4	1355.7	1263.4
371523117012601	497885	4123110	1	26	1213.5	2	4	5	1214.5	1140.0
371537115555001	603065	4124174	53	19	1320.7	100	4	5	1319.7	1190.2
371539115500301	603384	4124240	53	19	1322.6	100	4	4	1306.3	1243.5
371542116251202	551434	4123853	19	22	1375.3	1	3	4	1375.7	1249.9
371542116251203	551434	4123853	19	22	1355.8	1	3	4	1355.9	1287.9
371542116251301	551409	4123853	19	22	1355.5	1	3	4	1355.7	1244.7
371545115495401	603603	4124427	53	19	1322.5	100	4	4	1306.3	1243.5
371547116292601	545177	4123971	15	22	1303.1	1	4	4	1303.9	1263.8
371547117011101	498255	4123850	1	25	1206.9	1.6	4	5	1207.0	1169.5
371551116262501	549634	4124119	18	22	1356.2	1.1	3	4	1357.3	1325.6
371554116185301	560767	4124285	25	21	1429.2	100	3	5	1429.3	1175.1
371604116243801	552267	4124536	19	21	1357	1.1	3	4	1357.2	1338.9
371608116191001	560345	4124714	25	21	1428.9	100	3	7	1405.8	766.0
371608116191002	560345	4124714	25	21	1431.1	1.9	3	15	1405.8	-443.8
371617116291701	545393	4124897	15	22	1322.9	1.5	9	19	506.0	-2307.3
371617116291702	545393	4124897	15	22	1268.7	100	4	9	1268.6	479.5
371617116291801	545369	4124897	15	22	1276.2	100	4	9	1276.2	583.7
371618116260201	550196	4124986	18	21	1355.5	2.1	4	14	1234.7	-198.2
371620116213501	556771	4125058	22	21	1394.5	1	3	3	1394.7	1354.5
371623116243701	552288	4125122	19	21	1356.1	1.6	3	4	1357.9	1228.7
371626115074201	666586	4125688	67	15	1007.7	100	6	6	1007.7	996.1
371630116221202	555858	4125360	22	21	1392.7	100	3	4	1392.7	1203.4
371632116211301	557310	4125432	23	21	1396.9	1	3	3	1399.1	1388.7
371643116212001	557136	4125770	22	20	1398.9	100	3	3	1399.7	1373.4
371646117010101	498502	4125668	1	24	1205.8	100	5	5	1178.0	1159.7
371648116242001	552702	4125895	19	21	1349.2	100	4	15	1349.6	-308.3

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	top	bottom	top	bottom
371649116242101	552677	4125925	19	21	1354.5	1.2	3	15	1354.9	-306.4
371649116242102	552677	4125925	19	21	1359.3	1	15	15	-300.3	-357.6
371658116244401	552109	4126199	19	20	1371.4	1.6	3	3	1371.6	1367.0
371700115072601	666677	4127324	67	14	1012.8	100	6	6	1012.9	991.3
371707115071301	666639	4127971	67	14	1018.6	100	6	6	1018.6	972.3
371711115071501	666595	4127723	67	14	1015.3	100	6	6	1015.4	912.6
371714116230301	554593	4126708	21	20	1427.8	1	3	3	1428.0	1363.1
371746116184601	560914	4127738	25	19	1488.8	1	3	3	1488.9	1481.4
371750116195901	559116	4127848	24	19	1432	1.6	3	11	1354.4	278.5
371750116262701	549563	4127786	17	19	1363.1	1	3	3	1363.4	1352.1
371758116193601	559680	4128099	24	19	1429.7	100	3	4	1429.9	1246.1
371801116320301	541289	4128080	12	20	1412	100	4	13	1268.9	64.9
371802116320301	541289	4128111	12	20	1412.1	100	8	9	672.1	535.2
371807116243001	552441	4128328	19	19	1357.3	100	7	8	755.9	691.9
371830116215301	556301	4129061	22	18	1424.9	1.1	4	14	1240.3	-238.0
371836116215101	556349	4129247	22	18	1424.2	1.2	3	6	1425.2	1049.1
371851116273801	547805	4129656	16	18	1360.3	100	3	7	1360.3	750.7
371852116175701	562105	4129780	26	17	1427.9	1	3	7	1405.7	701.6
371852116281701	546844	4129681	15	18	1364.4	1	3	4	1366.1	1229.5
371901116272501	548123	4129966	16	18	1364.1	1.6	3	13	1365.4	-29.9
371929116185501	560669	4130910	24	17	1429	1.6	3	3	1429.9	1422.5
372003115085301	664400	4132860	67	12	1041.9	100	6	6	1041.9	1035.4
372005115084501	664884	4133301	67	11	1035.4	100	6	6	1035.4	1017.5
372034116222501	555488	4132877	21	16	1422.8	100	3	6	1359.2	1013.2
372034116222503	555488	4132877	21	16	1472.2	1	3	6	1472.7	937.3
372034116222504	555488	4132877	21	16	1423.1	1	3	3	1423.5	1370.7
372042116340501	538263	4133027	9	17	1443	1	6	16	940.5	-974.3
372054116191901	560060	4133525	24	15	1428	1.2	4	13	1310.8	91.3
372115115095401	662577	4135445	66	11	1043.6	100	6	6	1043.6	1035.1
372151115103101	662258	4136641	66	11	1051.6	100	5	6	1051.6	1041.2
372159115095101	663220	4136536	66	11	1216	100	4	5	1216.0	1116.0
372208115094601	663343	4137803	66	10	1053.6	100	5	6	1053.6	953.6
372240115095101	663090	4138168	66	10	1064	100	5	6	1064.0	1047.0
372247115093501	662938	4138381	66	10	1051.6	100	5	6	1051.5	1036.3

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	top	bottom	top	bottom
372248115101001	661757	4138389	66	10	1049.2	100	6	6	1049.2	1020.4
372257115100701	663308	4138326	66	10	1042.5	100	6	6	1042.5	1001.9
372318115100201	662624	4139331	66	10	1214.3	100	4	5	1214.3	1199.7
372341115104801	661110	4140010	66	10	1067.7	100	5	6	1067.7	1002.8
372345115083201	662577	4139237	66	10	1060.6	100	5	5	1060.6	1054.0
372354115054801	662239	4140186	66	10	1065.1	100	5	6	1065.1	1011.3
372411115105201	660952	4140593	66	10	1078.6	100	5	5	1078.6	1070.5
372417115104701	661848	4141320	66	10	1073.7	100	5	6	1073.7	973.7
372500115104002	661565	4143226	66	10	1063.9	1	5	5	1065.0	1054.3
372543116363501	534534	4142287	7	12	1523	1.6	2	2	1523.2	1505.7
372642116281301	546862	4144166	15	11	1421.2	100	3	3	1421.1	1417.0
372749115113401	659931	4147634	66	9	1101.9	100	5	5	1101.9	1100.9
372857115124001	658171	4149697	65	9	1114	100	5	5	1114.0	1113.0
373043115134901	656415	4152932	65	8	1186.1	100	5	5	1186.1	1169.0
373113115130401	657502	4153877	65	8	1148.9	100	5	5	1148.9	1125.6
373155115135801	656153	4155116	65	8	1161.3	100	5	5	1161.3	1160.3
373157115135101	655359	4155564	65	8	1159.1	1.6	5	5	1159.2	1144.0
373158115141001	655856	4155234	65	8	1158.5	100	5	5	1158.6	1137.2
373158115141601	655709	4155231	65	8	1160.7	100	5	5	1160.7	1127.1
373202115141301	655780	4155356	65	8	1159.2	100	5	5	1159.2	1136.9
373202115142301	655535	4155351	65	8	1161.3	100	5	5	1161.3	1107.7
373215115165801	651723	4155681	64	8	1214.7	100	4	5	1214.7	1114.7
373228116472001	518654	4154717	3	10	1652.3	1.2	2	2	1652.4	1651.1
373330115135101	657422	4158100	65	7	1155.6	100	5	5	1155.6	1133.3
373330115142002	655557	4158065	65	8	1199.6	1.2	4	5	1200.9	1189.9
373339115134901	656926	4158368	65	7	1160.4	100	5	5	1160.4	1060.4
373405115090001	663413	4159295	66	7	1109.3	2.8	6	7	923.5	893.1
373453115131401	657595	4160631	65	7	1169.2	100	5	5	1169.2	1146.0
373500115133301	656658	4160860	65	7	1170.1	100	5	5	1170.1	1056.2
373523115133001	656719	4161570	65	7	1171.9	100	5	5	1172.0	1120.2
373554115125201	657632	4162544	65	7	1181.1	100	5	5	1181.1	1180.1
373622116434601	523885	4161942	3	9	1928.8	10.3	1	1	1929.5	1829.5
373622116434701	523860	4161942	3	9	1929.6	10.4	1	1	1930.4	1830.4
373623116434701	523860	4161973	3	9	1929	10.3	1	1	1929.7	1829.7

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	(meters ²)	top	bottom	top	bottom
373623116565201	504123	4161323	1	9	1396	100	3	4	1396.0	1296.0
373624115434101	610612	4162461	55	7	1405.4	100	3	3	1405.4	1383.5
373635115450101	608842	4162807	54	7	1406	100	3	3	1406.0	1362.4
373704115465701	605890	4163478	53	7	1446	100	3	4	1446.0	1346.0
373704115490401	602605	4163467	50	7	1428	100	3	3	1428.0	1414.3
373708115482201	605369	4163995	52	7	1439.9	3.3	3	3	1439.9	1420.4
373713115125101	658199	4163695	65	7	1194.9	100	5	5	1194.9	1172.0
373721115470102	607349	4164421	54	7	1442	100	3	3	1425.8	1361.8
373721115473401	606540	4164411	53	7	1440	10.1	3	3	1442.7	1356.4
373721115483901	604947	4164391	52	7	1438.8	5.2	3	3	1440.2	1412.5
373729115442601	609680	4164329	55	7	1449.1	100	3	4	1449.1	1349.1
373729115454301	607619	4164425	54	7	1456	100	3	3	1456.0	1429.2
373741115480601	604084	4164780	51	7	1431	100	3	3	1431.0	1411.2
373803115050501	669004	4166745	67	6	1086.5	100	5	5	1086.5	1082.0
373813115454001	607381	4165747	53	7	1463	100	3	4	1463.1	1320.7
373815115434601	610442	4166034	55	7	1450.8	100	3	3	1450.9	1401.8
373817115483301	603286	4165819	51	7	1449.3	100	3	3	1449.4	1414.3
373819115465201	605836	4165820	52	7	1449.6	100	3	3	1449.7	1392.1
373833115441101	611487	4166696	56	7	1456.2	149.8	3	3	1446.6	1440.5
373838115424001	612269	4166829	56	7	1442.3	100	3	4	1442.4	1342.4
373851115472001	606848	4167189	53	7	1432.6	100	3	4	1432.6	1332.6
373907115461701	606624	4167433	53	7	1447.1	100	3	3	1447.1	1397.5
373907115472901	605396	4167664	52	7	1450.5	100	3	3	1450.5	1382.3
373943115495701	601096	4168535	49	7	1444.2	100	3	3	1444.2	1437.1
373944115454101	609252	4168854	54	7	1440.4	100	3	4	1440.4	1340.4
373954115114501	659582	4168285	65	6	1176.7	100	5	6	1176.7	1047.6
373955115490201	602484	4169199	50	7	1447.2	100	3	3	1447.2	1405.8
373955115512901	600722	4169085	49	7	1439.3	100	3	3	1439.3	1369.5
373957115440501	609736	4169323	55	6	1448	100	3	4	1447.9	1347.9
374020115494101	601498	4169680	49	7	1445.3	100	3	3	1445.3	1381.6
374024115502901	600739	4171705	49	6	1450.3	100	3	3	1450.3	1443.2
374029115501901	600639	4169855	49	7	1444.4	100	3	3	1444.4	1412.4
374041115114501	659328	4171302	65	6	1162.2	100	5	7	1162.2	866.6
374051115420802	614443	4170990	56	6	1446	3.7	3	3	1446.6	1397.9

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	(meters ²) variance	top	bottom	top	bottom
374052115403001	615401	4170787	57	6	1445.1	100	3	4	1445.1	1345.1
374058115113501	659340	4171949	65	6	1171.7	100	5	5	1171.7	1090.6
374140115490401	602178	4172185	50	6	1445.8	100	3	4	1445.8	1345.8
374230115491701	603322	4174696	50	6	1457.3	100	3	3	1457.3	1456.9
374241116264601	548825	4173732	14	7	1608.1	100	2	3	1591.0	1499.9
374244115420801	612802	4174481	56	6	1443.3	100	3	4	1443.3	1343.3
374247115433202	612336	4174537	56	6	1440.8	100	3	4	1440.9	1340.9
374247115474001	604404	4174340	51	6	1446.8	100	3	3	1446.8	1444.7
374345115415501	614686	4176357	56	6	1446.3	100	3	3	1429.6	1423.5
374356115422601	613923	4176685	56	6	1446.6	3.3	3	3	1446.8	1423.4
374419115453001	609409	4177333	54	5	1464.6	100	3	3	1464.6	1463.6
374506116292300	545571	4177627	12	6	1568	3.4	2	3	1547.2	1489.3
374523115440901	611365	4179332	55	5	1483.6	149.6	3	3	1459.1	1453.0
374525115061801	666939	4180332	66	4	1183.6	7	5	5	1186.0	1150.6
374530115455201	608842	4179514	54	5	1446.4	100	3	3	1446.3	1414.2
374536115445901	610137	4179716	54	5	1446.4	3.3	3	3	1446.4	1414.2
374619116435401	523636	4180340	3	6	1567.4	3.3	2	2	1567.8	1514.3
374658116464101	519548	4181531	2	6	1568.6	100	2	3	1568.6	1472.2
374658116464102	519548	4181531	2	6	1567.9	3.5	2	2	1568.8	1528.6
374700116455101	520771	4181595	2	6	1571.2	100	2	3	1571.3	1493.5
374700116455102	520771	4181595	2	6	1510.6	100	2	3	1510.6	1466.1
374703116445701	522091	4181691	3	6	1564.9	100	2	3	1564.9	1451.2
374716115253801	638494	4183227	61	4	1703.6	233.3	2	2	1703.8	1680.1
374725116452701	521356	4182367	3	6	1564	1	2	2	1564.6	1521.8
374729115483301	603388	4183112	50	5	1444.4	149.6	3	3	1444.5	1441.4
374739116453401	521183	4182798	3	6	1563.8	1	2	2	1559.7	1524.7
374806115413601	613595	4184480	56	5	1452.4	100	3	3	1452.4	1441.7
374844115202601	646078	4186071	63	4	1296.9	100	4	5	1296.9	1146.1
374856115205402	645387	4186429	63	4	1291.7	100	4	5	1291.8	1111.9
374910116373001	533009	4185642	5	5	1578.7	3.3	2	2	1578.8	1569.7
374915116460401	520442	4185755	2	5	1569.9	100	2	3	1517.6	1389.6
374946115460101	586463	4187510	38	4	1460.1	100	3	3	1460.1	1444.8
375051115445301	608413	4189743	53	4	1451.8	100	3	3	1451.7	1351.7
375054116460201	520459	4188806	2	5	1599.8	3.4	2	2	1589.5	1547.1

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	top	bottom	top	bottom
375055116460201	520459	4188837	2	5	1599	3.4	2	3	1599.6	1499.6
375103115463001	607778	4189765	52	4	1445.5	100	3	4	1445.5	1345.5
375139116460001	520407	4190193	2	5	1602	3.3	2	2	1602.2	1537.7
375248116541601	508407	4192298	1	5	1537.7	100	2	2	1536.2	1524.9
375310116472301	518495	4192993	2	5	1600.3	3.9	2	3	1601.1	1410.6
375310116472302	518495	4192993	2	5	1599.5	3.3	2	3	1535.8	1430.4
375348115324301	627910	4195141	59	3	1553.3	100	2	2	1544.1	1538.0
375357115465101	584869	4195106	37	4	1456.6	100	3	3	1456.6	1436.2
375453116450501	521857	4196176	2	4	1610.3	3.3	2	2	1610.3	1602.3
375619116035301	582190	4199209	35	3	1471.6	100	3	3	1471.6	1447.8
375751116030201	583753	4194324	36	4	1469.1	1	3	3	1469.6	1452.1
375820115442301	588966	4161645	42	8	1457.6	100	3	3	1457.6	1442.0
375829116230401	554653	4202986	16	3	1931.9	100	1	1	1932.0	1832.0
375937115414701	614472	4205701	55	2	1443.5	100	3	3	1443.5	1420.3
375951115582201	590198	4205828	40	2	1464	100	3	3	1464.0	1460.0
380018115592901	588554	4206643	39	2	1456	100	3	3	1456.1	1437.2
380054115472601	606173	4207962	50	2	1441.7	100	3	3	1441.7	1409.7
380059115441201	588712	4207816	39	2	1456.7	100	3	3	1456.7	1436.2
380132115333501	626198	4209480	58	2	1564.4	4	2	3	1565.8	1367.0
380132115333502	626419	4209422	59	2	1516	235.2	2	4	1517.3	1310.9
380132115333503	626346	4209421	59	2	1601.5	100	2	3	1601.4	1356.6
380235115475501	605425	4211066	50	2	1448.7	100	3	3	1448.7	1436.2
380301115252901	638436	4183781	61	4	1554.3	100	2	2	1554.3	1527.7
380313116012601	585644	4212006	36	2	1430.6	151.5	3	3	1431.9	1419.1
380348115265001	636224	4213773	60	1	1558.3	149.7	2	2	1558.5	1539.2
380400116380001	532728	4213070	4	2	1643	1	2	2	1643.6	1633.4
380407115262601	636799	4214368	61	1	1540.8	100	2	2	1540.8	1524.0
380453115435601	589142	4215403	38	1	1456	100	3	3	1456.0	1444.1
380511116044801	580685	4215592	33	1	1543.5	100	2	2	1542.0	1535.9
380616116192201	559818	4217416	19	1	1575.8	100	2	2	1575.9	1563.7
380652116200901	558227	4218514	18	1	1534.7	3.4	2	3	1534.9	1414.3
380652116200902	558227	4218514	18	1	1533.1	3.4	2	3	1533.4	1414.3
380652116200903	558227	4218514	18	1	1533.1	3.4	2	3	1533.4	1414.3
380906115410401	593580	4223529	41	1	1455.4	100	3	3	1455.4	1437.1

Table B-1. Target Head Data

Well ID	UTM Zone 11		Model Block		Head:		Estimated Open Interval:			
	Coordinates:		Address:		mean	est. error	Hydrostratigraphic Unit:		Elevation (m above msl):	
	Easting	Northing	Column	Row	(meters above msl)	(meters ²) variance	top	bottom	top	bottom
380906116050501	580200	4222831	32	1	1454.9	1.6	3	3	1428.0	1385.3
380906116050502	580200	4222831	32	1	1456.1	3.4	3	3	1456.6	1376.1
380920116090501	574354	4223207	28	1	1459.8	100	3	3	1459.8	1456.0
380932116051301	579997	4223631	32	1	1454.5	100	3	3	1454.5	1378.0
380932116051302	579997	4223631	32	1	1453.9	100	3	3	1453.9	1374.6
381023116152901	564993	4225069	22	1	1575.5	100	2	2	1574.0	1562.7
381105116221301	555154	4226290	15	1	1676.4	100	2	2	1676.4	1675.4
381232116344501	537141	4228623	5	1	1694.2	100	2	2	1694.2	1693.2
ASH-B-1	529047	4064213	7	60	719.1	100	9	10	504.7	443.1
ASH-B-2	529047	4064213	7	60	719.5	100	7	8	732.4	672.7
BT001	500746	4040131	2	72	-73.2	100	14	14	-73.2	-74.2
BT002	501990	4041363	2	71	-79.3	100	14	14	-79.3	-80.3
BT004	508452	4045681	2	69	-79.3	100	14	14	-79.3	-80.3
BT005	509949	4041061	3	71	-79.3	100	14	14	-79.3	-80.3
BT006	509698	4042909	3	70	-79.3	100	14	14	-79.3	-80.3
BT007	510195	4042910	3	70	-79.3	100	14	14	-79.3	-80.3
BT008	512189	4039523	3	71	3.1	100	13	13	3.1	2.1
BT009	513434	4039217	3	71	61	100	13	13	61.0	60.0
BT010	514427	4040143	3	71	158.5	100	12	12	158.5	157.5
BT012	515422	4040144	4	71	219.5	100	12	12	219.5	218.5
BT013	516168	4040454	4	71	158.5	100	12	12	158.5	157.5
BT120	524240	4088233	5	47	1060.7	100	5	5	1060.7	1059.7
BT128	525227	4089160	5	47	1060.7	100	5	5	1060.7	1059.7
BT139	524728	4090699	5	46	1082	100	5	5	1082.0	1081.0
BT172	525461	4093783	5	43	1112.5	100	5	5	1112.5	1111.5
DV006	510732	4010867	3	76	-79.3	100	14	14	-79.3	-80.3
DV007	513977	4010563	4	76	-86	100	14	14	-86.0	-87.0
DV008	520969	4009345	6	76	-79.3	100	14	14	-79.3	-80.3
DV009	507718	4032431	2	73	-79.3	100	14	14	-79.3	-80.3
DV010	514689	4032748	4	73	97.5	100	13	13	97.5	96.5
DV011	515186	4032749	4	73	97.5	100	13	13	97.5	96.5
DV012	514688	4033057	4	73	97.5	100	13	13	97.5	96.5
DV013	515435	4032750	4	73	121.9	100	12	12	121.9	120.9
DV016	515435	4033058	4	73	121.9	100	12	12	121.9	120.9

Table B-1. Target Head Data

Well ID	<i>UTM Zone 11</i>		<i>Model Block</i>		<i>Head:</i>		<i>Estimated Open Interval:</i>			
	<i>Coordinates:</i>		<i>Address:</i>		mean	est. error	<i>Hydrostratigraphic Unit:</i>		<i>Elevation (m above msl):</i>	
	Easting	Northing	Column	Row	(meters above msl)	(meters ²) variance	top	bottom	top	bottom
DV017	513442	4033979	3	73	15.2	100	13	13	15.2	14.2
DV018	506470	4036128	2	72	-79.2	100	14	14	-79.2	-80.2
DV019	514438	4033672	4	73	48.8	100	13	13	48.8	47.8
DV021	514687	4033673	4	73	121.9	100	12	12	121.9	120.9
DV022	514438	4033980	4	73	48.8	100	13	13	48.8	47.8
DV026	505474	4037976	2	72	-79.3	100	14	14	-79.3	-80.3
DV027	511198	4037057	3	72	-73.2	100	14	14	-73.2	-74.2
DV030	510947	4038597	3	72	-73.2	100	14	14	-73.2	-74.2
DV031	513186	4038600	3	72	30.5	100	13	13	30.5	29.5
DV114	562771	4028342	32	73	684.3	100	8	8	684.3	683.3
DV121	565297	4023738	34	74	686.7	100	8	8	686.7	685.7
DV127	561497	4032338	31	72	702.6	100	7	7	702.6	701.6
DV138	561997	4032034	31	72	709.6	100	7	7	709.6	708.6
DV141	562500	4031421	31	72	713.2	100	7	7	713.2	712.2
DV145	565162	4025554	34	73	682.5	100	8	8	682.5	681.5
DV154	564773	4027124	33	73	691.9	100	8	8	691.9	690.9
DV165	566289	4024362	34	74	693.4	100	8	8	693.4	692.4
DV170	559465	4038179	29	70	692.5	100	8	8	692.5	691.5
DV180	561226	4035418	30	71	714.8	100	7	7	714.8	713.8
DV204	565260	4028668	33	73	704.1	100	7	7	704.1	703.1
DV212	565509	4028670	34	73	708.7	100	7	7	708.7	707.7
ER-20-2-1S	553210	4118446	20	25	1349.8	100	1	1	2042.0	1942.0
ETW-I-4	515798	4078907	3	54	811.6	100	6	8	984.8	670.2
ETW-II-1	515602	4078167	3	54	780.8	100	6	8	984.8	632.7
ETW-II-2	517484	4078171	3	54	783.4	100	6	9	944.7	536.3
ETW-II-5	515828	4076196	3	56	779.9	100	6	9	969.8	543.0
IS017	619568	4046815	60	64	967.7	100	6	6	967.7	966.7
LWS-A-1	549022	4045693	22	68	693.6	100	11	12	227.1	112.8
LWS-A-2	549022	4045693	22	68	685.8	100	8	8	689.5	634.9
MSH-C-1	565375	4039731	33	70	710.2	100	11	12	258.9	199.8
MSH-C-2	565375	4039731	33	70	711.1	100	8	9	636.9	584.4
PM011	523970	4096244	5	42	1133.9	100	5	5	1133.9	1132.9
PM013	524466	4095629	5	42	1121.7	100	5	5	1121.7	1120.7
PM015	524954	4097787	5	41	1182.6	100	5	5	1182.6	1181.6

Table B-1. Target Head Data

Well ID	<i>UTM Zone 11 Coordinates:</i>		<i>Model Block Address:</i>		<i>Head:</i>		<i>Estimated Open Interval:</i>			
					mean	est. error				
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	Hydrostratigraphic Unit:		Elevation (m above msl):	
							top	bottom	top	bottom
PM018	525950	4095325	5	42	1170.4	100	5	5	1170.4	1169.4
PR017	664413	4132029	67	12	1042.4	100	6	6	1042.4	1041.4
PR029	658154	4150407	65	9	1127.8	100	5	5	1127.8	1126.8
PR032	671588	4118298	68	19	981.5	100	6	6	981.5	980.5
PR033	672808	4118940	68	18	960.1	100	6	6	960.1	959.1
QC022	627026	4209371	59	2	1676.4	100	2	2	1676.4	1675.4

Table B-1. Target Head Data

Well ID	<i>UTM Zone 11 Coordinates:</i>		<i>Model Block Address:</i>		<i>Head:</i>		<i>Estimated Open Interval:</i>			
					mean	est. error				
	Easting	Northing	Column	Row	(meters above msl)	variance (meters ²)	Hydrostratigraphic Unit:		Elevation (m above msl):	
							top	bottom	top	bottom
SM23-1	587967	4055901	47	61	724.8	100	8	8	683.1	674.0
SV017	498261	4050915	1	67	-36.6	100	13	13	-36.6	-37.6
UE-29a-1	555758	4088341	24	45	1191.6	1.1	4	5	1204.5	1149.7
UE-29a-2	555749	4088346	24	45	1186.9	1	4	7	1208.3	793.7

Note: The following wells were deleted due to anomolous values:

364556116413501

370254116082001

374256115485500

380643115344201

361994115394201

TR179

Appendix C

Drain Heads and Conductances

Table C-1. Drain Heads and Conductances.

<u>Model Block Address:</u>			<u>Drain:</u>		
layer	row	column	head (m)	conductance (m ² /day)	discharge area
7.00	70.00	35.00	706.66	756.80	AF
7.00	71.00	35.00	707.88	756.80	AF
7.00	71.00	36.00	707.88	756.70	AF
7.00	70.00	36.00	708.18	756.70	AF
7.00	71.00	37.00	708.18	756.80	AF
7.00	70.00	37.00	709.71	756.80	AF
7.00	70.00	38.00	710.28	756.70	AF
7.00	71.00	38.00	710.28	756.80	AF
7.00	69.00	37.00	711.33	504.50	AF
7.00	69.00	38.00	711.33	504.50	AF
7.00	71.00	39.00	711.38	756.80	AF
7.00	70.00	39.00	711.42	756.80	AF
7.00	71.00	40.00	712.42	756.80	AF
8.00	74.00	28.00	633.98	2,288.10	AM
8.00	74.00	29.00	637.03	2,288.20	AM
8.00	73.00	28.00	641.91	1,906.70	AM
8.00	73.00	29.00	646.18	1,906.80	AM
8.00	74.00	30.00	646.18	2,288.20	AM
8.00	73.00	30.00	652.27	1,906.80	AM
8.00	72.00	28.00	657.45	1,525.40	AM
8.00	72.00	27.00	658.37	1,525.40	AM
8.00	73.00	27.00	658.37	1,906.80	AM
8.00	74.00	31.00	658.37	2,288.20	AM
8.00	74.00	32.00	661.42	2,288.20	AM
8.00	71.00	28.00	670.56	1,144.00	AM
8.00	72.00	29.00	670.56	1,525.40	AM
8.00	73.00	31.00	670.56	1,906.80	AM
8.00	72.00	25.00	671.17	1,525.40	AM
8.00	71.00	29.00	672.69	1,144.10	AM
8.00	74.00	33.00	673.61	2,288.20	AM
8.00	72.00	30.00	682.75	1,525.40	AM
8.00	74.00	34.00	682.75	2,288.10	AM
8.00	73.00	32.00	685.80	1,906.80	AM
8.00	73.00	34.00	691.90	1,906.80	AM
8.00	72.00	31.00	694.94	1,525.40	AM
8.00	73.00	33.00	697.99	1,906.80	AM
7.00	70.00	28.00	707.14	1,144.00	AM
7.00	71.00	30.00	725.42	1,144.10	AM
8.00	73.00	24.00	646.18	101.00	AR
8.00	73.00	23.00	652.27	101.00	AR
8.00	73.00	22.00	661.42	101.00	AR
8.00	72.00	20.00	673.61	81.60	AR
8.00	73.00	21.00	673.61	101.00	AR
8.00	72.00	19.00	676.66	81.60	AR
7.00	73.00	20.00	726.95	101.00	AR
12.00	70.00	2.00	121.00	198.60	DV
14.00	76.00	5.00	-82.30	331.00	DV
8.00	74.00	6.00	634.00	132.40	DV

Table C-1. Drain Heads and Conductances.

<u>Model Block Address:</u>			<u>Drain:</u>		
layer	row	column	head (m)	conductance (m ² /day)	discharge area
11.00	74.00	5.00	337.80	231.70	DV
7.00	75.00	6.00	733.45	264.80	DV
14.00	72.00	3.00	-73.15	264.90	DV
14.00	76.00	4.00	-73.15	386.40	DV
14.00	75.00	4.00	-70.10	353.30	DV
14.00	74.00	3.00	-67.06	397.40	DV
14.00	73.00	3.00	-64.01	331.20	DV
13.00	73.00	4.00	75.00	220.80	DV
14.00	68.00	2.00	-58.00	176.50	DV
14.00	69.00	2.00	-67.00	176.50	DV
12.00	67.00	3.00	129.00	132.40	DV
12.00	68.00	3.00	117.00	132.40	DV
13.00	69.00	3.00	99.00	132.40	DV
12.00	70.00	3.00	121.00	198.60	DV
12.00	71.00	3.00	117.00	198.60	DV
10.00	70.00	4.00	427.00	132.40	DV
12.00	71.00	4.00	143.00	132.40	DV
13.00	72.00	4.00	61.00	176.50	DV
13.00	74.00	4.00	6.00	264.80	DV
10.00	73.00	5.00	442.00	193.10	DV
14.00	76.00	6.00	-82.30	331.00	DV
12.00	75.00	5.00	117.00	308.90	DV
8.00	74.00	7.00	634.00	132.40	DV
8.00	75.00	28.00	610.12	1,697.00	FL
8.00	76.00	28.00	600.00	2,121.20	FL
8.00	75.00	29.00	609.12	1,697.00	FL
8.00	76.00	29.00	600.00	2,121.30	FL
8.00	75.00	30.00	610.65	1,696.90	FL
6.00	63.00	60.00	937.00	900.00	IS
6.00	52.00	4.00	972.31	272.10	OV
6.00	51.00	5.00	975.36	238.10	OV
6.00	51.00	4.00	984.50	272.10	OV
6.00	50.00	4.00	999.74	272.10	OV
6.00	49.00	4.00	1,021.08	272.10	OV
6.00	49.00	5.00	1,027.18	238.10	OV
6.00	48.00	5.00	1,030.22	238.10	OV
5.00	47.00	5.00	1,066.80	238.10	OV
5.00	46.00	5.00	1,072.90	238.10	OV
5.00	47.00	6.00	1,082.04	204.10	OV
5.00	45.00	5.00	1,085.09	238.10	OV
5.00	44.00	5.00	1,103.38	238.10	OV
5.00	43.00	5.00	1,109.47	238.10	OV
5.00	46.00	6.00	1,121.66	204.10	OV
5.00	42.00	5.00	1,124.71	238.10	OV
5.00	41.00	5.00	1,143.00	238.10	OV
5.00	40.00	5.00	1,173.48	238.10	OV
5.00	39.00	5.00	1,185.67	238.10	OV
5.00	38.00	5.00	1,199.39	238.10	OV

Table C-1. Drain Heads and Conductances.

<u>Model Block Address:</u>			<u>Drain:</u>		
layer	row	column	head (m)	conductance (m ² /day)	discharge area
4.00	38.00	6.00	1,207.01	204.10	OV
4.00	37.00	6.00	1,219.20	204.10	OV
3.00	6.00	53.00	1,438.23	1,000.00	PV
3.00	6.00	54.00	1,438.23	1,333.30	PV
3.00	6.00	52.00	1,439.75	1,000.00	PV
3.00	6.00	55.00	1,439.75	1,333.30	PV
3.00	6.00	51.00	1,442.80	1,000.00	PV
3.00	6.00	50.00	1,445.04	1,000.00	PV

Appendix D

Distribution of HSUs for Model Layers

Figures

- D-1 Distribution of HSUs for Model Layer 1
- D-2 Distribution of HSUs for Model Layer 2
- D-3 Distribution of HSUs for Model Layer 3
- D-4 Distribution of HSUs for Model Layer 4
- D-5 Distribution of HSUs for Model Layer 5
- D-6 Distribution of HSUs for Model Layer 6
- D-7 Distribution of HSUs for Model Layer 7
- D-8 Distribution of HSUs for Model Layer 8
- D-9 Distribution of HSUs for Model Layer 9
- D-10 Distribution of HSUs for Model Layer 10
- D-11 Distribution of HSUs for Model Layer 11
- D-12 Distribution of HSUs for Model Layer 12
- D-13 Distribution of HSUs for Model Layer 13
- D-14 Distribution of HSUs for Model Layer 14
- D-15 Distribution of HSUs for Model Layer 15
- D-16 Distribution of HSUs for Model Layer 16
- D-17 Distribution of HSUs for Model Layer 17
- D-18 Distribution of HSUs for Model Layer 18
- D-19 Distribution of HSUs for Model Layer 19
- D-20 Distribution of HSUs for Model Layer 20

Figure D-1
Distribution of HSUs for Model Layer 1 (the thickest HSU in each cell is shown)

Figure D-2
Distribution of HSUs for Model Layer 2 (the thickest HSU in each cell is shown)

Figure D-3
Distribution of HSUs for Model Layer 3 (the thickest HSU in each cell is shown)

Figure D-4
Distribution of HSUs for Model Layer 4 (the thickest HSU in each cell is shown)

Figure D-5
Distribution of HSUs for Model Layer 5 (the thickest HSU in each cell is shown)

Figure D-6
Distribution of HSUs for Model Layer 6 (the thickest HSU in each cell is shown)

Figure D-7
Distribution of HSUs for Model Layer 7 (the thickest HSU in each cell is shown)

Figure D-8
Distribution of HSUs for Model Layer 8 (the thickest HSU in each cell is shown)

Figure D-9
Distribution of HSUs for Model Layer 9 (the thickest HSU in each cell is shown)

Figure D-10
Distribution of HSUs for Model Layer 10 (the thickest HSU in each cell is shown)

Figure D-11
Distribution of HSUs for Model Layer 11 (the thickest HSU in each cell is shown)

Figure D-12
Distribution of HSUs for Model Layer 12 (the thickest HSU in each cell is shown)

Figure D-13
Distribution of HSUs for Model Layer 13 (the thickest HSU in each cell is shown)

Figure D-14
Distribution of HSUs for Model Layer 14 (the thickest HSU in each cell is shown)

Figure D-15
Distribution of HSUs for Model Layer 15 (the thickest HSU in each cell is shown)

Figure D-16
Distribution of HSUs for Model Layer 16 (the thickest HSU in each cell is shown)

Figure D-17
Distribution of HSUs for Model Layer 17 (the thickest HSU in each cell is shown)

Figure D-18
Distribution of HSUs for Model Layer 18 (the thickest HSU in each cell is shown)

Figure D-19
Distribution of HSUs for Model Layer 19 (the thickest HSU in each cell is shown)

Figure D-20
Distribution of HSUs for Model Layer 20 (the thickest HSU in each cell is shown)

Appendix E

Distribution of Transmissivity for Model Layers

Figures

E-1	Distribution of Transmissivity for Model Layer 1
E-2	Distribution of Transmissivity for Model Layer 2
E-3	Distribution of Transmissivity for Model Layer 3
E-4	Distribution of Transmissivity for Model Layer 4
E-5	Distribution of Transmissivity for Model Layer 5
E-6	Distribution of Transmissivity for Model Layer 6
E-7	Distribution of Transmissivity for Model Layer 7
E-8	Distribution of Transmissivity for Model Layer 8
E-9	Distribution of Transmissivity for Model Layer 9
E-10	Distribution of Transmissivity for Model Layer 10
E-11	Distribution of Transmissivity for Model Layer 11
E-12	Distribution of Transmissivity for Model Layer 12
E-13	Distribution of Transmissivity for Model Layer 13
E-14	Distribution of Transmissivity for Model Layer 14
E-15	Distribution of Transmissivity for Model Layer 15
E-16	Distribution of Transmissivity for Model Layer 16
E-17	Distribution of Transmissivity for Model Layer 17
E-18	Distribution of Transmissivity for Model Layer 18
E-19	Distribution of Transmissivity for Model Layer 19
E-20	Distribution of Transmissivity for Model Layer 20

Figure E-1
Distribution of Transmissivity for Model Layer 1

Figure E-2
Distribution of Transmissivity for Model Layer 2

Figure E-3
Distribution of Transmissivity for Model Layer 3

Figure E-4
Distribution of Transmissivity for Model Layer 4

Figure E-5
Distribution of Transmissivity for Model Layer 5

Figure E-6
Distribution of Transmissivity for Model Layer 6

Figure E-7
Distribution of Transmissivity for Model Layer 7

Figure E-8
Distribution of Transmissivity for Model Layer 8

Figure E-9
Distribution of Transmissivity for Model Layer 9

Figure E-10
Distribution of Transmissivity for Model Layer 10

Figure E-11
Distribution of Transmissivity for Model Layer 11

Figure E-12
Distribution of Transmissivity for Model Layer 12

Figure E-13
Distribution of Transmissivity for Model Layer 13

Figure E-14
Distribution of Transmissivity for Model Layer 14

Figure E-15
Distribution of Transmissivity for Model Layer 15

Figure E-16
Distribution of Transmissivity for Model Layer 16

Figure E-17
Distribution of Transmissivity for Model Layer 17

Figure E-18
Distribution of Transmissivity for Model Layer 18

Figure E-19
Distribution of Transmissivity for Model Layer 19

Figure E-20
Distribution of Transmissivity for Model Layer 20

Appendix F

Log Leakance Values for Active Model Cells in Model Layers

Figures

- F-1 Log Leakance Values for Active Model Cells in Model Layer 1
- F-2 Log Leakance Values for Active Model Cells in Model Layer 2
- F-3 Log Leakance Values for Active Model Cells in Model Layer 3
- F-4 Log Leakance Values for Active Model Cells in Model Layer 4
- F-5 Log Leakance Values for Active Model Cells in Model Layer 5
- F-6 Log Leakance Values for Active Model Cells in Model Layer 6
- F-7 Log Leakance Values for Active Model Cells in Model Layer 7
- F-8 Log Leakance Values for Active Model Cells in Model Layer 8
- F-9 Log Leakance Values for Active Model Cells in Model Layer 9
- F-10 Log Leakance Values for Active Model Cells in Model Layer 10
- F-11 Log Leakance Values for Active Model Cells in Model Layer 11
- F-12 Log Leakance Values for Active Model Cells in Model Layer 12
- F-13 Log Leakance Values for Active Model Cells in Model Layer 13
- F-14 Log Leakance Values for Active Model Cells in Model Layer 14
- F-15 Log Leakance Values for Active Model Cells in Model Layer 15
- F-16 Log Leakance Values for Active Model Cells in Model Layer 16
- F-17 Log Leakance Values for Active Model Cells in Model Layer 17
- F-18 Log Leakance Values for Active Model Cells in Model Layer 18
- F-19 Log Leakance Values for Active Model Cells in Model Layer 19

Figure F-1
Log Leakance Values for Active Model Cells in Model Layer 1

Figure F-2
Log Leakance Values for Active Model Cells in Model Layer 2

Figure F-3
Log Leakance Values for Active Model Cells in Model Layer 3

Figure F-4
Log Leakance Values for Active Model Cells in Model Layer 4

Figure F-5
Log Leakance Values for Active Model Cells in Model Layer 5

Figure F-6
Log Leakance Values for Active Model Cells in Model Layer 6

Figure F-7
Log Leakance Values for Active Model Cells in Model Layer 7

Figure F-8
Log Leakance Values for Active Model Cells in Model Layer 8

Figure F-9
Log Leakance Values for Active Model Cells in Model Layer 9

Figure F-10
Log Leakance Values for Active Model Cells in Model Layer 10

Figure F-11
Log Leakance Values for Active Model Cells in Model Layer 11

Figure F-12
Log Leakance Values for Active Model Cells in Model Layer 12

Figure F-13
Log Leakance Values for Active Model Cells in Model Layer 13

Figure F-14
Log Leakance Values for Active Model Cells in Model Layer 14

Figure F-15
Log Leakance Values for Active Model Cells in Model Layer 15

Figure F-16
Log Leakance Values for Active Model Cells in Model Layer 16

Figure F-17
Log Leakance Values for Active Model Cells in Model Layer 17

Figure F-18
Log Leakance Values for Active Model Cells in Model Layer 18

Figure F-19
Log Leakance Values for Active Model Cells in Model Layer 19

Appendix G

Simulated Heads for Model Layers

Figures

- G-1 Simulated Heads for Model Layer 1
- G-2 Simulated Heads for Model Layer 2
- G-3 Simulated Heads for Model Layer 3
- G-4 Simulated Heads for Model Layer 4
- G-5 Simulated Heads for Model Layer 5
- G-6 Simulated Heads for Model Layer 6
- G-7 Simulated Heads for Model Layer 7
- G-8 Simulated Heads for Model Layer 8
- G-9 Simulated Heads for Model Layer 9
- G-10 Simulated Heads for Model Layer 10
- G-11 Simulated Heads for Model Layer 11
- G-12 Simulated Heads for Model Layer 12
- G-13 Simulated Heads for Model Layer 13
- G-14 Simulated Heads for Model Layer 14
- G-15 Simulated Heads for Model Layer 15
- G-16 Simulated Heads for Model Layer 16
- G-17 Simulated Heads for Model Layer 17
- G-18 Simulated Heads for Model Layer 18
- G-19 Simulated Heads for Model Layer 19
- G-20 Simulated Heads for Model Layer 20

Figure G-1
Simulated Heads for Model Layer 1

Figure G-2
Simulated Heads for Model Layer 2

Figure G-3
Simulated Heads for Model Layer 3

Figure G-4
Simulated Heads for Model Layer 4

Figure G-5
Simulated Heads for Model Layer 5

Figure G-6
Simulated Heads for Model Layer 6

Figure G-7
Simulated Heads for Model Layer 7

Figure G-8
Simulated Heads for Model Layer 8

Figure G-9
Simulated Heads for Model Layer 9

Figure G-10
Simulated Heads for Model Layer 10

Figure G-11
Simulated Heads for Model Layer 11

Figure G-12
Simulated Heads for Model Layer 12

Figure G-13
Simulated Heads for Model Layer 13

Figure G-14
Simulated Heads for Model Layer 14

Figure G-15
Simulated Heads for Model Layer 15

Figure G-16
Simulated Heads for Model Layer 16

Figure G-17
Simulated Heads for Model Layer 17

Figure G-18
Simulated Heads for Model Layer 18

Figure G-19
Simulated Heads for Model Layer 19

Figure G-20
Simulated Heads for Model Layer 20

Appendix H

Changes in Mean Weighted Residuals Between Sensitivity Runs and Calibration Run

Table H-1. Changes in Mean Weighted Residuals Between Sensitivity Runs and Calibration Run

	NRTH	OASI	PM	BARR	WYF	EYF	SHON	DV	LCA	PAHR	SPMT	SHRG	TMBR	FARM	FF	% Change
BASE*	5.80	38.30	-5.80	107.20	70.40	1.30	21.70	22.90	-7.30	-9.90	-1.70	49.30	6.70	6.30	0.80	
Kh_I	-0.10	0.00	-0.20	0.10	2.50	0.40	1.00	0.00	0.10	0.00	0.10	0.10	-0.30	0.00	0.10	100
Kh_LCCU(1)	-1.90	1.10	-4.10	-1.00	-5.20	1.30	0.20	0.20	0.10	-3.90	-3.40	-0.90	-5.70	0.70	1.10	100
Kh_LCCU(2)	-0.10	0.00	-0.20	0.20	8.30	1.00	1.10	0.10	0.00	-28.20	-4.30	-12.40	0.00	0.00	0.20	100
Kh_LCCU(3)	0.00	-9.20	-0.30	-0.70	-42.40	0.90	-0.60	3.80	-1.30	-0.60	-0.20	-0.50	-0.80	-3.20	-0.90	100
Kh_LCA(1)	-0.20	-0.10	-0.50	-12.20	2.70	-8.30	-4.10	0.70	-0.10	-10.20	-4.30	-22.60	-0.60	0.40	-5.40	100
Kh_LCA(2)	0.00	-1.90	0.10	-5.00	-47.10	-4.20	-4.00	-0.50	-1.20	-2.50	-1.60	-2.70	0.10	-1.90	-5.50	100
Kh_LCA(3)	0.00	0.20	-0.10	0.70	2.40	0.90	1.10	0.10	0.20	-0.70	-18.50	-6.40	-0.20	0.20	0.60	100
Kh_LCA(4)	-0.10	-3.90	-0.30	-5.20	1.80	-4.60	-2.60	3.90	-2.20	-2.50	-1.60	-2.70	-0.50	-2.00	-5.60	100
Kh_LCA(5)	-4.50	0.20	-3.20	2.80	2.10	2.20	1.90	0.70	0.40	2.30	1.00	0.90	-1.60	0.60	1.80	100
Kh_LCA(6)	-0.10	-0.10	-0.20	0.20	-3.10	0.60	1.80	0.00	0.00	-0.90	-4.40	0.30	-0.30	0.00	0.10	100
Kh_LCA(7)	-1.40	0.10	-2.80	0.10	2.60	0.40	0.50	0.00	0.00	-0.10	0.10	0.00	-1.50	0.00	0.00	100
Kh_LCA(8)	-2.80	0.90	-0.50	0.70	3.30	2.60	2.00	0.30	0.80	-60.80	0.60	-0.10	-0.40	1.10	2.50	100
Kh_LCA(9)	-0.10	-3.90	-0.10	-1.80	8.80	-1.10	-0.80	8.30	-2.30	-0.90	-0.50	-1.00	0.00	-7.50	-2.00	100
Kh_UCCU	-0.20	-0.30	-0.90	0.40	-29.00	2.20	-4.30	0.00	-0.10	-0.80	0.10	0.10	-2.10	0.00	0.30	100
Kh_LCA3	-0.10	-0.10	-0.30	0.20	-46.40	0.10	-13.20	0.00	0.00	-0.90	0.10	0.00	-0.70	0.00	0.10	100
Kh_TSDV(1)	0.00	-0.20	-0.10	0.00	2.90	0.40	0.70	0.10	0.10	-0.10	0.00	0.00	-0.20	-0.10	0.00	100
Kh_TSDV(2)	0.00	-0.70	-0.20	0.00	-42.50	1.60	-0.30	-3.70	-0.30	-0.20	0.00	-0.10	-0.80	-1.10	-0.20	100
Kh_VU(1)	-10.00	0.60	-5.10	3.40	-1.30	2.70	0.70	0.00	0.40	-0.70	0.80	0.70	-2.50	0.70	1.80	100
Kh_VU(2)	-0.10	0.00	-0.40	0.30	-41.80	1.90	-0.90	0.00	0.00	0.10	0.10	0.00	-0.80	0.00	0.10	100
Kh_VU(3)	-1.00	4.70	-6.20	0.30	-1.00	0.60	-2.90	0.50	0.00	-0.80	0.10	0.20	-10.70	0.90	0.30	100
Kh_VCU(1)	-0.40	8.80	-4.20	0.90	-6.90	-0.10	-4.90	0.50	5.20	-0.50	0.30	0.50	-15.50	1.50	0.90	100
Kh_VCU(2)	0.00	-0.10	-0.30	0.30	-39.80	2.00	-0.90	0.00	0.00	0.00	0.10	0.00	-0.80	0.00	0.10	100
Kh_VA(1)	0.10	-4.70	0.90	-0.10	4.10	0.10	-2.20	0.00	-6.20	-0.20	0.00	-0.10	6.00	-0.20	-0.30	100
Kh_VA(2)	0.00	0.00	-0.10	0.20	-3.00	-1.80	-1.10	0.00	0.00	0.00	0.10	0.00	-0.30	0.00	0.10	100
Kh_VA(3)	0.00	-8.90	-0.20	0.20	-39.80	1.90	-1.30	0.10	-2.60	-0.10	0.10	0.00	-0.70	0.40	0.00	100
Kh_BAQ(1)	-0.30	0.10	-2.10	0.20	1.20	0.70	1.10	0.00	0.10	0.00	0.10	0.00	-0.40	0.00	0.10	100
Kh_BAQ(3)	0.00	0.00	0.00	0.20	-43.20	0.70	-0.40	0.00	0.00	0.00	0.10	0.00	-0.30	0.00	0.10	100
Kh_BAQ(4)	-0.10	0.00	-0.30	0.20	-43.10	1.70	-0.40	0.00	0.00	0.00	0.10	0.00	-0.90	0.00	0.10	100
Kh_BAQ(5)	0.00	0.00	0.00	0.20	-26.50	0.40	1.30	0.00	0.00	0.00	0.10	0.00	-0.30	0.00	0.10	100
Kh_BAQ(6)	0.00	0.00	-0.10	0.20	1.40	0.40	0.20	0.00	0.00	0.00	0.10	0.00	-0.10	0.00	0.10	100
Kh_BCU(1)	-0.70	-0.10	-2.80	0.60	-1.30	0.70	0.70	0.10	0.10	0.10	0.10	0.20	-1.40	0.10	0.30	100
Kh_BCU(3)	0.10	0.00	0.10	0.00	-33.20	0.00	-0.70	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	100
Kh_BCU(4)	0.00	0.00	-0.20	0.30	-41.90	1.80	-0.60	0.00	0.00	0.00	0.10	0.00	-0.70	0.00	0.10	100
Kh_BCU(5)	0.00	0.00	-0.20	0.30	-41.80	1.90	-0.90	0.00	0.00	0.00	0.10	0.00	-0.70	0.00	0.10	100
Kh_BCU(6)	-0.10	-0.10	-0.20	0.20	-20.00	1.40	-0.40	0.00	0.00	0.00	0.10	0.10	-0.60	0.00	0.10	100
Kh_TBA(1)	-1.00	-0.20	-3.20	0.40	-42.30	0.30	-0.40	0.30	0.00	-1.10	0.10	0.10	1.60	-0.10	0.10	100

* "Base" includes actual values from calibrated run (m), all other values are expressed as the difference relative to the calibration run (m)

Table H-1. Changes in Mean Weighted Residuals Between Sensitivity Runs and Calibration Run

	NRTH	OASI	PM	BARR	WYF	EYF	SHON	DV	LCA	PAHR	SPMT	SHRG	TMBR	FARM	FF	% Change
Kh_TBA(3)	0.00	-0.10	-0.30	0.30	-42.30	1.80	0.60	0.00	0.00	0.00	0.10	0.10	-0.80	0.00	0.10	100
Kh_TBA(4)	0.00	-0.10	-0.30	0.20	-43.90	1.80	-1.30	0.00	0.00	0.00	0.10	0.00	-0.80	0.00	0.10	100
Kh_TBA(6)	0.00	-0.10	-0.20	0.30	-41.30	1.90	-0.90	0.00	0.00	0.00	0.10	0.00	-0.70	0.00	0.10	100
Kh_TCB(1)	-0.10	0.00	-0.30	0.30	-43.80	1.70	-0.40	0.00	0.00	-0.80	0.10	0.00	-0.70	0.00	0.10	100
Kh_TCB(4)	-0.10	-0.10	-0.30	0.30	-42.80	1.80	-0.20	0.00	0.00	-0.80	0.10	0.00	-0.80	0.00	0.10	100
Kh_TCB(6)	0.00	-0.10	-0.30	0.30	-39.80	2.00	-0.90	0.00	0.00	0.00	0.10	0.00	-0.80	0.00	0.10	100
Kh_TC(1)	-5.70	0.10	-15.80	-1.00	0.10	1.30	1.30	0.00	0.00	0.00	0.00	-0.10	1.90	-0.10	-0.10	100
Kh_TC(3)	0.00	-0.10	-0.40	0.30	-44.30	1.80	-0.90	0.00	0.00	0.00	0.10	0.00	-0.80	0.00	0.10	100
Kh_TC(4)	-0.30	0.30	-2.70	0.20	0.70	0.40	1.00	0.00	0.20	0.00	0.10	0.00	-2.40	0.00	0.10	100
Kh_TC(5)	-0.10	0.60	-0.50	0.30	-41.90	1.90	1.50	0.10	0.30	0.00	0.10	0.10	-1.40	0.10	0.20	100
Kh_TC(6)	-0.10	-0.10	-0.70	0.20	-44.00	1.80	-0.90	0.00	0.00	0.00	0.10	0.00	-0.70	0.00	0.10	100
Kh_TMA(1)	-3.00	-0.40	-13.80	0.20	-4.60	1.20	-0.10	0.00	-0.30	0.20	0.10	0.10	-5.70	-0.10	0.10	100
Kh_TMA(2)	-0.20	-0.10	-2.00	0.10	1.30	0.40	-0.20	0.00	-0.10	-0.10	0.10	0.00	-3.80	-0.10	0.00	100
Kh_TMA(3)	-0.50	-0.40	-5.20	0.00	2.70	0.50	0.00	0.00	-0.30	-0.10	0.00	0.00	-7.30	-0.10	0.00	100
Kh_TMA(4)	-1.00	-0.40	-9.70	0.00	-3.60	0.50	0.30	0.00	-0.20	0.00	0.10	0.00	-7.00	-0.10	0.00	100
Kh_TMA(6)	-0.40	0.00	-2.10	0.10	3.80	0.40	0.90	0.00	0.00	0.00	0.10	0.00	-0.60	0.00	0.10	100
Kh_AA(1)	-12.00	-0.20	-1.60	-2.30	0.80	0.50	-2.20	-2.60	0.40	-2.10	-11.70	8.30	-2.70	1.40	-0.30	100
Kh_AA(2)	-0.10	-4.50	-0.40	-8.20	-4.90	-7.10	-5.80	-5.00	-4.40	-4.30	-2.60	-4.30	-0.70	-6.00	-8.90	100
Kh_AA(3)	0.00	0.00	0.00	0.30	-43.40	0.70	-0.40	0.00	0.10	0.00	-1.60	-0.30	-0.30	0.00	0.20	100
Kh_AA(4)	0.00	0.20	-0.20	0.10	2.50	-2.20	-0.70	0.40	0.00	0.10	0.10	0.00	-0.40	-0.10	0.00	100
Kh_AA(5)	0.00	-0.10	-0.20	0.20	-40.90	1.90	-1.10	0.00	0.00	0.00	0.10	0.00	-0.70	0.00	0.00	100
Kh_AA(6)	-0.10	-7.80	-0.20	-3.00	4.80	-2.10	-1.00	-0.10	-2.20	-1.50	-0.90	-1.60	-0.20	-2.50	-3.20	100
Id_I	0.00	-0.10	-0.20	0.20	-41.60	1.80	-0.60	0.00	0.00	0.00	0.10	0.00	-0.70	0.00	0.10	10
Id_LCCU(1)	0.50	-0.20	1.30	0.20	3.90	0.10	0.30	0.00	0.00	-0.80	1.30	0.00	1.90	-0.20	-0.30	10
Id_LCCU(2)	-0.10	0.00	-0.40	0.10	4.30	1.40	-0.20	0.00	0.00	2.40	1.60	4.20	-0.50	0.00	0.10	10
Id_LCCU(3)	0.00	1.70	0.00	0.40	-10.00	0.80	0.40	-2.00	0.30	-0.70	0.50	-0.10	-0.10	0.70	0.30	10
Id_LCA(1)	0.10	0.00	-0.10	6.60	4.30	5.20	2.90	0.00	0.10	2.60	1.40	2.90	-0.10	-0.20	2.60	10
Id_LCA(2)	0.00	0.50	0.10	1.60	-32.60	1.80	0.30	0.20	0.40	-0.10	0.90	0.60	-0.10	0.50	1.60	10
Id_LCA(3)	0.00	-0.10	-0.10	0.00	2.50	0.30	0.10	0.00	0.00	-0.10	3.80	0.70	-0.20	-0.10	0.00	10
Id_LCA(4)	0.00	0.60	-0.10	1.10	4.20	1.40	0.20	-1.40	0.40	-0.60	0.70	0.20	-0.20	0.20	1.00	10
Id_LCA(5)	1.20	0.30	0.70	-0.70	2.00	-0.10	0.40	0.00	-0.10	-0.90	0.30	-0.50	0.20	-0.20	-0.40	10
Id_LCA(6)	0.00	0.00	-0.30	0.20	-43.40	1.70	-0.20	0.00	0.00	0.00	1.60	-0.50	-0.70	0.00	0.10	10
Id_LCA(7)	0.50	0.00	0.90	0.20	-1.00	0.90	1.80	0.00	0.10	-0.90	0.40	-0.20	0.10	0.00	0.10	10
Id_LCA(8)	0.50	-0.30	-0.20	0.00	-3.30	-0.10	1.50	0.00	-0.20	14.70	0.30	-0.40	0.20	-0.30	-0.50	10
Id_LCA(9)	0.00	1.00	-0.20	0.60	2.60	0.90	1.30	-2.20	0.60	-0.60	0.60	0.00	-0.30	2.10	0.60	10
Id_UCCU	0.00	0.10	0.10	0.10	7.90	0.40	1.70	0.00	0.10	-0.90	0.40	-0.20	0.10	0.00	0.00	10
Id_LCA3	0.00	0.00	-0.10	0.10	3.60	0.60	1.90	0.00	0.10	-0.10	0.40	-0.20	-0.10	0.00	0.10	10

* "Base" includes actual values from calibrated run (m), all other values are expressed as the difference relative to the calibration run (m)

Table H-1. Changes in Mean Weighted Residuals Between Sensitivity Runs and Calibration Run

	NRTH	OASI	PM	BARR	WYF	EYF	SHON	DV	LCA	PAHR	SPMT	SHRG	TMBR	FARM	FF	% Change
ld_TSDV(1)	0.00	0.00	-0.20	0.30	-44.20	1.60	-0.50	0.00	0.00	-0.80	0.40	-0.20	-0.60	0.00	0.10	10
ld_TSDV(2)	0.00	0.10	-0.30	0.30	-41.70	2.00	-0.80	1.00	0.10	0.00	0.40	-0.20	-0.70	0.30	0.20	10
ld_VU(1)	2.70	-0.50	1.90	-0.90	2.20	-0.40	1.10	0.10	-0.20	-0.10	0.30	-0.50	1.50	-0.40	-0.50	10
ld_VU(2)	0.00	0.00	-0.10	0.10	3.20	0.50	-0.20	0.00	0.00	0.00	0.40	-0.20	-0.10	0.00	0.10	10
ld_VU(3)	0.10	-1.00	0.40	0.10	5.80	1.10	2.10	0.00	0.00	-0.10	0.40	-0.20	0.70	-0.20	0.00	10
ld_VCU(1)	0.10	-2.60	0.90	-0.10	3.10	1.30	4.50	-0.10	-1.50	-0.10	0.40	-0.30	3.90	-0.40	-0.10	10
ld_VCU(2)	0.00	0.00	-0.10	0.10	3.90	0.40	-0.50	0.00	0.00	0.10	0.40	-0.30	-0.20	0.00	0.00	10
ld_VA(1)	0.00	0.70	0.00	0.20	-27.10	1.30	5.20	0.00	1.70	0.00	0.40	-0.20	0.60	-0.10	0.10	10
ld_VA(2)	-0.10	0.00	-0.50	0.30	7.20	6.40	-0.80	0.00	0.00	-0.10	0.50	0.00	-1.10	0.00	0.10	10
ld_VA(3)	0.00	3.40	-0.20	0.30	-39.80	2.00	-0.50	0.00	1.10	0.00	0.40	-0.20	-0.70	-0.10	0.10	10
ld_BAQ(1)	-0.20	0.00	-0.80	0.00	2.60	0.30	1.30	0.00	0.10	-0.10	0.40	-0.20	1.40	0.00	0.00	10
ld_BAQ(3)	0.00	-0.10	-0.20	0.30	-41.70	1.90	-0.90	0.00	0.00	0.10	0.40	-0.20	-0.70	0.00	0.10	10
ld_BAQ(4)	0.00	0.00	-0.10	0.10	2.80	0.40	0.90	0.00	0.00	0.00	0.40	-0.20	-0.20	0.00	0.10	10
ld_BAQ(5)	0.00	-0.10	-0.20	0.30	-41.60	1.90	-0.90	0.00	0.00	0.00	0.40	-0.20	-0.70	0.00	0.10	10
ld_BAQ(6)	0.00	-0.10	-0.20	0.30	-40.10	2.00	-0.90	0.00	0.00	0.00	0.40	-0.20	-0.80	0.00	0.10	10
ld_BCU(1)	0.30	0.00	1.20	-0.10	5.00	0.30	-0.50	0.00	0.00	-0.90	0.40	-0.30	0.40	-0.10	0.00	10
ld_BCU(3)	0.00	0.00	-0.10	0.10	4.10	0.50	-0.50	0.00	0.00	0.00	0.40	-0.20	-0.20	0.00	0.10	10
ld_BCU(4)	-0.10	-0.10	-0.20	0.30	-42.30	1.80	-0.10	0.00	0.00	-0.80	0.40	-0.20	-0.80	0.00	0.10	10
ld_BCU(5)	0.00	-0.10	-0.20	0.30	-41.70	1.90	-0.90	0.00	0.00	0.10	0.40	-0.20	-0.70	0.00	0.10	10
ld_BCU(6)	0.00	0.00	-0.10	0.10	4.20	0.50	0.20	0.00	0.00	0.00	0.40	-0.20	-0.20	0.00	0.10	10
ld_TBA(1)	0.50	-0.10	2.00	0.00	-45.00	0.60	-0.20	0.00	-0.10	-0.10	0.40	-0.30	-0.60	-0.10	0.00	10
ld_TBA(3)	0.00	-0.10	-0.20	0.30	-41.30	1.90	-0.90	0.00	0.00	0.00	0.40	-0.20	-0.70	0.00	0.10	10
ld_TBA(4)	0.00	0.00	0.10	0.20	-42.70	0.70	-0.80	0.00	0.00	0.00	0.40	-0.20	-0.20	0.00	0.10	10
ld_TBA(6)	0.00	-0.10	-0.20	0.30	-39.80	2.00	-0.90	0.00	0.00	0.00	0.40	-0.20	-0.80	0.00	0.10	10
ld_TCB(1)	0.00	-0.10	-0.20	0.30	-41.60	1.90	-0.70	0.00	0.00	0.00	0.40	-0.20	-0.70	0.00	0.10	10
ld_TCB(4)	0.00	0.00	-0.10	0.10	3.90	0.40	-0.50	0.00	0.00	0.10	0.40	-0.30	-0.20	0.00	0.00	10
ld_TCB(6)	0.00	0.00	-0.10	0.10	2.80	0.40	0.50	0.00	0.00	0.00	0.40	-0.20	-0.20	0.00	0.10	10
ld_TC(1)	3.30	0.10	9.50	0.50	2.50	0.60	0.30	0.10	0.00	-1.10	0.40	-0.20	-2.00	0.00	0.20	10
ld_TC(3)	0.00	-0.10	-0.20	0.30	-41.40	1.90	-0.90	0.00	0.00	0.00	0.40	-0.20	-0.70	0.00	0.10	10
ld_TC(4)	0.10	-0.20	1.10	0.10	4.00	0.40	0.00	0.00	-0.10	-0.10	0.40	-0.20	0.70	0.00	0.10	10
ld_TC(5)	0.00	-0.30	0.20	0.10	-35.00	0.20	-1.00	0.00	-0.10	-0.10	0.40	-0.20	0.20	-0.10	0.00	10
ld_TC(6)	0.00	-0.10	0.00	0.20	-41.70	1.80	-0.60	0.00	0.00	0.00	0.40	-0.20	-0.70	0.00	0.10	10
ld_TMA(1)	1.20	0.30	5.30	0.10	1.60	0.30	1.40	0.10	0.10	-1.20	0.40	-0.30	2.00	0.00	0.00	10
ld_TMA(2)	0.10	0.00	0.90	0.20	4.90	0.50	0.20	0.00	0.10	0.00	0.40	-0.20	1.70	0.00	0.10	10
ld_TMA(3)	0.00	0.40	1.10	0.10	4.30	0.50	0.00	0.10	0.10	0.00	0.40	-0.20	3.20	0.00	0.10	10
ld_TMA(4)	0.40	0.40	3.70	0.10	3.00	0.40	-0.40	0.10	0.10	0.00	0.40	-0.20	2.40	0.10	0.10	10
ld_TMA(6)	0.20	0.00	0.80	0.20	-43.30	0.70	-0.50	0.00	0.00	0.00	0.40	-0.20	-0.20	0.00	0.10	10

* "Base" includes actual values from calibrated run (m), all other values are expressed as the difference relative to the calibration run (m)

Table H-1. Changes in Mean Weighted Residuals Between Sensitivity Runs and Calibration Run

	NRTH	OASI	PM	BARR	WYF	EYF	SHON	DV	LCA	PAHR	SPMT	SHRG	TMBR	FARM	FF	% Change
Id_AA(1)	3.30	-0.10	0.00	0.80	4.00	0.20	1.00	0.90	0.00	-0.20	3.10	-2.10	0.30	-0.20	0.00	10
Id_AA(2)	-0.10	0.40	-0.20	1.10	-41.60	2.60	0.00	0.90	0.50	-0.30	0.70	0.30	-0.70	0.70	1.00	10
Id_AA(3)	0.00	0.00	-0.10	0.20	2.80	0.40	0.50	0.00	0.00	0.00	0.70	-0.20	-0.20	0.00	0.00	10
Id_AA(4)	-0.10	0.00	-0.10	0.10	2.10	1.80	-0.30	0.00	0.00	0.00	0.40	-0.20	-0.10	0.00	0.10	10
Id_AA(5)	0.00	-0.10	-0.20	0.30	-44.00	1.80	-0.90	0.00	0.00	0.00	0.40	-0.20	-0.70	0.00	0.10	10
Id_AA(6)	0.10	1.30	0.20	0.50	-32.60	0.40	-0.40	0.00	0.30	0.30	0.50	0.00	0.10	0.10	0.40	10
Kh_I	-0.10	-0.10	-0.30	0.20	-42.00	1.90	0.10	0.00	0.00	0.00	0.10	0.00	-0.90	0.00	0.10	-50
Kh_LCCU(1)	1.00	-0.80	2.10	0.40	5.30	-0.20	1.50	-0.10	-0.10	0.70	2.30	0.60	3.10	-0.40	-0.50	-50
Kh_LCCU(2)	0.00	-0.20	-0.10	0.10	2.60	0.30	1.00	0.00	-0.10	14.10	3.10	10.70	0.20	-0.10	0.00	-50
Kh_LCCU(3)	0.00	2.60	0.10	0.60	-41.60	2.20	0.30	-2.50	0.30	-0.70	0.20	0.20	0.00	1.20	0.40	-50
Kh_LCA(1)	0.10	0.00	0.20	21.40	5.40	17.60	7.40	-0.20	0.30	14.30	7.70	27.00	0.10	-0.60	9.90	-50
Kh_LCA(2)	0.00	2.40	-0.10	7.20	3.50	7.60	6.40	0.70	1.50	2.20	2.40	4.00	-0.10	2.50	7.60	-50
Kh_LCA(3)	-0.10	-0.20	-0.20	-0.20	-0.20	0.20	1.60	0.00	-0.10	-0.20	12.20	3.80	-0.30	-0.20	-0.30	-50
Kh_LCA(4)	0.00	3.00	-0.10	3.40	-2.70	3.50	4.10	-3.40	1.30	-0.10	1.20	1.80	0.00	1.30	3.50	-50
Kh_LCA(5)	4.90	-0.70	3.20	-2.80	2.60	-1.40	-0.30	0.10	-0.50	-2.40	-0.40	-0.90	1.90	-1.00	-1.70	-50
Kh_LCA(6)	0.00	-0.30	0.00	0.10	9.50	0.60	0.50	0.30	-0.10	0.20	6.50	-1.20	0.10	-0.20	0.00	-50
Kh_LCA(7)	0.90	0.00	1.80	0.20	4.50	0.50	0.50	0.00	0.10	-1.10	0.10	0.00	0.70	0.00	0.10	-50
Kh_LCA(8)	2.00	-0.80	0.10	-0.60	0.60	-1.30	-1.20	-0.20	-0.70	71.40	-0.40	-0.20	0.40	-0.90	-1.80	-50
Kh_LCA(9)	0.00	2.80	0.10	1.60	3.50	1.80	1.90	-7.60	1.70	0.00	0.50	0.80	0.30	5.90	1.60	-50
Kh_UCCU	0.10	0.30	0.80	-0.10	-31.40	-1.00	-8.50	0.00	0.20	-0.10	0.00	-0.10	1.70	-0.10	-0.10	-50
Kh_LCA3	0.00	0.10	0.20	0.10	11.10	0.60	3.40	0.00	0.10	-0.10	0.00	0.00	0.60	0.00	0.00	-50
Kh_TSDV(1)	0.00	0.10	-0.10	0.20	3.70	0.50	-0.70	0.00	0.00	0.00	0.10	0.10	-0.10	0.00	0.10	-50
Kh_TSDV(2)	0.00	0.40	0.10	0.30	-34.70	0.40	-0.20	3.60	0.30	-0.80	0.10	0.10	-0.10	0.70	0.20	-50
Kh_VU(1)	8.10	-0.20	4.40	-3.00	6.90	-1.20	0.00	0.00	-0.30	-0.60	-0.30	-0.60	3.90	-0.60	-1.20	-50
Kh_VU(2)	0.00	-0.10	-0.10	0.20	-44.00	1.80	-0.90	0.00	0.00	0.00	0.10	0.00	-0.60	0.00	0.10	-50
Kh_VU(3)	0.60	-4.50	4.20	-0.10	4.40	-0.10	1.90	-0.30	0.10	-0.20	0.00	-0.10	8.50	-0.80	-0.20	-50
Kh_VCU(1)	0.30	-9.80	3.30	-0.70	8.70	0.70	10.70	-0.40	-6.80	-0.50	-0.20	-0.40	17.20	-1.40	-0.80	-50
Kh_VCU(2)	-0.10	0.00	-0.20	0.10	2.50	0.40	0.90	0.00	0.10	0.00	0.10	0.00	-0.30	0.00	0.10	-50
Kh_VA(1)	0.00	2.60	0.50	0.10	-45.80	0.60	-3.30	0.00	5.30	0.00	0.10	0.00	3.00	-0.20	0.10	-50
Kh_VA(2)	-0.10	0.00	-0.40	0.30	-21.20	6.40	0.50	0.00	0.00	0.00	0.10	0.10	-1.20	0.00	0.20	-50
Kh_VA(3)	0.00	8.10	-0.10	0.20	3.90	0.60	1.50	-0.10	2.50	0.00	0.10	0.10	-0.20	-0.40	0.20	-50
Kh_BAQ(1)	-0.20	0.00	-0.10	0.10	6.30	0.40	0.90	0.00	0.00	-1.10	0.10	0.00	1.80	0.00	0.10	-50
Kh_BAQ(3)	0.00	-0.10	-0.20	0.30	-39.80	2.00	-0.90	0.00	0.00	0.00	0.10	0.00	-0.80	0.00	0.10	-50
Kh_BAQ(4)	0.00	-0.10	-0.20	0.20	-42.20	1.70	-0.50	0.00	0.00	0.00	0.10	0.00	-0.50	0.00	0.10	-50
Kh_BAQ(5)	0.00	0.00	0.10	0.10	-33.40	0.00	0.20	0.00	0.00	-0.10	0.10	0.00	0.00	0.00	0.00	-50
Kh_BAQ(6)	0.00	-0.10	-0.20	0.20	-42.40	1.70	-0.50	0.00	0.00	0.00	0.10	0.00	-0.70	0.00	0.10	-50
Kh_BCU(1)	0.30	0.00	1.40	-0.10	7.00	0.60	-0.40	0.00	0.00	-0.90	0.00	-0.10	0.30	-0.10	-0.10	-50

* "Base" includes actual values from calibrated run (m), all other values are expressed as the difference relative to the calibration run (m)

Table H-1. Changes in Mean Weighted Residuals Between Sensitivity Runs and Calibration Run

	NRTH	OASI	PM	BARR	WYF	EYF	SHON	DV	LCA	PAHR	SPMT	SHRG	TMBR	FARM	FF	% Change
Kh_BCU(3)	0.00	0.00	0.10	0.10	-33.10	0.40	-0.20	0.00	0.00	0.00	0.10	0.00	-0.10	0.00	0.10	-50
Kh_BCU(4)	0.00	0.00	0.00	0.20	-44.30	0.80	-0.50	0.00	0.00	0.00	0.10	0.00	-0.30	0.00	0.10	-50
Kh_BCU(5)	0.00	0.00	-0.10	0.10	3.20	0.40	0.00	0.00	0.00	0.00	0.10	0.00	-0.20	0.00	0.10	-50
Kh_BCU(6)	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-50
Kh_TBA(1)	0.80	-0.10	3.20	-0.30	3.60	0.20	-0.30	0.00	0.00	-0.10	0.00	0.00	-0.60	-0.10	-0.10	-50
Kh_TBA(3)	0.00	0.00	-0.20	0.10	2.70	0.40	1.00	0.00	0.00	0.00	0.10	0.00	-0.30	0.00	0.10	-50
Kh_TBA(4)	0.00	0.00	-0.10	0.20	-43.00	1.70	-0.60	0.00	0.00	0.00	0.10	0.00	-0.60	0.00	0.10	-50
Kh_TBA(6)	0.00	0.00	-0.10	0.20	1.90	0.40	0.50	0.00	0.00	0.00	0.10	0.00	-0.20	0.00	0.10	-50
Kh_TCB(1)	0.00	0.00	-0.10	0.10	3.80	0.40	-0.40	0.00	0.00	0.10	0.00	0.00	-0.20	0.00	0.00	-50
Kh_TCB(4)	0.00	-0.10	-0.20	0.20	-41.90	1.80	-0.60	0.00	0.00	0.00	0.10	0.00	-0.70	0.00	0.10	-50
Kh_TCB(6)	0.00	-0.10	-0.30	0.30	-39.80	2.00	-0.90	0.00	0.00	0.00	0.10	0.00	-0.80	0.00	0.10	-50
Kh_TC(1)	5.90	-0.40	13.60	0.60	3.40	0.90	0.20	0.00	-0.10	-1.00	0.10	0.10	-3.50	0.00	0.20	-50
Kh_TC(3)	0.00	0.00	-0.10	0.30	-43.50	1.70	-0.30	0.00	0.00	0.00	0.10	0.00	-0.60	0.00	0.10	-50
Kh_TC(4)	0.20	-0.50	2.00	0.10	3.00	0.40	-0.30	0.00	-0.30	0.00	0.10	0.00	1.70	-0.10	0.00	-50
Kh_TC(5)	0.00	-0.80	0.10	0.20	-39.40	2.00	-2.90	0.00	-0.40	-0.10	0.10	0.00	0.00	-0.10	0.00	-50
Kh_TC(6)	0.00	-0.10	0.10	0.30	-42.50	1.80	0.70	0.00	0.00	0.00	0.10	0.00	-0.80	0.00	0.10	-50
Kh_TMA(1)	2.20	0.50	9.40	0.30	6.10	0.50	0.60	0.10	0.30	-1.10	0.50	-0.10	5.50	0.10	0.10	-50
Kh_TMA(2)	0.10	0.00	1.50	0.20	3.40	0.40	0.20	0.00	0.10	-0.90	0.10	0.00	3.00	0.00	0.10	-50
Kh_TMA(3)	0.20	0.40	3.60	0.20	5.60	0.40	1.00	0.10	0.20	-0.80	0.10	0.00	7.30	0.10	0.10	-50
Kh_TMA(4)	0.80	0.10	8.50	0.10	7.90	0.50	1.70	0.40	0.20	0.30	0.10	0.00	8.20	-0.10	0.10	-50
Kh_TMA(6)	0.30	0.00	1.40	0.20	-43.60	1.80	-0.60	0.00	0.00	0.00	0.10	0.00	-0.50	0.00	0.10	-50
Kh_AA(1)	14.20	0.30	0.90	1.60	3.90	0.70	2.00	2.60	0.50	0.80	19.30	-7.00	1.40	-1.10	0.60	-50
Kh_AA(2)	0.00	2.20	0.00	4.40	3.90	4.50	3.40	4.40	2.10	0.50	1.50	2.40	0.00	3.00	4.60	-50
Kh_AA(3)	0.00	-0.10	-0.10	0.10	0.00	0.50	0.20	0.00	0.00	-0.10	1.00	0.20	-0.20	0.00	0.00	-50
Kh_AA(4)	0.00	0.00	-0.10	0.10	-0.10	2.80	0.40	0.00	0.00	0.00	0.10	0.00	-0.10	0.00	0.10	-50
Kh_AA(5)	-0.10	-0.10	-0.20	0.30	-41.80	1.90	-0.80	0.00	0.00	-0.80	0.10	0.00	-0.70	0.00	0.20	-50
Kh_AA(6)	0.00	7.20	-0.10	2.20	3.80	2.40	1.90	-0.50	2.30	-0.50	0.70	1.10	-0.10	0.40	2.20	-50
Id_I	0.00	0.00	-0.10	0.10	1.10	0.40	1.10	0.00	0.10	0.00	0.10	0.00	-0.20	0.00	0.10	-10
Id_LCCU(1)	-0.80	0.10	-2.10	-0.40	1.20	1.00	-0.20	0.10	0.00	-0.90	-0.60	-0.50	-3.10	0.20	0.50	-10
Id_LCCU(2)	0.00	-0.10	-0.20	0.20	0.20	1.10	0.90	0.00	0.00	-7.50	-0.70	-3.50	0.00	0.00	0.10	-10
Id_LCCU(3)	-0.10	-2.50	-0.30	0.00	-41.90	1.60	-1.10	2.00	-0.30	-0.10	0.30	-0.40	-0.90	-1.00	-0.20	-10
Id_LCA(1)	0.00	-0.20	-0.20	-5.30	-1.00	-3.50	-1.50	0.10	-0.10	-2.90	-0.50	-3.10	0.20	0.20	-2.20	-10
Id_LCA(2)	0.00	-0.50	-0.10	-1.30	3.90	-0.90	-1.70	-0.10	-0.30	-0.80	-0.10	-1.00	-0.30	-0.60	-1.50	-10
Id_LCA(3)	0.00	0.00	-0.20	0.30	-43.20	1.80	-0.30	0.10	0.10	0.00	-3.30	-1.30	-0.70	0.00	0.20	-10
Id_LCA(4)	-0.10	-1.00	0.00	-1.10	3.10	-0.70	0.40	2.00	-0.50	-0.40	0.00	-0.90	0.00	-0.30	-1.20	-10
Id_LCA(5)	-1.20	0.00	-0.90	0.90	2.40	0.90	0.90	0.10	0.20	-0.60	0.60	0.00	-0.40	0.20	0.50	-10
Id_LCA(6)	0.00	0.00	-0.20	0.20	-0.60	0.30	1.80	0.00	0.00	0.00	-0.50	0.00	-0.20	0.00	0.10	-10

* "Base" includes actual values from calibrated run (m), all other values are expressed as the difference relative to the calibration run (m)

Table H-1. Changes in Mean Weighted Residuals Between Sensitivity Runs and Calibration Run

	NRTH	OASI	PM	BARR	WYF	EYF	SHON	DV	LCA	PAHR	SPMT	SHRG	TMBR	FARM	FF	% Change
ld_LCA(7)	-0.80	0.00	-1.70	0.10	3.60	0.50	0.80	0.00	-0.10	0.00	0.40	-0.20	-0.60	0.00	0.10	-10
ld_LCA(8)	-0.80	0.30	-0.20	-0.20	4.00	1.10	1.20	0.10	0.30	-14.70	0.60	0.00	-0.40	0.30	0.80	-10
ld_LCA(9)	-0.10	-1.50	-0.10	-0.50	1.20	-0.20	1.20	2.60	-0.70	-0.10	0.20	-0.60	0.10	-2.40	-0.60	-10
ld_UCCU	-0.10	-0.10	-0.40	0.20	-2.70	0.40	-0.20	0.00	0.00	0.10	0.40	-0.20	-0.70	0.00	0.10	-10
ld_LCA3	0.00	0.00	-0.20	0.20	1.20	0.30	-0.30	0.00	0.00	0.00	0.40	-0.20	-0.40	0.00	0.10	-10
ld_TSDV(1)	-0.10	-0.10	-0.20	0.20	-41.10	1.90	-1.20	0.00	0.00	0.00	0.40	-0.20	-0.70	0.00	0.10	-10
ld_TSDV(2)	0.00	-0.20	-0.10	0.10	3.90	0.40	-0.30	-1.10	-0.10	-0.10	0.40	-0.30	-0.20	-0.50	-0.10	-10
ld_VU(1)	-3.30	0.40	-2.30	1.00	3.80	1.40	1.10	0.10	0.10	-0.70	0.60	0.10	-1.20	0.30	0.70	-10
ld_VU(2)	-0.10	-0.10	-0.30	0.30	-41.80	1.90	-0.80	0.00	0.00	-0.80	0.40	-0.20	-0.70	0.00	0.10	-10
ld_VU(3)	-0.20	0.90	-0.90	0.10	0.20	0.40	1.20	0.40	0.00	0.30	0.40	-0.20	-1.20	0.00	0.10	-10
ld_VCU(1)	-0.10	2.80	-1.20	0.40	-27.90	-0.20	-3.60	0.20	1.60	-0.70	0.50	-0.10	-5.10	0.50	0.40	-10
ld_VCU(2)	0.00	0.00	-0.10	0.10	2.60	0.40	-0.10	0.00	0.00	0.00	0.40	-0.20	-0.20	0.00	0.10	-10
ld_VA(1)	-0.10	-1.00	-0.40	0.20	-3.90	0.80	-4.60	0.10	-1.60	-0.80	0.40	-0.20	-1.70	0.10	0.10	-10
ld_VA(2)	0.00	0.00	0.10	0.20	-30.30	-0.80	-0.10	0.00	0.00	0.00	0.40	-0.20	-0.30	0.00	0.10	-10
ld_VA(3)	0.00	-3.60	-0.20	0.20	-43.10	1.70	-0.60	0.10	-1.10	0.00	0.40	-0.20	-0.60	0.10	0.10	-10
ld_BAQ(1)	-0.20	0.00	-1.40	0.10	1.80	0.40	-0.20	0.20	0.10	0.00	0.40	-0.20	0.00	0.00	0.10	-10
ld_BAQ(3)	0.00	-0.10	-0.20	0.20	-41.90	1.80	-0.60	0.00	0.00	0.00	0.40	-0.20	-0.70	0.00	0.10	-10
ld_BAQ(4)	0.00	0.00	0.00	0.10	1.10	0.10	0.00	0.00	0.10	-0.10	0.40	-0.20	-0.10	0.00	0.00	-10
ld_BAQ(5)	0.00	0.00	-0.10	0.10	3.60	0.40	0.90	0.00	0.00	0.00	0.40	-0.20	-0.30	0.00	0.10	-10
ld_BAQ(6)	-0.10	0.00	-0.20	0.10	2.40	0.40	1.00	0.00	0.10	0.00	0.40	-0.20	-0.30	0.00	0.10	-10
ld_BCU(1)	-0.50	-0.10	-2.10	0.50	4.10	0.90	0.70	0.10	0.10	0.10	0.50	-0.10	-1.20	0.10	0.30	-10
ld_BCU(3)	0.00	0.00	0.10	0.10	-48.10	0.60	-0.40	0.00	0.00	0.00	0.40	-0.20	-0.20	0.00	0.10	-10
ld_BCU(4)	0.00	-0.10	-0.30	0.20	-39.30	2.10	-0.90	0.00	0.00	0.00	0.40	-0.20	-0.80	0.00	0.10	-10
ld_BCU(5)	0.00	0.00	-0.20	0.30	-41.70	1.90	-0.90	0.00	0.00	0.00	0.40	-0.20	-0.80	0.00	0.10	-10
ld_BCU(6)	-0.10	0.00	-0.20	0.10	2.40	0.40	1.00	0.00	0.00	0.00	0.40	-0.20	-0.30	0.00	0.10	-10
ld_TBA(1)	-0.70	-0.20	-2.20	0.20	1.40	0.40	0.80	0.30	0.00	0.30	0.40	-0.20	1.10	-0.20	0.10	-10
ld_TBA(3)	0.00	-0.10	-0.20	0.30	-41.90	1.80	-0.60	0.00	0.00	0.00	0.40	-0.20	-0.70	0.00	0.10	-10
ld_TBA(4)	-0.10	-0.10	-0.30	0.30	-41.50	1.90	-0.80	0.00	0.00	-0.80	0.40	-0.20	-0.80	0.00	0.10	-10
ld_TBA(6)	0.00	-0.10	-0.20	0.30	-41.30	1.90	-0.90	0.00	0.00	0.00	0.40	-0.20	-0.70	0.00	0.10	-10
ld_TCB(1)	-0.10	0.00	-0.10	0.10	1.70	0.40	0.10	0.00	0.10	0.00	0.40	-0.20	-0.10	0.00	0.10	-10
ld_TCB(4)	0.00	0.00	0.00	0.20	-42.60	0.70	-0.80	0.00	0.00	0.00	0.40	-0.20	-0.30	0.00	0.10	-10
ld_TCB(6)	0.00	-0.10	-0.20	0.20	-44.10	1.80	-0.90	0.00	0.00	0.00	0.40	-0.20	-0.70	0.00	0.10	-10
ld_TC(1)	-3.50	0.10	-10.90	-0.30	3.00	0.20	1.30	0.00	0.10	-0.10	0.40	-0.30	1.40	-0.10	-0.10	-10
ld_TC(3)	-0.10	0.00	-0.30	0.10	3.60	0.40	0.50	0.00	0.00	0.00	0.40	-0.20	-0.40	0.00	0.10	-10
ld_TC(4)	-0.20	0.10	-1.60	0.20	2.60	0.40	1.20	0.00	0.10	0.20	0.40	-0.20	-1.40	0.00	0.10	-10
ld_TC(5)	0.00	0.20	-0.40	0.30	-42.10	1.90	0.40	0.10	0.20	0.00	0.40	-0.20	-1.10	0.00	0.10	-10
ld_TC(6)	-0.10	-0.10	-0.50	0.20	-41.70	1.80	-0.60	0.00	0.00	0.00	0.40	-0.20	-0.70	0.00	0.10	-10

* "Base" includes actual values from calibrated run (m), all other values are expressed as the difference relative to the calibration run (m)

Table H-1. Changes in Mean Weighted Residuals Between Sensitivity Runs and Calibration Run

	NRTH	OASI	PM	BARR	WYF	EYF	SHON	DV	LCA	PAHR	SPMT	SHRG	TMBR	FARM	FF	% Change
Id_TMA(1)	-1.50	-0.50	-7.00	0.30	1.00	0.60	0.40	0.00	-0.20	0.00	0.40	-0.10	-3.80	0.00	0.20	-10
Id_TMA(2)	-0.20	-0.10	-1.20	0.10	3.00	0.40	0.70	0.00	-0.10	-0.90	0.40	-0.20	-2.30	0.00	0.10	-10
Id_TMA(3)	-0.20	-0.20	-2.10	0.10	-0.50	0.30	-0.30	0.00	-0.10	-0.10	0.40	-0.20	-3.40	-0.10	0.00	-10
Id_TMA(4)	-0.40	-0.30	-3.90	0.10	-0.20	0.40	0.30	0.00	-0.10	-0.10	0.40	-0.20	-2.90	-0.10	0.10	-10
Id_TMA(6)	-0.20	0.00	-0.80	0.20	-44.20	0.80	-0.90	0.00	0.00	0.00	0.40	-0.20	-0.40	0.00	0.10	-10
Id_AA(1)	-3.50	0.00	-0.30	-1.40	7.40	1.10	0.10	-1.10	0.00	-1.20	-2.30	1.60	-0.40	0.20	0.10	-10
Id_AA(2)	0.00	-0.60	0.00	-0.80	-44.30	-0.10	-1.60	-0.90	-0.50	-0.60	0.10	-0.80	-0.30	-0.70	-1.00	-10
Id_AA(3)	0.00	0.00	-0.10	0.10	3.60	0.50	-0.40	0.00	0.00	0.00	0.10	-0.30	-0.20	0.00	0.10	-10
Id_AA(4)	0.00	0.00	0.10	0.10	-26.10	-0.90	0.30	0.00	0.00	0.00	0.40	-0.20	-0.30	0.00	0.10	-10
Id_AA(5)	0.00	0.00	-0.10	0.10	3.80	0.40	-0.30	0.00	0.00	0.00	0.40	-0.30	-0.20	0.00	0.00	-10
Id_AA(6)	-0.10	-1.50	-0.30	-0.20	-41.90	1.40	-1.20	0.10	-0.30	-0.30	0.30	-0.50	-0.80	-0.20	-0.40	-10

* "Base" includes actual values from calibrated run (m), all other values are expressed as the difference relative to the calibration run (m)

Table H-2. Percentage Change in Roots Mean Square of Mean Weighted Residuals Between Sensitivity Runs and Calibration Run

	NRTH	OASI	PM	BARR	WYF	EYF	SHON	DV	LCA	PAHR	SPMT	SHRG	TMBR	FARM	FF	% Change
BASE*	42.90	72.20	35.70	146.80	139.50	22.90	80.50	41.00	28.80	11.40	53.30	47.30	61.00	9.00	5.20	
Kh_I	0.00	0.00	0.00	-0.07	-0.86	0.44	0.37	0.00	0.00	0.00	0.00	-0.21	0.16	0.00	0.00	100
Kh_LCCU(1)	0.93	-1.94	-0.28	-0.34	-0.57	-0.87	-1.61	-0.98	-2.08	-30.70	-2.44	2.11	1.64	-5.56	0.00	100
Kh_LCCU(2)	0.00	0.00	0.00	-0.14	-11.18	1.75	0.37	0.00	-0.69	62.28	-1.50	27.48	0.49	0.00	0.00	100
Kh_LCCU(3)	0.00	15.10	-0.28	0.34	3.08	4.37	0.75	10.49	-3.13	-5.26	0.00	1.06	0.16	31.11	5.77	100
Kh_LCA(1)	0.23	0.28	0.00	5.65	-0.50	12.23	4.22	0.98	-0.69	-64.04	2.06	48.41	0.16	-3.33	55.77	100
Kh_LCA(2)	-0.23	1.25	0.00	2.38	7.60	6.11	3.35	2.20	-3.47	-21.05	0.56	5.50	0.33	16.67	57.69	100
Kh_LCA(3)	0.00	-0.14	0.00	-0.27	-1.51	0.44	0.12	-0.24	0.35	-6.14	-3.00	13.95	0.00	-2.22	0.00	100
Kh_LCA(4)	0.00	2.91	0.00	2.52	-0.65	5.68	3.98	-8.54	-3.82	-21.93	0.56	5.50	0.16	16.67	59.62	100
Kh_LCA(5)	-0.93	-0.28	-1.12	-1.09	-1.22	0.00	-0.62	0.98	0.00	18.42	0.38	-1.90	0.66	-3.33	1.92	100
Kh_LCA(6)	0.00	0.00	0.00	-0.07	1.43	0.87	0.87	0.00	0.00	-7.02	-3.56	-0.63	0.16	0.00	0.00	100
Kh_LCA(7)	5.36	0.00	-1.40	0.00	-1.29	0.44	0.12	0.00	-0.35	-0.88	0.00	0.00	0.49	0.00	0.00	100
Kh_LCA(8)	-0.93	-0.69	-0.28	-0.89	-1.36	0.00	-1.37	-1.46	1.04	342.98	-0.38	0.63	0.16	-7.78	5.77	100
Kh_LCA(9)	0.00	2.49	0.00	0.89	-5.52	2.18	1.74	6.34	-2.43	-7.89	0.19	1.90	0.16	76.67	13.46	100
Kh_UCCU	0.23	0.14	-0.28	-0.20	-6.09	4.37	-1.86	0.00	-1.39	-7.02	0.00	-0.21	0.66	0.00	0.00	100
Kh_LCA3	0.00	0.00	0.00	-0.07	10.18	-0.44	-0.37	0.00	-0.69	-7.02	0.00	0.00	0.00	0.00	0.00	100
Kh_TSDV(1)	0.00	0.14	0.00	0.00	-1.72	0.44	0.37	0.00	-0.35	-1.75	0.00	0.00	0.00	1.11	1.92	100
Kh_TSDV(2)	0.00	0.42	0.00	0.00	3.15	4.37	0.00	15.12	-0.69	-1.75	0.00	0.21	0.16	10.00	1.92	100
Kh_VU(1)	18.41	-0.55	0.00	-1.63	-1.22	-0.44	-1.74	0.24	-0.69	-7.02	0.19	-1.48	1.48	-5.56	1.92	100
Kh_VU(2)	0.23	0.00	-0.28	-0.07	2.72	4.37	-0.50	0.00	-0.35	0.00	0.00	0.00	0.16	0.00	0.00	100
Kh_VU(3)	3.50	-8.59	-0.84	-0.14	0.00	0.44	-3.35	-1.46	-2.08	-7.02	0.00	-0.42	1.48	-8.89	0.00	100
Kh_VCU(1)	1.40	-6.65	-1.40	-0.41	2.44	-1.31	-3.60	-1.95	34.38	-4.39	-0.19	-1.06	-0.16	-12.22	0.00	100
Kh_VCU(2)	0.00	0.00	0.00	-0.07	1.36	4.80	-0.50	0.00	-0.35	-0.88	0.00	0.00	0.16	0.00	0.00	100
Kh_VA(1)	-0.47	2.77	0.56	0.07	-1.86	0.44	10.56	0.24	-42.36	-1.75	0.00	0.21	4.26	1.11	1.92	100
Kh_VA(2)	0.00	0.00	0.00	-0.07	1.15	-3.06	1.49	0.00	0.00	-0.88	0.00	0.00	0.16	0.00	0.00	100
Kh_VA(3)	0.00	11.22	0.00	-0.07	1.36	4.80	-0.75	-0.49	-15.63	-0.88	0.00	0.00	0.16	-3.33	0.00	100
Kh_BAQ(1)	0.70	-0.14	0.56	-0.07	-2.08	1.31	0.62	0.00	0.35	-0.88	0.00	0.00	2.95	0.00	0.00	100
Kh_BAQ(3)	-0.23	0.00	0.00	-0.07	5.45	1.31	-0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100
Kh_BAQ(4)	0.00	0.00	0.00	-0.07	3.73	3.93	-0.37	0.00	-0.35	-0.88	0.00	0.00	0.98	0.00	0.00	100
Kh_BAQ(5)	-0.23	0.00	0.00	-0.07	1.65	0.87	0.62	0.00	0.00	-0.88	0.00	0.00	0.00	0.00	0.00	100
Kh_BAQ(6)	0.00	0.00	0.00	-0.07	-1.43	0.44	0.12	0.00	0.00	-0.88	0.00	0.00	0.00	0.00	0.00	100
Kh_BCU(1)	1.40	0.00	-0.28	-0.34	-1.86	0.00	0.00	-0.24	-0.35	0.00	0.00	-0.42	0.33	0.00	0.00	100
Kh_BCU(3)	0.00	0.00	0.00	0.00	-8.10	-0.44	-0.25	0.00	0.00	0.00	0.00	0.00	-0.16	0.00	1.92	100
Kh_BCU(4)	0.00	0.00	0.00	-0.07	3.08	3.93	-0.37	0.00	-0.35	-0.88	0.00	0.00	0.16	0.00	0.00	100
Kh_BCU(5)	0.00	0.00	0.00	-0.07	2.72	4.37	-0.50	0.00	-0.35	-0.88	0.00	0.00	0.16	0.00	0.00	100
Kh_BCU(6)	0.23	0.00	-0.28	-0.07	0.86	3.06	-0.25	0.00	-0.35	-0.88	0.00	-0.21	0.16	0.00	0.00	100

* "BASE" includes actual values from calibrated run (m), all other values are expressed as a percentage difference from the calibration run (m)

Table H-2. Percentage Change in Roots Mean Square of Mean Weighted Residuals Between Sensitivity Runs and Calibration Run

	NRTH	OASI	PM	BARR	WYF	EYF	SHON	DV	LCA	PAHR	SPMT	SHRG	TMBR	FARM	FF	% Change
Kh_TBA(1)	2.56	-0.14	1.40	-0.20	1.36	0.00	0.12	3.17	0.00	-9.65	0.00	-0.21	-1.48	1.11	0.00	100
Kh_TBA(3)	0.00	0.00	-0.28	-0.07	3.01	4.37	0.12	0.00	-0.35	-0.88	0.00	-0.21	0.16	0.00	0.00	100
Kh_TBA(4)	0.00	0.00	0.00	-0.07	4.80	3.93	-0.62	0.00	-0.35	-0.88	0.00	0.00	0.66	0.00	0.00	100
Kh_TBA(6)	0.00	0.00	-0.28	-0.07	2.37	4.37	-0.50	0.00	-0.35	-0.88	0.00	0.00	0.16	0.00	0.00	100
Kh_TCB(1)	0.00	0.00	0.00	-0.07	4.09	3.93	-0.37	0.00	0.00	-7.02	0.00	0.00	0.16	0.00	0.00	100
Kh_TCB(4)	0.00	0.00	0.00	-0.14	3.37	3.93	-0.25	0.00	-0.35	-7.02	0.00	0.00	0.16	0.00	0.00	100
Kh_TCB(6)	0.00	0.00	0.00	-0.07	1.36	4.80	-0.50	0.00	-0.35	-0.88	0.00	0.00	0.16	0.00	0.00	100
Kh_TC(1)	21.91	-0.28	10.08	0.20	-7.17	3.49	1.24	0.00	0.35	-0.88	0.00	0.21	0.98	1.11	1.92	100
Kh_TC(3)	0.00	0.00	-0.28	-0.07	5.02	3.93	-0.50	0.00	-0.35	-0.88	0.00	0.00	0.16	0.00	0.00	100
Kh_TC(4)	0.93	-0.28	-1.40	-0.07	-1.08	0.44	0.99	0.00	1.04	0.00	0.00	0.00	1.48	0.00	0.00	100
Kh_TC(5)	0.00	-0.83	-0.28	-0.14	2.72	4.37	1.74	-0.24	1.74	-0.88	0.00	-0.21	0.33	-1.11	0.00	100
Kh_TC(6)	0.23	0.00	0.28	-0.07	4.87	3.93	-0.50	0.00	-0.35	-0.88	0.00	0.00	0.16	0.00	0.00	100
Kh_TMA(1)	11.19	-0.28	-0.84	-0.07	1.15	2.62	-0.62	0.00	-2.08	0.88	0.00	-0.21	3.11	1.11	0.00	100
Kh_TMA(2)	0.70	0.00	-1.12	0.00	-1.08	0.44	-0.12	0.00	-1.04	-0.88	0.00	0.00	2.46	1.11	0.00	100
Kh_TMA(3)	1.63	0.00	-0.84	0.00	-3.30	0.87	0.00	0.24	-1.74	-1.75	0.00	0.00	5.57	1.11	1.92	100
Kh_TMA(4)	3.50	-0.14	-1.68	0.00	2.29	0.87	-0.25	0.24	-1.39	-0.88	0.00	0.00	6.72	1.11	0.00	100
Kh_TMA(6)	1.63	0.00	0.84	-0.07	-1.00	0.44	0.37	0.00	0.00	-0.88	0.00	0.00	0.33	0.00	0.00	100
Kh_AA(1)	26.57	0.14	-0.56	0.14	-1.36	0.44	-1.37	5.85	-3.13	-17.54	-2.81	-17.55	1.15	-8.89	1.92	100
Kh_AA(2)	0.00	3.19	0.00	3.95	6.95	10.48	5.47	11.22	-2.78	-35.09	0.94	8.67	0.16	55.56	111.54	100
Kh_AA(3)	0.00	-0.14	0.00	-0.14	5.73	1.31	-0.25	0.00	0.00	0.00	-1.31	0.63	0.00	0.00	0.00	100
Kh_AA(4)	0.00	-0.28	0.00	-0.07	2.72	-2.62	-0.25	2.68	-0.35	0.00	0.00	0.00	0.16	1.11	0.00	100
Kh_AA(5)	0.00	0.00	0.00	-0.07	2.08	4.37	-0.62	0.00	-0.35	-0.88	0.00	0.00	0.16	0.00	1.92	100
Kh_AA(6)	0.00	6.09	0.00	1.43	-2.44	3.49	2.61	0.24	-4.86	-13.16	0.19	3.17	0.16	16.67	26.92	100
Id_I	0.00	0.00	0.00	-0.07	2.87	4.37	-0.37	0.00	-0.35	-0.88	0.00	0.00	0.16	0.00	0.00	10
Id_LCCU(1)	-0.47	0.28	0.28	0.07	-1.72	0.87	0.75	0.24	0.69	-7.02	1.13	0.00	-0.16	2.22	1.92	10
Id_LCCU(2)	0.23	0.00	0.00	-0.07	-2.29	3.06	-0.12	0.00	0.00	18.42	0.94	-9.30	0.16	0.00	0.00	10
Id_LCCU(3)	0.00	-2.91	0.00	-0.14	-18.14	0.87	0.00	-1.22	0.35	-6.14	0.38	0.21	0.00	-6.67	0.00	10
Id_LCA(1)	0.00	-0.14	0.00	-3.00	-2.65	0.00	-1.37	0.24	0.35	21.05	0.19	-5.92	0.00	2.22	5.77	10
Id_LCA(2)	-0.23	-0.42	0.00	-0.75	-8.39	0.00	-1.24	-0.73	0.69	-0.88	0.38	-1.06	0.00	-4.44	1.92	10
Id_LCA(3)	0.00	0.00	0.00	0.00	-1.86	0.44	0.12	0.00	0.00	-1.75	3.38	-1.48	0.00	1.11	1.92	10
Id_LCA(4)	0.00	-0.55	0.00	-0.48	-2.58	0.44	-0.87	2.68	0.69	-5.26	0.38	-0.42	0.00	-1.11	0.00	10
Id_LCA(5)	0.47	-0.42	0.28	0.27	-1.43	0.87	0.62	0.24	0.00	-7.89	0.56	1.06	0.00	2.22	1.92	10
Id_LCA(6)	0.00	0.00	0.00	-0.07	4.16	3.93	-0.25	0.00	-0.35	-0.88	1.88	1.06	0.16	0.00	0.00	10
Id_LCA(7)	-2.33	0.00	0.56	-0.07	-0.72	1.31	0.87	0.00	0.00	-7.02	0.38	0.42	-0.16	0.00	0.00	10
Id_LCA(8)	0.23	0.14	0.00	0.14	0.07	0.87	1.24	0.24	-0.69	124.56	0.56	0.85	0.33	2.22	1.92	10
Id_LCA(9)	0.00	-0.69	0.00	-0.27	-0.86	0.44	0.12	1.46	0.69	-5.26	0.38	0.00	0.16	-17.78	0.00	10

* "BASE" includes actual values from calibrated run (m), all other values are expressed as a percentage difference from the calibration run (m)

Table H-2. Percentage Change in Roots Mean Square of Mean Weighted Residuals Between Sensitivity Runs and Calibration Run

	NRTH	OASI	PM	BARR	WYF	EYF	SHON	DV	LCA	PAHR	SPMT	SHRG	TMBR	FARM	FF	% Change
ld_UCCU	-0.23	-0.14	0.00	0.00	-0.50	0.87	0.87	0.00	0.35	-7.89	0.38	0.42	0.00	0.00	0.00	10
ld_LCA3	0.00	0.00	0.00	-0.07	-1.00	1.31	0.87	0.00	0.00	-0.88	0.38	0.42	0.00	0.00	0.00	10
ld_TSDV(1)	0.00	0.00	0.00	-0.14	5.38	3.49	-0.37	0.00	0.00	-7.02	0.38	0.42	0.16	0.00	0.00	10
ld_TSDV(2)	0.00	-0.14	0.00	-0.14	2.65	4.37	-0.62	-4.15	0.00	0.00	0.38	0.42	0.16	-3.33	0.00	10
ld_VU(1)	-2.80	0.00	0.28	0.48	-1.51	0.87	1.61	-0.49	-0.69	-1.75	0.56	1.06	-0.33	3.33	3.85	10
ld_VU(2)	-0.23	0.00	0.00	-0.07	-1.94	0.44	-0.12	0.00	0.00	0.00	0.38	0.42	0.00	0.00	0.00	10
ld_VU(3)	-0.47	1.80	0.28	-0.07	-3.58	2.18	1.24	0.24	0.00	-0.88	0.38	0.42	0.16	2.22	0.00	10
ld_VCU(1)	-0.47	1.94	0.56	0.07	-2.01	3.06	4.10	0.49	-9.72	-1.75	0.38	0.63	1.48	4.44	1.92	10
ld_VCU(2)	0.00	0.00	0.00	-0.07	-2.51	0.87	-0.25	0.00	0.00	0.00	0.38	0.63	0.00	0.00	0.00	10
ld_VA(1)	0.00	-0.55	0.00	-0.07	1.08	2.62	2.11	0.00	13.19	0.00	0.38	0.42	0.66	1.11	0.00	10
ld_VA(2)	0.00	0.00	0.00	-0.14	-23.94	20.96	-1.24	0.00	-0.35	-0.88	0.38	0.00	0.66	0.00	0.00	10
ld_VA(3)	0.00	-3.60	0.00	-0.14	1.36	4.80	-0.12	0.24	6.60	-0.88	0.38	0.42	0.16	1.11	0.00	10
ld_BAQ(1)	0.47	-0.14	0.28	0.00	-2.58	0.44	0.75	0.00	0.00	-0.88	0.38	0.42	-3.28	0.00	0.00	10
ld_BAQ(3)	0.00	0.00	0.00	-0.14	2.65	4.37	-0.50	0.00	-0.35	0.00	0.38	0.42	0.16	0.00	0.00	10
ld_BAQ(4)	0.00	0.00	0.00	-0.07	-0.86	0.44	0.37	0.00	0.00	-0.88	0.38	0.42	-0.16	0.00	0.00	10
ld_BAQ(5)	0.00	0.00	0.00	-0.07	2.44	4.37	-0.50	0.00	-0.35	-0.88	0.38	0.42	0.16	0.00	0.00	10
ld_BAQ(6)	0.00	0.00	0.00	-0.07	1.58	4.37	-0.50	0.00	-0.35	-0.88	0.38	0.42	0.16	0.00	0.00	10
ld_BCU(1)	-0.70	-0.14	0.00	0.07	-2.37	0.87	0.00	0.00	0.00	-7.89	0.38	0.63	0.00	1.11	1.92	10
ld_BCU(3)	0.00	0.00	0.00	-0.07	-2.51	0.87	-0.25	0.00	0.00	-0.88	0.38	0.42	0.00	0.00	0.00	10
ld_BCU(4)	0.00	0.00	0.00	-0.14	3.30	3.93	-0.25	0.00	-0.35	-7.02	0.38	0.42	0.16	0.00	0.00	10
ld_BCU(5)	0.00	0.00	0.00	-0.07	2.65	4.37	-0.50	0.00	-0.35	0.00	0.38	0.42	0.16	0.00	0.00	10
ld_BCU(6)	0.00	0.00	0.00	-0.07	-1.36	0.44	0.12	0.00	0.00	-0.88	0.38	0.42	0.16	0.00	0.00	10
ld_TBA(1)	-1.40	0.00	-0.56	0.00	7.10	1.75	-0.12	0.00	-0.69	-0.88	0.38	0.63	1.15	1.11	1.92	10
ld_TBA(3)	0.00	0.00	0.00	-0.07	2.37	4.37	-0.50	0.00	-0.35	-0.88	0.38	0.42	0.16	0.00	0.00	10
ld_TBA(4)	-0.23	0.00	0.00	-0.07	5.09	1.31	-0.37	0.00	0.00	-0.88	0.38	0.42	-0.16	0.00	0.00	10
ld_TBA(6)	0.00	0.00	0.00	-0.07	1.36	4.80	-0.50	0.00	-0.35	-0.88	0.38	0.42	0.16	0.00	0.00	10
ld_TCB(1)	0.00	0.00	0.00	-0.07	2.58	4.37	-0.37	0.00	-0.35	-0.88	0.38	0.42	0.16	0.00	0.00	10
ld_TCB(4)	0.00	0.00	0.00	-0.07	-2.51	0.87	-0.25	0.00	0.00	0.00	0.38	0.63	0.00	0.00	0.00	10
ld_TCB(6)	0.00	0.00	0.00	-0.07	-1.51	0.44	0.25	0.00	0.00	-0.88	0.38	0.42	0.16	0.00	0.00	10
ld_TC(1)	-11.42	-0.14	5.04	-0.20	-1.72	0.44	-0.25	0.00	-0.69	-8.77	0.38	0.42	-0.33	0.00	0.00	10
ld_TC(3)	0.00	0.00	0.00	-0.07	2.44	4.37	-0.50	0.00	-0.35	-0.88	0.38	0.42	0.16	0.00	0.00	10
ld_TC(4)	-0.47	0.14	0.84	-0.07	-2.01	0.44	-0.25	0.00	-0.69	-0.88	0.38	0.42	-0.49	0.00	0.00	10
ld_TC(5)	-0.23	0.28	0.00	-0.07	-6.45	0.00	-0.87	0.00	-1.04	-0.88	0.38	0.42	0.00	1.11	0.00	10
ld_TC(6)	0.00	0.00	-0.28	-0.07	2.94	3.93	-0.37	0.00	-0.35	-0.88	0.38	0.42	0.16	0.00	0.00	10
ld_TMA(1)	-4.66	0.14	4.48	0.00	-1.22	0.44	0.99	0.00	0.35	-9.65	0.38	0.63	-0.82	0.00	0.00	10
ld_TMA(2)	-0.47	0.00	0.56	-0.07	-2.72	0.87	0.12	0.00	0.35	-0.88	0.38	0.42	-0.66	0.00	0.00	10

* "BASE" includes actual values from calibrated run (m), all other values are expressed as a percentage difference from the calibration run (m)

Table H-2. Percentage Change in Roots Mean Square of Mean Weighted Residuals Between Sensitivity Runs and Calibration Run

	NRTH	OASI	PM	BARR	WYF	EYF	SHON	DV	LCA	PAHR	SPMT	SHRG	TMBR	FARM	FF	% Change
Id_TMA(3)	-0.23	-0.42	1.40	-0.07	-1.94	0.44	0.12	0.00	0.35	-0.88	0.38	0.42	-1.97	0.00	0.00	10
Id_TMA(4)	-1.40	-0.28	3.08	-0.07	-2.08	0.44	0.00	0.00	0.69	-0.88	0.38	0.42	-2.13	0.00	0.00	10
Id_TMA(6)	-0.70	0.00	-0.28	-0.07	5.59	1.31	-0.25	0.00	0.00	-0.88	0.38	0.42	-0.16	0.00	0.00	10
Id_AA(1)	-4.66	0.00	0.00	0.00	-2.15	0.87	0.62	-2.44	0.00	-1.75	2.25	4.44	0.33	2.22	0.00	10
Id_AA(2)	0.00	-0.28	0.00	-0.48	2.87	3.93	-0.87	-2.20	0.35	-3.51	0.38	-0.42	0.16	-5.56	0.00	10
Id_AA(3)	0.00	0.00	0.00	-0.07	-1.51	0.44	0.25	0.00	0.00	-0.88	0.56	0.42	0.00	0.00	0.00	10
Id_AA(4)	0.00	0.00	0.00	-0.07	-1.51	3.93	-0.25	0.00	0.00	-0.88	0.38	0.42	0.00	0.00	0.00	10
Id_AA(5)	0.00	0.00	0.00	-0.07	4.87	3.93	-0.50	0.00	-0.35	-0.88	0.38	0.42	0.16	0.00	0.00	10
Id_AA(6)	-0.23	-1.11	0.00	-0.20	-8.46	-0.44	-0.50	0.49	0.69	1.75	0.38	0.21	-0.16	1.11	0.00	10
Kh_I	0.00	0.00	-0.28	-0.14	2.87	4.37	-0.12	0.00	-0.35	-0.88	0.00	0.00	0.16	0.00	0.00	-50
Kh_LCCU(1)	-0.47	1.25	0.56	0.20	-1.36	0.87	1.74	0.49	0.35	4.39	1.88	-1.48	-0.33	3.33	1.92	-50
Kh_LCCU(2)	0.00	0.00	0.00	0.00	-0.65	0.44	0.50	0.00	-0.69	117.54	1.69	-23.47	0.49	1.11	1.92	-50
Kh_LCCU(3)	-0.23	-6.65	0.00	-0.27	2.65	3.93	0.00	-4.88	0.00	-6.14	0.00	-0.42	0.16	-10.00	0.00	-50
Kh_LCA(1)	-0.23	-0.14	0.00	-9.47	-7.81	20.52	-6.58	0.98	1.04	121.93	2.06	-54.55	0.16	4.44	103.85	-50
Kh_LCA(2)	0.00	-1.66	0.00	-3.27	-4.23	3.06	-3.48	-3.17	4.51	16.67	-0.38	-8.03	0.16	-17.78	65.38	-50
Kh_LCA(3)	0.00	0.14	0.00	0.14	0.50	0.87	1.12	0.24	-0.35	-1.75	12.95	-8.03	0.16	1.11	1.92	-50
Kh_LCA(4)	0.00	-2.22	0.00	-1.57	-0.22	0.00	-0.99	8.29	3.47	-1.75	-0.19	-3.59	0.00	-11.11	13.46	-50
Kh_LCA(5)	3.50	0.14	1.68	1.09	-1.72	1.75	1.86	4.88	-0.69	-20.18	0.19	1.90	-0.49	8.89	9.62	-50
Kh_LCA(6)	0.00	0.00	0.00	-0.07	-4.95	0.87	0.50	3.17	-0.35	1.75	10.32	2.54	0.16	2.22	0.00	-50
Kh_LCA(7)	-3.73	-0.14	1.12	-0.07	-2.51	0.87	0.37	0.00	0.35	-9.65	0.00	0.00	-0.16	0.00	0.00	-50
Kh_LCA(8)	0.93	0.42	0.00	0.68	-1.51	1.31	1.12	0.98	-1.74	621.05	0.19	0.21	0.33	6.67	11.54	-50
Kh_LCA(9)	-0.23	-2.08	0.00	-0.75	-1.43	0.00	-0.25	3.66	2.43	-0.88	-0.19	-1.69	0.16	-37.78	1.92	-50
Kh_UCCU	-0.47	-0.28	0.28	0.07	-2.44	-1.31	-1.24	0.00	1.39	-1.75	0.00	0.21	-0.33	1.11	1.92	-50
Kh_LCA3	-0.23	-0.14	0.00	0.00	0.14	2.18	1.37	0.00	0.69	-0.88	0.00	0.00	0.16	0.00	0.00	-50
Kh_TSDV(1)	0.00	-0.14	0.00	-0.07	-0.93	0.44	-0.37	0.00	0.00	-0.88	0.00	-0.21	0.16	0.00	0.00	-50
Kh_TSDV(2)	-0.23	-0.28	0.00	-0.14	-6.74	0.00	-0.25	-9.02	0.35	-7.02	0.00	-0.21	0.00	-6.67	0.00	-50
Kh_VU(1)	-5.13	-0.28	1.68	1.23	-2.72	2.18	1.99	-0.24	0.00	-5.26	0.19	1.27	-1.64	5.56	7.69	-50
Kh_VU(2)	-0.23	0.00	0.00	-0.07	4.87	3.93	-0.50	0.00	-0.35	-0.88	0.00	0.00	0.16	0.00	0.00	-50
Kh_VU(3)	-2.56	8.59	3.36	0.07	-4.59	0.00	2.73	1.22	1.74	-1.75	0.00	0.21	-0.33	7.78	1.92	-50
Kh_VCU(1)	-1.17	9.97	2.52	0.34	-4.16	2.62	15.40	1.95	-41.32	-5.26	0.00	0.85	9.67	12.22	3.85	-50
Kh_VCU(2)	0.00	0.00	0.00	-0.07	-0.86	0.44	0.37	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	-50
Kh_VA(1)	-0.23	-1.52	0.28	-0.07	7.17	1.31	-7.20	0.24	42.71	-0.88	0.00	0.00	1.97	2.22	0.00	-50
Kh_VA(2)	0.23	0.00	-0.28	-0.20	-12.54	20.96	-1.86	0.00	-0.35	-0.88	0.00	-0.21	0.49	0.00	0.00	-50
Kh_VA(3)	0.00	-8.31	0.00	-0.07	-1.51	0.44	0.99	0.49	15.63	-0.88	0.00	-0.21	0.16	4.44	0.00	-50
Kh_BAQ(1)	0.23	0.00	0.00	0.00	-3.66	0.44	0.50	0.00	0.00	-9.65	0.00	0.00	-5.41	0.00	0.00	-50
Kh_BAQ(3)	0.00	0.00	0.00	-0.07	1.36	4.80	-0.50	0.00	-0.35	-0.88	0.00	0.00	0.16	0.00	0.00	-50

* "BASE" includes actual values from calibrated run (m), all other values are expressed as a percentage difference from the calibration run (m)

Table H-2. Percentage Change in Roots Mean Square of Mean Weighted Residuals Between Sensitivity Runs and Calibration Run

	NRTH	OASI	PM	BARR	WYF	EYF	SHON	DV	LCA	PAHR	SPMT	SHRG	TMBR	FARM	FF	% Change
Kh_BAQ(4)	0.00	0.00	0.00	-0.07	3.15	3.93	-0.37	0.00	-0.35	-0.88	0.00	0.00	-0.33	0.00	0.00	-50
Kh_BAQ(5)	-0.23	0.00	0.00	-0.07	-7.81	-0.44	0.12	0.00	0.00	-0.88	0.00	0.00	-0.16	0.00	0.00	-50
Kh_BAQ(6)	0.00	0.00	0.00	-0.07	3.23	3.93	-0.37	0.00	-0.35	-0.88	0.00	0.00	0.16	0.00	0.00	-50
Kh_BCU(1)	-0.93	-0.14	0.28	0.07	-3.66	1.75	0.00	0.00	0.00	-7.89	0.00	0.21	0.00	1.11	1.92	-50
Kh_BCU(3)	-0.23	0.00	0.00	-0.07	-8.10	0.44	-0.12	0.00	0.00	-0.88	0.00	0.00	0.00	0.00	0.00	-50
Kh_BCU(4)	0.00	0.00	0.00	-0.07	6.09	1.31	-0.25	0.00	0.00	-0.88	0.00	0.00	0.00	0.00	0.00	-50
Kh_BCU(5)	0.00	0.00	0.00	-0.07	-1.22	0.44	0.00	0.00	0.00	-0.88	0.00	0.00	0.16	0.00	0.00	-50
Kh_BCU(6)	-0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-50
Kh_TBA(1)	-2.33	0.00	-0.56	0.07	-1.22	0.87	0.00	0.00	0.00	-1.75	0.00	0.00	0.98	1.11	1.92	-50
Kh_TBA(3)	0.00	0.00	0.00	-0.07	-0.79	0.44	0.37	0.00	0.00	-0.88	0.00	0.00	0.16	0.00	0.00	-50
Kh_TBA(4)	0.00	0.00	0.00	-0.07	3.51	3.93	-0.37	0.00	-0.35	-0.88	0.00	0.00	-0.16	0.00	0.00	-50
Kh_TBA(6)	0.00	0.00	0.00	-0.07	-1.65	0.44	0.25	0.00	0.00	-0.88	0.00	0.00	0.00	0.00	0.00	-50
Kh_TCB(1)	0.00	0.00	0.00	-0.07	-2.51	0.87	-0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-50
Kh_TCB(4)	0.00	0.00	0.00	-0.07	3.01	3.93	-0.37	0.00	-0.35	-0.88	0.00	0.00	0.16	0.00	0.00	-50
Kh_TCB(6)	0.00	0.00	0.00	-0.07	1.36	4.80	-0.50	0.00	-0.35	-0.88	0.00	0.00	0.16	0.00	0.00	-50
Kh_TC(1)	-19.35	0.42	8.40	-0.27	-4.09	0.87	-0.50	0.00	-1.04	-8.77	-0.19	-0.21	-0.33	0.00	0.00	-50
Kh_TC(3)	0.00	0.00	0.00	-0.07	3.87	3.93	-0.25	0.00	0.00	-0.88	0.00	0.00	0.16	0.00	0.00	-50
Kh_TC(4)	-0.70	0.42	1.12	-0.07	-1.72	0.44	-0.99	0.00	-2.43	-0.88	0.00	0.00	-1.31	1.11	0.00	-50
Kh_TC(5)	0.00	0.69	0.00	-0.07	1.15	4.80	-2.61	0.24	-2.78	-0.88	0.00	0.00	0.16	1.11	0.00	-50
Kh_TC(6)	0.00	0.00	-0.56	-0.07	3.44	3.93	0.25	0.00	-0.35	-0.88	0.00	0.00	0.16	0.00	0.00	-50
Kh_TMA(1)	-8.16	0.28	10.08	-0.07	-3.37	0.44	0.87	-0.24	1.39	-9.65	0.38	0.21	-2.30	0.00	0.00	-50
Kh_TMA(2)	-0.70	0.00	0.84	-0.07	-2.80	0.44	0.25	0.00	0.35	-7.02	0.00	0.00	-1.31	0.00	0.00	-50
Kh_TMA(3)	-1.17	-0.14	3.36	-0.07	-3.15	0.44	0.75	-0.24	1.04	-7.02	0.00	0.00	-4.92	-1.11	0.00	-50
Kh_TMA(4)	-3.26	-0.28	10.36	-0.07	-4.44	0.44	1.86	3.17	1.04	1.75	0.00	0.00	-6.39	1.11	0.00	-50
Kh_TMA(6)	-1.40	0.00	-0.56	-0.07	4.01	3.93	-0.37	0.00	0.00	-0.88	0.00	0.00	0.00	0.00	0.00	-50
Kh_AA(1)	-9.79	-0.28	0.28	-0.27	-2.58	0.44	0.87	-2.68	2.78	5.26	18.20	15.22	-0.82	8.89	0.00	-50
Kh_AA(2)	0.00	-1.39	0.00	-2.04	-2.80	0.00	-2.48	0.24	2.78	3.51	-0.38	-4.86	0.00	-20.00	25.00	-50
Kh_AA(3)	0.00	0.00	0.00	0.00	-0.43	0.87	0.12	0.00	0.00	-0.88	0.38	-0.42	0.00	0.00	0.00	-50
Kh_AA(4)	0.00	0.00	0.00	-0.07	-3.37	6.55	0.12	0.00	0.00	-0.88	0.00	0.00	0.00	0.00	0.00	-50
Kh_AA(5)	0.00	0.00	0.00	-0.14	2.72	4.37	-0.37	0.00	-0.35	-7.02	0.00	0.00	0.16	0.00	0.00	-50
Kh_AA(6)	0.00	-5.12	0.00	-1.02	-0.86	0.00	-0.99	3.41	4.86	-5.26	-0.19	-2.33	0.16	10.00	3.85	-50
ld_l	0.00	0.00	0.00	-0.07	-1.22	0.44	0.50	0.00	0.00	-0.88	0.00	0.00	0.00	0.00	0.00	-10
ld_LCCU(1)	0.47	-0.42	-0.56	-0.20	-0.86	0.00	-0.99	-0.24	-1.39	-8.77	-0.38	1.06	1.15	-1.11	0.00	-10
ld_LCCU(2)	0.00	0.00	0.00	-0.07	0.29	2.18	0.37	0.00	-0.69	-53.51	0.00	7.61	0.49	0.00	0.00	-10
ld_LCCU(3)	0.00	4.02	-0.28	0.07	2.80	4.37	-0.37	2.44	-1.04	-1.75	0.38	0.63	0.16	8.89	1.92	-10
ld_LCA(1)	0.23	0.14	0.00	2.52	0.50	4.80	1.74	-0.24	-1.04	-24.56	0.75	6.55	0.49	-1.11	15.38	-10

* "BASE" includes actual values from calibrated run (m), all other values are expressed as a percentage difference from the calibration run (m)

Table H-2. Percentage Change in Roots Mean Square of Mean Weighted Residuals Between Sensitivity Runs and Calibration Run

	NRTH	OASI	PM	BARR	WYF	EYF	SHON	DV	LCA	PAHR	SPMT	SHRG	TMBR	FARM	FF	% Change
ld_LCA(2)	0.00	0.28	0.00	0.61	-2.44	1.75	0.62	0.73	-1.04	-7.02	0.56	2.11	0.00	4.44	9.62	-10
ld_LCA(3)	0.00	0.00	0.00	-0.14	3.66	3.93	-0.25	0.00	0.00	0.00	-2.06	2.75	0.16	0.00	0.00	-10
ld_LCA(4)	0.00	0.55	0.00	0.54	-2.08	1.31	1.61	0.00	-1.39	-3.51	0.56	1.69	0.16	2.22	7.69	-10
ld_LCA(5)	-0.70	0.00	-0.28	-0.34	-1.72	0.44	0.12	-0.24	0.00	-5.26	0.38	0.00	0.16	-1.11	0.00	-10
ld_LCA(6)	0.00	0.00	0.00	-0.07	-1.15	0.44	0.87	0.00	0.00	-0.88	-0.56	0.00	0.00	0.00	0.00	-10
ld_LCA(7)	3.03	0.00	-0.56	-0.07	-2.01	0.87	0.25	0.00	-0.69	-0.88	0.38	0.42	0.66	0.00	0.00	-10
ld_LCA(8)	-0.23	-0.28	0.00	-0.20	-1.22	0.44	-0.12	-0.49	0.35	-48.25	0.38	0.00	0.16	-2.22	0.00	-10
ld_LCA(9)	0.00	0.83	0.00	0.20	-2.58	0.87	1.49	2.68	-1.04	-0.88	0.56	1.06	0.00	23.33	3.85	-10
ld_UCCU	0.00	0.00	0.00	-0.07	-0.93	0.44	-0.12	0.00	-0.35	0.00	0.38	0.42	0.16	0.00	0.00	-10
ld_LCA3	0.00	0.00	0.00	-0.07	-3.08	0.00	0.00	0.00	-0.35	0.00	0.38	0.42	0.00	0.00	0.00	-10
ld_TSDV(1)	0.00	0.14	0.00	-0.07	2.22	4.37	-0.62	0.00	-0.35	-0.88	0.38	0.42	0.16	0.00	0.00	-10
ld_TSDV(2)	0.00	0.14	0.00	0.00	-1.94	0.87	0.00	5.37	-0.35	-1.75	0.38	0.63	0.16	4.44	1.92	-10
ld_VU(1)	4.43	-0.42	-0.28	-0.61	-4.44	0.00	-0.25	0.00	-0.35	-6.14	0.38	0.00	0.82	-2.22	0.00	-10
ld_VU(2)	0.00	0.00	-0.28	-0.07	2.72	4.37	-0.50	0.00	-0.35	-7.02	0.38	0.42	0.16	0.00	0.00	-10
ld_VU(3)	0.47	-2.08	-0.28	-0.07	-1.94	0.44	0.62	2.93	-0.35	1.75	0.38	0.42	0.00	0.00	0.00	-10
ld_VCU(1)	0.47	-2.22	-0.56	-0.20	-0.43	-0.87	-3.23	-0.73	10.07	-6.14	0.38	0.21	-0.98	-4.44	0.00	-10
ld_VCU(2)	0.00	0.00	0.00	-0.07	-1.15	0.44	-0.12	0.00	0.00	-0.88	0.38	0.42	0.00	0.00	0.00	-10
ld_VA(1)	0.00	0.69	-0.28	-0.07	1.29	1.31	-1.49	0.00	-12.85	-7.02	0.38	0.42	-0.49	0.00	0.00	-10
ld_VA(2)	-0.23	0.00	0.00	-0.07	1.72	-1.75	0.75	0.00	0.00	-0.88	0.38	0.42	-0.16	0.00	0.00	-10
ld_VA(3)	0.00	4.16	0.00	-0.07	3.58	3.93	-0.37	-0.24	-7.29	-0.88	0.38	0.42	0.16	-1.11	0.00	-10
ld_BAQ(1)	0.47	-0.14	0.28	-0.07	-1.51	0.44	0.00	-0.98	0.35	-0.88	0.38	0.42	1.31	0.00	0.00	-10
ld_BAQ(3)	0.00	0.00	0.00	-0.07	3.08	3.93	-0.37	0.00	-0.35	-0.88	0.38	0.42	0.16	0.00	0.00	-10
ld_BAQ(4)	0.00	0.00	0.00	-0.07	0.00	0.00	0.00	0.00	0.00	-0.88	0.38	0.42	0.33	0.00	0.00	-10
ld_BAQ(5)	0.00	0.00	0.00	-0.07	-0.79	0.44	0.37	0.00	0.00	-0.88	0.38	0.42	0.16	0.00	0.00	-10
ld_BAQ(6)	0.00	0.00	0.00	-0.07	-0.79	0.44	0.37	0.00	0.00	0.00	0.38	0.42	0.16	0.00	0.00	-10
ld_BCU(1)	0.93	0.00	-0.28	-0.27	-5.45	0.44	0.00	0.00	-0.35	0.00	0.38	0.21	0.33	0.00	0.00	-10
ld_BCU(3)	-0.23	0.00	0.00	-0.07	9.39	1.31	-0.12	0.00	0.00	-0.88	0.38	0.42	0.00	0.00	0.00	-10
ld_BCU(4)	0.00	0.00	-0.28	-0.14	1.08	4.80	-0.50	0.00	-0.35	-0.88	0.38	0.42	0.16	0.00	0.00	-10
ld_BCU(5)	0.00	0.00	0.00	-0.07	2.65	4.37	-0.50	0.00	-0.35	-0.88	0.38	0.42	0.16	0.00	0.00	-10
ld_BCU(6)	0.00	0.00	0.00	-0.07	-0.72	0.44	0.37	0.00	0.00	-0.88	0.38	0.42	0.16	0.00	0.00	-10
ld_TBA(1)	1.63	-0.14	1.12	-0.07	-2.08	0.44	0.75	3.17	0.00	1.75	0.38	0.42	-0.98	1.11	0.00	-10
ld_TBA(3)	0.00	0.00	0.00	-0.07	3.01	3.93	-0.37	0.00	-0.35	-0.88	0.38	0.42	0.16	0.00	0.00	-10
ld_TBA(4)	0.00	0.00	0.00	-0.14	2.80	4.37	-0.50	0.00	-0.35	-7.02	0.38	0.42	0.33	0.00	0.00	-10
ld_TBA(6)	0.00	0.00	-0.28	-0.07	2.37	4.37	-0.50	0.00	-0.35	-0.88	0.38	0.42	0.16	0.00	0.00	-10
ld_TCB(1)	0.00	0.00	0.00	-0.07	-1.43	0.44	0.00	0.00	0.00	-0.88	0.38	0.42	0.00	0.00	0.00	-10
ld_TCB(4)	-0.23	0.00	0.00	-0.07	5.23	1.31	-0.37	0.00	0.00	0.00	0.38	0.42	0.00	0.00	0.00	-10

* "BASE" includes actual values from calibrated run (m), all other values are expressed as a percentage difference from the calibration run (m)

Table H-2. Percentage Change in Roots Mean Square of Mean Weighted Residuals Between Sensitivity Runs and Calibration Run

	NRTH	OASI	PM	BARR	WYF	EYF	SHON	DV	LCA	PAHR	SPMT	SHRG	TMBR	FARM	FF	% Change
ld_TCB(6)	0.00	0.00	0.00	-0.07	4.95	3.93	-0.50	0.00	-0.35	-0.88	0.38	0.42	0.16	0.00	0.00	-10
ld_TC(1)	13.29	-0.14	4.48	0.07	-2.37	0.87	1.24	0.00	0.35	-0.88	0.38	0.63	0.66	1.11	1.92	-10
ld_TC(3)	0.00	0.00	0.00	-0.07	-1.36	0.44	0.25	0.00	0.00	-0.88	0.38	0.42	0.16	0.00	0.00	-10
ld_TC(4)	0.47	-0.14	-1.12	-0.07	-1.65	0.44	0.87	0.00	0.35	0.88	0.38	0.42	0.66	0.00	0.00	-10
ld_TC(5)	0.00	-0.28	-0.28	-0.14	2.94	4.37	0.50	0.00	0.69	-0.88	0.38	0.42	0.16	0.00	0.00	-10
ld_TC(6)	0.00	0.00	0.28	-0.07	2.94	3.93	-0.37	0.00	-0.35	-0.88	0.38	0.42	0.16	0.00	0.00	-10
ld_TMA(1)	5.59	0.14	-2.80	-0.14	-0.14	0.44	-0.25	0.00	-1.74	0.00	0.38	0.42	1.97	1.11	0.00	-10
ld_TMA(2)	0.23	0.00	-0.84	-0.07	-1.22	0.44	0.25	0.00	-0.69	-7.89	0.38	0.42	1.48	0.00	0.00	-10
ld_TMA(3)	0.70	0.00	-1.40	0.00	-0.93	0.44	-0.12	0.00	-1.04	-0.88	0.38	0.42	1.64	1.11	0.00	-10
ld_TMA(4)	1.40	-0.14	-2.24	-0.07	-0.79	0.44	0.12	0.00	-0.69	-0.88	0.38	0.42	2.46	1.11	0.00	-10
ld_TMA(6)	0.70	0.00	0.28	-0.07	6.59	1.75	-0.37	0.00	0.00	-0.88	0.38	0.42	0.00	0.00	0.00	-10
ld_AA(1)	6.29	0.00	0.00	0.00	-5.81	1.31	0.00	3.17	-0.35	-9.65	-0.94	-3.38	0.16	-1.11	0.00	-10
ld_AA(2)	0.00	0.42	0.00	0.41	6.45	2.18	0.25	2.20	-0.69	-6.14	0.56	1.48	0.00	6.67	5.77	-10
ld_AA(3)	0.00	0.00	0.00	-0.07	-1.72	0.44	-0.25	0.00	0.00	-0.88	0.38	0.63	0.00	0.00	0.00	-10
ld_AA(4)	-0.23	0.00	0.00	-0.07	-1.36	-1.75	0.25	0.00	0.00	-0.88	0.38	0.42	0.00	0.00	0.00	-10
ld_AA(5)	0.00	0.00	0.00	0.00	-2.51	0.87	-0.12	0.00	0.00	0.00	0.38	0.63	0.00	0.00	0.00	-10
ld_AA(6)	0.00	1.11	0.00	0.14	2.80	4.37	-0.25	-0.49	-1.04	-2.63	0.56	1.06	0.16	0.00	1.92	-10

* "BASE" includes actual values from calibrated run (m), all other values are expressed as a percentage difference from the calibration run (m)

Table H-3. Percentage Changes in Discharge Rates Between Sensitivity Runs and Calibration Run

	Drain Fluxes								GHB Fluxes		% Change
	Dval	OV	Ariv	AM	FL	AF	PV	IS	PP	EM	
BASE*	-59782.9	-25785	-334.81	-77332.5	-37873.7	-5232.56	-19105.9	-2456.55	1719.51	-4928.82	
Kh_I	0.04	-0.35	0.39	0.22	-0.02	2.54	-1.18	0.07	0.01	-0.03	100
Kh_LCCU(1)	0.15	-9.15	7.23	3.82	0.55	36.34	-7.84	-12.08	60.83	0.24	100
Kh_LCCU(2)	0.01	-0.38	0.92	0.52	0.07	6.06	-1.09	-18.23	0.02	0.03	100
Kh_LCCU(3)	16.91	-6.30	-39.34	-6.93	-2.58	-40.87	-0.82	-0.52	0.21	5.85	100
Kh_LCA(1)	0.85	-0.72	3.02	0.62	0.15	-2.84	-1.96	-17.44	0.01	0.06	100
Kh_LCA(2)	-0.30	-0.30	-15.27	6.78	-0.78	-82.59	-1.01	-3.24	2.32	-0.24	100
Kh_LCA(3)	0.04	-0.22	2.93	1.54	0.21	17.62	-0.87	-81.94	0.08	0.09	100
Kh_LCA(4)	7.41	-0.78	34.52	-4.54	7.22	-100.00	-1.15	-3.31	-2.50	38.92	100
Kh_LCA(5)	0.78	-2.38	5.25	3.93	0.36	49.09	-29.65	1.39	0.04	0.16	100
Kh_LCA(6)	0.01	-0.40	0.55	0.27	0.04	3.06	-1.04	-4.19	0.04	0.02	100
Kh_LCA(7)	0.01	0.55	0.22	0.09	0.02	0.97	-1.46	0.03	0.00	0.01	100
Kh_LCA(8)	0.18	-0.57	11.80	6.16	0.86	74.19	-47.24	1.03	0.02	0.36	100
Kh_LCA(9)	37.70	0.20	-100.00	-17.83	-10.24	-78.69	-1.31	-1.14	-0.46	-4.16	100
Kh_UCCU	0.01	-2.30	0.90	0.57	0.07	6.87	-1.32	0.13	0.01	0.03	100
Kh_LCA3	0.01	-0.80	0.54	0.30	0.04	3.41	-1.19	0.12	0.01	0.02	100
Kh_TSDV(1)	0.05	-0.29	1.62	-0.81	2.45	-3.13	-0.91	0.00	0.24	1.81	100
Kh_TSDV(2)	6.42	-0.88	-22.32	-2.75	-1.96	-9.45	-0.81	-0.07	-0.02	-0.43	100
Kh_VU(1)	0.07	-4.31	8.20	4.25	0.58	49.88	-26.77	0.67	0.04	0.25	100
Kh_VU(2)	0.01	-0.78	0.47	0.27	0.03	3.21	-1.09	0.11	0.01	0.01	100
Kh_VU(3)	0.41	-9.67	9.09	1.94	0.64	13.99	-1.48	0.19	0.02	0.25	100
Kh_VCU(1)	0.39	-20.99	14.14	4.00	0.99	35.32	-1.17	0.55	0.04	0.40	100
Kh_VCU(2)	0.01	-0.85	0.39	0.23	0.03	2.77	-0.79	0.11	0.01	0.01	100
Kh_VA(1)	-0.03	4.30	-1.29	-0.66	-0.09	-7.34	-0.82	-0.10	-0.02	-0.04	100
Kh_VA(2)	0.00	-0.35	0.30	0.17	0.02	1.99	-0.82	0.08	0.00	0.01	100
Kh_VA(3)	0.04	-0.70	3.59	0.30	0.25	-0.82	-0.78	0.05	0.00	0.09	100
Kh_BAQ(1)	0.01	-0.30	0.44	0.21	0.03	2.42	-1.22	0.10	0.00	0.01	100
Kh_BAQ(3)	0.00	-0.36	0.36	0.20	0.03	2.36	-1.03	0.10	0.00	0.01	100
Kh_BAQ(4)	0.01	-0.81	0.44	0.25	0.03	2.95	-0.85	0.12	0.01	0.01	100
Kh_BAQ(5)	0.00	-0.39	0.29	0.17	0.02	1.95	-0.76	0.10	0.00	0.01	100
Kh_BAQ(6)	0.00	-0.17	0.25	0.14	0.02	1.59	-0.83	0.09	0.00	0.01	100
Kh_BCU(1)	0.02	-2.30	1.42	0.78	0.10	9.12	-2.86	0.21	0.02	0.04	100

* "BASE" includes actual values from calibrated run (m3/day), all other values are expressed as the percentage difference from the calibration run.

Table H-3. Percentage Changes in Discharge Rates Between Sensitivity Runs and Calibration Run

	Drain Fluxes								GHB Fluxes		% Change
	Dval	OV	Ariv	AM	FL	AF	PV	IS	PP	EM	
Kh_BCU(3)	0.00	0.10	-0.06	-0.03	0.00	-0.31	0.05	0.01	0.00	0.00	100
Kh_BCU(4)	0.01	-0.80	0.41	0.24	0.03	2.80	-0.76	0.12	0.01	0.01	100
Kh_BCU(5)	0.01	-0.84	0.43	0.25	0.03	2.88	-0.73	0.11	0.01	0.01	100
Kh_BCU(6)	0.00	-0.67	0.38	0.22	0.03	2.61	-0.78	0.07	0.01	0.01	100
Kh_TBA(1)	0.69	0.65	-2.17	0.01	-0.20	2.90	-3.41	0.09	0.00	0.00	100
Kh_TBA(3)	0.01	-0.94	0.45	0.26	0.03	3.12	-0.79	0.08	0.01	0.01	100
Kh_TBA(4)	0.01	-0.75	0.40	0.23	0.03	2.74	-0.78	0.11	0.00	0.00	100
Kh_TBA(6)	0.01	-0.76	0.39	0.23	0.03	2.73	-0.76	0.10	0.01	0.02	100
Kh_TCB(1)	0.01	-0.76	0.48	0.27	0.04	3.18	-1.10	0.10	0.00	0.00	100
Kh_TCB(4)	0.01	-0.87	0.48	0.28	0.04	3.29	-1.06	0.09	0.00	0.00	100
Kh_TCB(6)	0.01	-0.85	0.42	0.25	0.03	2.91	-0.79	0.13	-0.01	-0.02	100
Kh_TC(1)	-0.01	4.44	-0.66	-0.32	-0.05	-3.68	-3.54	-0.07	0.00	0.00	100
Kh_TC(3)	0.00	-0.68	0.36	0.21	0.03	2.51	-0.75	0.08	0.00	0.01	100
Kh_TC(4)	0.01	-0.22	0.49	0.21	0.04	2.25	-1.29	0.06	0.01	0.04	100
Kh_TC(5)	0.02	-2.02	1.24	0.47	0.09	4.89	-0.81	0.08	0.01	0.01	100
Kh_TC(6)	0.01	-0.70	0.39	0.23	0.03	2.68	-0.80	0.13	0.01	-0.01	100
Kh_TMA(1)	-0.02	1.06	-0.36	0.16	-0.02	2.91	-2.80	0.07	0.00	0.00	100
Kh_TMA(2)	0.00	0.67	-0.10	0.00	-0.01	0.19	-0.94	0.02	0.00	-0.02	100
Kh_TMA(3)	-0.02	1.92	-0.90	-0.18	-0.06	-1.23	-1.29	0.01	0.00	-0.02	100
Kh_TMA(4)	-0.02	1.74	-0.72	-0.07	-0.05	0.18	-1.94	0.05	0.00	0.00	100
Kh_TMA(6)	0.00	-0.03	0.26	0.15	0.02	1.76	-1.11	0.05	1.36	80.73	100
Kh_AA(1)	3.93	0.68	12.13	3.81	-14.23	16.91	-18.69	-56.93	1.78	6.56	100
Kh_AA(2)	2.97	-0.93	28.02	-0.87	11.58	-100.00	-1.40	-5.09	0.01	0.02	100
Kh_AA(3)	0.01	-0.34	0.70	0.39	0.05	4.50	-0.72	-13.73	0.00	-0.08	100
Kh_AA(4)	0.71	-0.64	-2.06	-0.21	-0.20	-0.35	0.01	0.05	0.01	0.01	100
Kh_AA(5)	0.01	-0.78	0.41	0.24	0.03	2.82	-0.79	0.11	10.66	87.81	100
Kh_AA(6)	-0.21	-0.63	-50.95	-17.33	40.19	-100.00	-1.16	-1.95	0.01	-0.07	100
ld_l	-0.01	-0.79	0.39	0.23	0.06	2.77	-0.76	0.11	0.01	0.04	10
ld_LCCU(1)	-0.03	2.66	-1.53	-0.80	-0.12	-8.06	0.91	3.49	-9.29	-0.05	10
ld_LCCU(2)	0.00	-0.62	0.28	0.17	0.02	1.96	-1.22	5.31	0.00	0.01	10
ld_LCCU(3)	-4.38	1.82	10.32	1.95	0.69	11.88	-1.11	0.21	-0.13	-1.41	10
ld_LCA(1)	-0.03	-0.19	-1.73	-0.19	-0.11	1.86	0.46	2.98	-0.01	-0.04	10

* "BASE" includes actual values from calibrated run (m3/day), all other values are expressed as the percentage difference from the calibration run.

Table H-3. Percentage Changes in Discharge Rates Between Sensitivity Runs and Calibration Run

	Drain Fluxes								GHB Fluxes		% Change
	Dval	OV	Ariv	AM	FL	AF	PV	IS	PP	EM	
ld_LCA(2)	0.09	-0.08	4.42	-1.68	0.20	24.18	-0.68	1.07	-0.16	0.05	10
ld_LCA(3)	0.00	-0.25	-0.15	-0.07	-0.01	-0.86	-0.89	13.96	-0.02	0.00	10
ld_LCA(4)	-2.76	-0.17	-13.06	0.82	-3.22	46.86	0.06	0.64	0.06	-3.25	10
ld_LCA(5)	-0.02	0.27	-1.72	-0.96	-0.13	-11.48	7.07	-0.22	-0.03	-0.05	10
ld_LCA(6)	0.01	-0.83	0.39	0.23	0.03	2.75	-0.83	1.44	-0.01	0.01	10
ld_LCA(7)	0.01	-0.85	0.55	0.27	0.04	3.07	-0.94	0.11	0.00	0.02	10
ld_LCA(8)	-0.04	-0.17	-2.44	-1.23	-0.18	-14.58	9.69	-0.27	-0.04	-0.08	10
ld_LCA(9)	-9.69	-0.29	34.09	4.85	2.14	24.77	-0.83	0.39	0.03	0.85	10
ld_UCCU	0.00	0.11	0.26	0.12	0.02	1.36	-1.11	0.06	0.00	0.01	10
ld_LCA3	0.00	-0.11	0.25	0.13	0.02	1.55	-0.89	0.04	0.00	0.01	10
ld_TSDV(1)	-0.01	-0.69	0.36	0.43	-0.40	4.09	-1.08	0.08	-0.04	-0.34	10
ld_TSDV(2)	-2.01	-0.82	7.48	1.20	0.64	6.95	-0.85	0.15	0.01	0.19	10
ld_VU(1)	-0.02	2.65	-3.17	-1.34	-0.21	-15.04	6.44	-0.20	-0.04	-0.09	10
ld_VU(2)	0.00	-0.19	0.33	0.19	0.02	2.14	-1.17	0.09	0.00	0.01	10
ld_VU(3)	-0.05	1.15	-1.19	-0.11	-0.08	0.27	-0.84	0.08	0.00	-0.03	10
ld_VCU(1)	-0.09	5.44	-3.59	-0.86	-0.25	-6.80	-1.12	-0.04	-0.02	-0.10	10
ld_VCU(2)	0.00	-0.24	0.05	0.04	0.00	0.45	0.04	0.05	0.00	0.00	10
ld_VA(1)	-0.01	0.19	-0.13	0.10	-0.01	1.58	-1.05	0.04	0.00	0.00	10
ld_VA(2)	0.00	-0.58	0.28	0.18	0.02	2.14	-0.89	1.56	0.00	0.01	10
ld_VA(3)	-0.01	-0.73	-0.69	0.20	-0.05	3.85	-0.78	0.08	0.00	-0.02	10
ld_BAQ(1)	0.00	0.34	0.21	0.10	0.02	1.12	-1.21	0.06	0.00	0.01	10
ld_BAQ(3)	0.01	-0.82	0.49	0.28	0.04	3.32	-1.06	0.09	0.00	0.02	10
ld_BAQ(4)	0.00	-0.37	0.33	0.18	0.02	2.11	-0.87	0.07	0.00	0.01	10
ld_BAQ(5)	0.01	-0.76	0.39	0.23	0.03	2.70	-0.74	0.10	0.00	0.01	10
ld_BAQ(6)	0.01	-0.85	0.42	0.25	0.03	2.94	-0.78	0.09	0.00	0.01	10
ld_BCU(1)	0.00	0.73	-0.17	-0.09	-0.01	-1.10	-0.28	0.02	-0.01	-0.01	10
ld_BCU(3)	0.00	-0.27	0.29	0.16	0.02	1.89	-0.90	0.11	0.00	0.01	10
ld_BCU(4)	0.01	-0.85	0.49	0.29	0.04	3.36	-1.07	0.15	0.00	0.02	10
ld_BCU(5)	0.01	-0.79	0.45	0.27	0.03	3.17	-1.02	0.11	0.00	0.01	10
ld_BCU(6)	0.00	-0.31	0.30	0.17	0.02	1.94	-0.87	0.08	0.00	0.01	10
ld_TBA(1)	0.00	-0.13	-0.16	-0.04	-0.01	-0.37	0.48	0.06	0.00	0.00	10
ld_TBA(3)	0.01	-0.77	0.40	0.24	0.03	2.79	-0.74	0.10	0.00	0.01	10

* "BASE" includes actual values from calibrated run (m3/day), all other values are expressed as the percentage difference from the calibration run.

Table H-3. Percentage Changes in Discharge Rates Between Sensitivity Runs and Calibration Run

	Drain Fluxes									GHB Fluxes		%
	Dval	OV	Ariv	AM	FL	AF	PV	IS	PP	EM	Change	
ld_TBA(4)	0.00	-0.29	0.24	0.14	0.02	1.64	-0.69	0.05	0.00	0.01	10	
ld_TBA(6)	0.01	-0.86	0.43	0.25	0.03	2.97	-0.78	0.10	0.00	0.01	10	
ld_TCB(1)	0.01	-0.83	0.42	0.25	0.03	2.92	-0.77	0.08	0.00	0.01	10	
ld_TCB(4)	0.00	-0.24	0.05	0.04	0.00	0.44	0.04	0.06	0.00	0.00	10	
ld_TCB(6)	0.00	-0.29	0.29	0.16	0.02	1.90	-0.90	0.07	0.00	0.01	10	
ld_TC(1)	0.01	-3.56	0.89	0.42	0.06	4.70	1.56	0.14	0.01	0.03	10	
ld_TC(3)	0.01	-0.85	0.43	0.25	0.03	2.95	-0.77	0.06	0.00	0.01	10	
ld_TC(4)	0.00	-0.10	0.10	0.10	0.01	1.34	-0.80	0.06	0.00	0.00	10	
ld_TC(5)	-0.01	0.50	-0.19	0.01	-0.01	0.47	-0.79	0.07	0.00	0.00	10	
ld_TC(6)	0.01	-0.78	0.40	0.24	0.03	2.78	-0.76	0.10	0.00	0.01	10	
ld_TMA(1)	0.09	-0.87	0.67	0.13	0.05	0.82	0.00	0.04	0.00	0.02	10	
ld_TMA(2)	0.01	-0.56	0.39	0.19	0.03	2.11	-0.69	0.07	0.00	0.01	10	
ld_TMA(3)	0.01	-0.89	0.73	0.29	0.05	3.01	-0.96	0.10	0.00	0.02	10	
ld_TMA(4)	0.02	-1.00	0.87	0.26	0.06	2.40	-0.59	0.06	0.00	0.02	10	
ld_TMA(6)	0.00	-0.41	0.25	0.15	0.02	1.73	-0.60	0.06	0.00	0.01	10	
ld_AA(1)	-1.68	-0.05	1.40	-0.16	0.07	-3.92	5.23	12.44	-0.05	0.03	10	
ld_AA(2)	-1.12	-0.73	-8.73	-1.32	-1.65	52.72	-1.06	0.68	-0.07	-0.92	10	
ld_AA(3)	0.00	-0.26	0.22	0.13	0.02	1.46	-0.81	1.66	0.00	0.01	10	
ld_AA(4)	0.00	-0.17	0.33	0.18	0.02	2.06	-1.15	0.09	0.00	0.01	10	
ld_AA(5)	0.01	-0.73	0.39	0.23	0.03	2.70	-0.77	0.10	0.00	0.01	10	
ld_AA(6)	-0.02	0.30	4.65	2.22	-6.47	19.60	0.18	0.31	-0.60	-8.68	10	
Kh_I	-0.02	-0.97	0.43	0.27	0.09	3.26	-0.83	0.12	0.01	0.07	-50	
Kh_LCCU(1)	-0.09	5.03	-3.75	-1.86	-0.29	-16.98	1.96	8.04	-36.67	-0.13	-50	
Kh_LCCU(2)	0.00	-0.12	-0.23	-0.09	-0.02	-1.00	-1.07	13.41	-0.01	-0.01	-50	
Kh_LCCU(3)	-10.13	9.89	18.12	3.17	1.18	17.17	-1.02	0.30	-0.32	-3.37	-50	
Kh_LCA(1)	-0.12	0.12	-5.02	-0.81	-0.33	1.70	0.27	26.55	-0.02	-0.13	-50	
Kh_LCA(2)	0.42	-0.14	20.94	-8.07	1.06	105.54	-0.74	4.79	-2.46	0.32	-50	
Kh_LCA(3)	-0.02	-0.40	-1.54	-0.79	-0.11	-9.15	-1.08	59.36	-0.06	-0.05	-50	
Kh_LCA(4)	-5.86	0.04	-30.50	-4.60	-6.10	204.73	-0.98	2.23	-0.16	-22.81	-50	
Kh_LCA(5)	1.00	3.54	-11.94	-4.38	-0.92	-48.85	25.44	-1.01	-0.18	-0.38	-50	
Kh_LCA(6)	0.68	0.48	-2.78	-0.30	-0.24	-0.49	-1.11	1.70	-0.07	-0.09	-50	
Kh_LCA(7)	0.00	-0.89	0.40	0.20	0.03	2.25	-0.36	0.05	0.00	0.01	-50	

* "BASE" includes actual values from calibrated run (m3/day), all other values are expressed as the percentage difference from the calibration run.

Table H-3. Percentage Changes in Discharge Rates Between Sensitivity Runs and Calibration Run

	Drain Fluxes								GHB Fluxes		% Change
	Dval	OV	Ariv	AM	FL	AF	PV	IS	PP	EM	
Kh_LCA(8)	-0.13	0.11	-8.56	-4.26	-0.63	-51.84	32.97	-0.85	-0.20	-0.27	-50
Kh_LCA(9)	-27.20	0.84	144.28	13.34	4.53	69.05	-1.07	0.97	0.02	1.79	-50
Kh_UCCU	0.00	1.77	-0.29	-0.23	-0.02	-2.93	-0.59	-0.02	-0.01	-0.01	-50
Kh_LCA3	0.00	0.57	0.03	-0.01	0.00	-0.13	-0.71	0.02	0.00	0.00	-50
Kh_TSDV(1)	-0.03	-0.18	-0.65	0.85	-1.65	4.93	-0.89	0.08	-0.18	-1.18	-50
Kh_TSDV(2)	-4.42	-0.09	15.66	2.17	1.43	9.74	-0.79	0.20	0.02	0.44	-50
Kh_VU(1)	-0.05	5.14	-5.73	-2.75	-0.40	-33.03	14.43	-0.63	-0.10	-0.17	-50
Kh_VU(2)	0.01	-0.76	0.39	0.23	0.03	2.68	-0.76	0.12	0.01	0.01	-50
Kh_VU(3)	-0.28	7.74	-7.00	-1.34	-0.49	-8.65	-0.65	-0.07	-0.02	-0.19	-50
Kh_VCU(1)	-0.28	19.72	-12.51	-3.45	-0.88	-32.08	-0.85	-0.44	-0.10	-0.35	-50
Kh_VCU(2)	0.01	-0.37	0.38	0.21	0.03	2.43	-1.17	0.11	0.00	0.01	-50
Kh_VA(1)	-0.03	1.65	-1.25	-0.18	-0.09	-0.72	-1.00	0.05	0.00	-0.03	-50
Kh_VA(2)	0.01	-1.13	0.68	0.37	0.05	4.36	-1.30	0.10	0.01	0.02	-50
Kh_VA(3)	-0.04	-0.07	-3.04	0.05	-0.21	5.00	-0.87	0.11	0.01	-0.08	-50
Kh_BAQ(1)	0.00	0.28	0.26	0.14	0.02	1.60	-1.46	0.02	0.00	0.01	-50
Kh_BAQ(3)	0.01	-0.86	0.42	0.25	0.03	2.92	-0.78	0.12	0.01	0.01	-50
Kh_BAQ(4)	0.01	-0.75	0.39	0.23	0.03	2.68	-0.75	0.12	0.01	0.01	-50
Kh_BAQ(5)	0.00	0.02	0.18	0.10	0.01	1.14	-0.79	0.08	0.00	0.01	-50
Kh_BAQ(6)	0.01	-0.75	0.39	0.23	0.03	2.71	-0.76	0.08	0.01	0.01	-50
Kh_BCU(1)	0.00	0.79	-0.24	-0.14	-0.02	-1.57	-0.03	0.00	0.00	-0.01	-50
Kh_BCU(3)	0.00	-0.14	0.23	0.13	0.02	1.49	-0.80	0.09	0.00	0.01	-50
Kh_BCU(4)	0.00	-0.35	0.29	0.17	0.02	2.01	-1.03	0.09	0.00	0.01	-50
Kh_BCU(5)	0.00	-0.25	0.29	0.16	0.02	1.88	-0.90	0.05	0.00	0.01	-50
Kh_BCU(6)	0.00	-0.01	-0.02	-0.01	0.00	-0.13	0.01	0.02	0.00	0.00	-50
Kh_TBA(1)	-0.01	0.52	-0.44	-0.23	-0.03	-2.57	1.01	-0.07	-0.01	-0.01	-50
Kh_TBA(3)	0.00	-0.39	0.32	0.18	0.02	2.07	-0.87	0.06	0.00	0.01	-50
Kh_TBA(4)	0.01	-0.71	0.39	0.23	0.03	2.65	-0.79	0.11	0.01	0.01	-50
Kh_TBA(6)	0.00	-0.21	0.27	0.15	0.02	1.70	-0.83	0.05	0.00	0.01	-50
Kh_TCB(1)	0.00	-0.25	0.05	0.04	0.00	0.45	0.05	-0.01	0.00	0.00	-50
Kh_TCB(4)	0.01	-0.77	0.39	0.23	0.03	2.70	-0.76	0.12	0.01	0.01	-50
Kh_TCB(6)	0.01	-0.86	0.42	0.25	0.03	2.94	-0.79	0.12	0.01	0.01	-50
Kh_TC(1)	0.01	-5.46	0.83	0.50	0.06	6.00	3.38	0.13	0.01	0.03	-50

* "BASE" includes actual values from calibrated run (m3/day), all other values are expressed as the percentage difference from the calibration run.

Table H-3. Percentage Changes in Discharge Rates Between Sensitivity Runs and Calibration Run

	Drain Fluxes								GHB Fluxes		%
	Dval	OV	Ariv	AM	FL	AF	PV	IS	PP	EM	Change
Kh_TC(3)	0.01	-0.78	0.40	0.23	0.03	2.74	-0.75	0.11	0.01	0.01	-50
Kh_TC(4)	-0.01	0.51	-0.22	0.03	-0.01	0.80	-1.01	0.08	0.00	-0.01	-50
Kh_TC(5)	-0.02	0.66	-0.65	-0.05	-0.04	0.35	-0.76	0.08	0.00	-0.02	-50
Kh_TC(6)	0.01	-0.93	0.45	0.26	0.03	3.08	-0.77	0.12	0.01	0.01	-50
Kh_TMA(1)	0.09	-2.03	1.03	0.28	0.07	2.40	0.41	0.29	0.00	0.03	-50
Kh_TMA(2)	0.01	-0.53	0.45	0.21	0.03	2.39	-0.94	0.10	0.00	0.01	-50
Kh_TMA(3)	0.02	-1.62	1.19	0.44	0.08	4.44	-1.10	0.12	0.01	0.03	-50
Kh_TMA(4)	0.69	-0.64	-2.27	-0.12	-0.20	1.18	-0.68	0.04	0.00	-0.08	-50
Kh_TMA(6)	0.01	-1.02	0.47	0.27	0.03	3.12	-0.69	0.11	0.01	0.01	-50
Kh_AA(1)	-2.84	-1.30	-2.14	-0.47	-0.68	-2.34	11.73	21.98	-0.92	-0.25	-50
Kh_AA(2)	0.16	0.00	-58.83	-12.87	-10.67	275.34	-0.90	2.86	-2.55	-5.45	-50
Kh_AA(3)	0.00	-0.29	0.07	0.04	0.00	0.43	-0.92	7.78	0.00	0.00	-50
Kh_AA(4)	0.00	-0.18	0.27	0.15	0.02	1.73	-0.88	0.03	0.00	0.01	-50
Kh_AA(5)	0.01	-0.82	0.48	0.28	0.04	3.24	-1.06	0.11	0.01	0.02	-50
Kh_AA(6)	-0.09	0.48	27.75	11.29	-40.22	100.30	-1.04	1.37	-17.36	19.40	-50
ld_l	0.03	-0.30	0.28	0.16	-0.01	1.92	-0.90	0.05	0.00	-0.02	-10
ld_LCCU(1)	0.05	-4.43	2.85	1.51	0.21	16.06	-3.69	-4.13	10.98	0.09	-10
ld_LCCU(2)	0.00	-0.29	0.40	0.24	0.03	2.90	-0.85	-4.92	0.00	0.01	-10
ld_LCCU(3)	5.56	-3.07	-12.43	-2.00	-0.85	-9.71	-1.05	-0.04	0.12	1.84	-10
ld_LCA(1)	0.04	-0.18	2.02	0.27	0.13	-1.28	-0.63	-2.46	0.00	0.05	-10
ld_LCA(2)	-0.08	-0.32	-3.94	1.87	-0.18	-22.88	-0.08	-0.91	0.13	-0.05	-10
ld_LCA(3)	0.01	-0.76	0.90	0.50	0.07	5.76	-0.79	-15.10	0.02	0.03	-10
ld_LCA(4)	3.86	0.37	14.42	-1.26	3.82	-54.43	-1.26	-0.70	-0.29	3.62	-10
ld_LCA(5)	0.03	-0.66	2.29	1.29	0.17	15.02	-9.02	0.44	0.02	0.07	-10
ld_LCA(6)	0.00	-0.28	0.32	0.17	0.02	1.95	-0.76	-1.55	0.01	0.01	-10
ld_LCA(7)	0.00	0.26	0.26	0.14	0.02	1.62	-1.44	0.04	0.00	0.01	-10
ld_LCA(8)	0.06	-0.45	3.66	1.92	0.27	22.00	-14.04	0.50	0.03	0.11	-10
ld_LCA(9)	11.59	0.43	-40.38	-5.39	-2.88	-25.61	-1.24	-0.32	-0.08	-1.14	-10
ld_UCCU	0.01	-0.83	0.53	0.31	0.04	3.65	-1.24	0.07	0.00	0.02	-10
ld_LCA3	0.01	-0.42	0.38	0.21	0.03	2.48	-1.07	0.07	0.00	0.01	-10
ld_TSDV(1)	0.02	-0.81	0.51	0.06	0.60	1.84	-1.07	0.13	0.06	0.48	-10
ld_TSDV(2)	2.60	-0.28	-8.83	-1.06	-0.77	-3.24	-0.84	0.00	-0.01	-0.23	-10

* "BASE" includes actual values from calibrated run (m3/day), all other values are expressed as the percentage difference from the calibration run.

Table H-3. Percentage Changes in Discharge Rates Between Sensitivity Runs and Calibration Run

	Drain Fluxes								GHB Fluxes		% Change
	Dval	OV	Ariv	AM	FL	AF	PV	IS	PP	EM	
ld_VU(1)	0.04	-2.27	3.35	1.74	0.25	19.89	-10.17	0.51	0.03	0.10	-10
ld_VU(2)	0.01	-0.81	0.48	0.28	0.04	3.29	-1.08	0.11	0.00	0.02	-10
ld_VU(3)	0.75	-1.62	-0.80	0.14	-0.10	2.75	-1.29	0.09	0.00	-0.04	-10
ld_VCU(1)	0.11	-7.11	5.06	1.46	0.36	13.10	-1.14	0.27	0.02	0.14	-10
ld_VCU(2)	0.00	-0.21	0.27	0.15	0.02	1.73	-0.89	0.11	0.00	0.01	-10
ld_VA(1)	0.02	-1.46	1.12	0.42	0.08	4.38	-1.21	0.12	0.00	0.03	-10
ld_VA(2)	0.00	-0.29	0.24	0.14	0.02	1.67	-0.69	0.09	0.00	0.01	-10
ld_VA(3)	0.02	-0.69	1.48	0.25	0.10	1.47	-0.80	0.06	0.00	0.04	-10
ld_BAQ(1)	0.04	-0.18	0.29	0.17	0.04	1.96	-1.22	0.10	0.00	0.02	-10
ld_BAQ(3)	0.01	-0.77	0.39	0.23	0.03	2.73	-0.77	0.10	0.00	0.01	-10
ld_BAQ(4)	0.00	-0.04	0.22	0.12	0.02	1.37	-0.87	0.09	0.00	0.01	-10
ld_BAQ(5)	0.00	-0.31	0.31	0.17	0.02	1.99	-0.89	0.08	0.00	0.01	-10
ld_BAQ(6)	0.01	-0.36	0.39	0.22	0.03	2.49	-1.19	0.13	0.00	0.01	-10
ld_BCU(1)	0.02	-1.92	1.16	0.65	0.08	7.51	-2.36	0.21	0.01	0.04	-10
ld_BCU(3)	0.00	-0.24	0.24	0.14	0.02	1.64	-0.77	0.07	0.00	0.01	-10
ld_BCU(4)	0.01	-0.96	0.48	0.28	0.04	3.28	-0.85	0.10	0.00	0.02	-10
ld_BCU(5)	0.01	-0.85	0.43	0.25	0.03	2.91	-0.78	0.06	0.00	0.01	-10
ld_BCU(6)	0.00	-0.39	0.32	0.18	0.02	2.07	-0.87	0.07	0.00	0.01	-10
ld_TBA(1)	0.69	0.58	-2.39	-0.11	-0.21	1.59	-2.46	0.08	0.00	-0.08	-10
ld_TBA(3)	0.00	-0.76	0.38	0.22	0.03	2.63	-0.71	0.07	0.00	0.01	-10
ld_TBA(4)	0.01	-0.86	0.49	0.29	0.04	3.35	-1.06	0.13	0.00	0.02	-10
ld_TBA(6)	0.01	-0.76	0.39	0.23	0.03	2.71	-0.75	0.09	0.00	0.01	-10
ld_TCB(1)	0.00	-0.19	0.34	0.18	0.02	2.11	-1.19	0.11	0.00	0.01	-10
ld_TCB(4)	0.00	-0.34	0.34	0.19	0.03	2.27	-1.03	0.07	0.00	0.01	-10
ld_TCB(6)	0.01	-0.73	0.39	0.23	0.03	2.68	-0.78	0.09	0.00	0.01	-10
ld_TC(1)	-0.01	3.19	-0.51	-0.23	-0.04	-2.61	-2.54	-0.01	-0.01	-0.02	-10
ld_TC(3)	0.00	-0.28	0.29	0.16	0.02	1.90	-0.89	0.07	0.00	0.01	-10
ld_TC(4)	0.01	-0.25	0.34	0.16	0.02	1.83	-0.92	0.08	0.00	0.01	-10
ld_TC(5)	0.01	-1.43	0.83	0.36	0.06	3.87	-0.80	0.11	0.00	0.02	-10
ld_TC(6)	0.01	-0.75	0.39	0.23	0.03	2.73	-0.79	0.06	0.00	0.01	-10
ld_TMA(1)	-0.01	-1.19	0.22	0.44	0.02	6.05	-1.91	0.17	0.01	0.01	-10
ld_TMA(2)	0.00	0.22	0.14	0.11	0.01	1.43	-1.21	0.04	0.00	0.00	-10

* "BASE" includes actual values from calibrated run (m3/day), all other values are expressed as the percentage difference from the calibration run.

Table H-3. Percentage Changes in Discharge Rates Between Sensitivity Runs and Calibration Run

	Drain Fluxes								GHB Fluxes		%
	Dval	OV	Ariv	AM	FL	AF	PV	IS	PP	EM	Change
ld_TMA(3)	-0.01	0.66	-0.24	0.01	-0.02	0.57	-1.05	0.06	0.00	-0.01	-10
ld_TMA(4)	-0.01	0.54	-0.41	0.05	-0.03	1.29	-1.18	0.10	0.00	-0.01	-10
ld_TMA(6)	0.00	-0.16	0.22	0.13	0.02	1.53	-0.78	0.05	0.00	0.01	-10
ld_AA(1)	1.99	-0.43	-1.51	0.49	-0.09	8.44	-8.06	-12.90	0.05	-0.04	-10
ld_AA(2)	1.25	-0.38	10.53	2.01	1.93	-54.76	-0.76	-0.53	-0.24	1.07	-10
ld_AA(3)	0.00	-0.20	0.33	0.18	0.02	2.13	-0.89	-1.69	0.00	0.01	-10
ld_AA(4)	0.00	-0.31	0.27	0.16	0.02	1.82	-0.77	0.10	0.00	0.01	-10
ld_AA(5)	0.00	-0.24	0.04	0.03	0.00	0.42	0.04	0.06	0.00	0.00	-10
ld_AA(6)	0.02	-1.07	-4.94	-2.17	7.19	-19.90	-1.10	-0.21	0.50	10.18	-10

* "BASE" includes actual values from calibrated run (m3/day), all other values are expressed as the percentage difference from the calibration run.

Appendix I

Travel Distances for Sensitivity Runs

Table I-1 - Travel Distances for Sensitivity Runs

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
base	BOURBON	B	10108	17405	28763	43145
kh_01_1	BOURBON	B	10119	17425	28770	42985
kh_06_1	BOURBON	B	10472	18182	26846	32748
kh_06_2	BOURBON	B	10127	17443	28773	41864
kh_06_3	BOURBON	B	10162	17503	28789	42984
kh_07_1	BOURBON	B	10240	17596	29006	46753
kh_07_2	BOURBON	B	10265	17758	28764	37660
kh_07_3	BOURBON	B	10103	17396	28811	47643
kh_07_4	BOURBON	B	10183	17532	28878	47351
kh_07_5	BOURBON	B	10366	17852	28976	55038
kh_07_6	BOURBON	B	10107	17407	28766	42998
kh_07_7	BOURBON	B	10098	17391	28763	43203
kh_07_8	BOURBON	B	9907	17120	31164	63544
kh_07_9	BOURBON	B	10146	17470	28820	43293
kh_08_1	BOURBON	B	10246	17713	28646	34580
kh_09_1	BOURBON	B	10142	17459	28780	43002
kh_10_1	BOURBON	B	10121	17429	28770	42978
kh_10_2	BOURBON	B	10159	17504	28784	42286
kh_11_1	BOURBON	B	11341	19793	24533	28075
kh_11_2	BOURBON	B	10154	17496	28754	42249
kh_11_3	BOURBON	B	10091	17377	28759	43123
kh_12_1	BOURBON	B	10125	17439	28742	40954
kh_12_2	BOURBON	B	10160	17511	28756	41386
kh_13_1	BOURBON	B	10110	17401	28801	47727
kh_13_2	BOURBON	B	10114	17432	28743	41312
kh_13_3	BOURBON	B	10158	17503	28783	41960
kh_14_1	BOURBON	B	10116	17423	28769	42931
kh_14_2	BOURBON	B	10108	17405	28763	43145
kh_14_3	BOURBON	B	10142	17452	28776	43146
kh_14_4	BOURBON	B	10159	17504	28754	41740
kh_14_5	BOURBON	B	10135	17441	28772	43145
kh_14_6	BOURBON	B	10110	17410	28767	43186
kh_15_1	BOURBON	B	10366	17916	28471	33031
kh_15_2	BOURBON	B	10108	17405	28763	43145
kh_15_3	BOURBON	B	10107	17403	28763	43167
kh_15_4	BOURBON	B	10155	17496	28753	42329
kh_15_5	BOURBON	B	10151	17491	28753	42120
kh_15_6	BOURBON	B	10148	17478	28779	42250
kh_16_1	BOURBON	B	10228	17632	28771	38638
kh_16_2	BOURBON	B	10108	17405	28763	43145
kh_16_3	BOURBON	B	10157	17502	28753	41444
kh_16_4	BOURBON	B	10154	17497	28754	41987
kh_16_5	BOURBON	B	10108	17405	28763	43145
kh_16_6	BOURBON	B	10153	17494	28753	42196
kh_17_1	BOURBON	B	10151	17484	28781	42246
kh_17_2	BOURBON	B	10108	17405	28763	43145
kh_17_3	BOURBON	B	10108	17405	28763	43145

* --- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
kh_17_4	BOURBON	B	10153	17494	28754	42405
kh_17_5	BOURBON	B	10108	17405	28763	43145
kh_17_6	BOURBON	B	10160	17511	28755	41247
kh_18_1	BOURBON	B	10013	17263	28734	43062
kh_18_2	BOURBON	B	10108	17405	28763	43145
kh_18_3	BOURBON	B	10149	17484	28780	42366
kh_18_4	BOURBON	B	10097	17390	28764	43140
kh_18_5	BOURBON	B	10157	17505	28754	41281
kh_18_6	BOURBON	B	10154	17494	28753	42405
kh_19_1	BOURBON	B	10123	17484	28720	37755
kh_19_2	BOURBON	B	10104	17400	28765	43117
kh_19_3	BOURBON	B	10105	17404	28766	43109
kh_19_4	BOURBON	B	10097	17395	28765	42980
kh_19_5	BOURBON	B	10108	17405	28763	43145
kh_19_6	BOURBON	B	10116	17421	28769	42973
kh_20_1	BOURBON	B	10617	18400	28786	34247
kh_20_2	BOURBON	B	10265	17726	28888	43770
kh_20_3	BOURBON	B	10138	17446	28808	43148
kh_20_4	BOURBON	B	10115	17432	28765	41919
kh_20_5	BOURBON	B	10162	17524	28755	40697
kh_20_6	BOURBON	B	10170	17511	28833	43522
ld_01_1	BOURBON	B	10117	17422	28768	42979
ld_06_1	BOURBON	B	10324	17869	28384	32956
ld_06_2	BOURBON	B	10129	17440	28772	42444
ld_06_3	BOURBON	B	10153	17492	28783	42329
ld_07_1	BOURBON	B	9060	15554	25945	59961
ld_07_2	BOURBON	B	10153	17505	28753	41052
ld_07_3	BOURBON	B	10151	17482	28783	42487
ld_07_4	BOURBON	B	10132	17446	28811	43149
ld_07_5	BOURBON	B	10175	17517	28837	44287
ld_07_6	BOURBON	B	10103	17399	28764	43189
ld_07_7	BOURBON	B	10106	17406	28766	42991
ld_07_8	BOURBON	B	10064	17348	28871	55874
ld_07_9	BOURBON	B	10124	17435	28775	43133
ld_08_1	BOURBON	B	10150	17482	28780	42225
ld_09_1	BOURBON	B	10108	17410	28768	42990
ld_10_1	BOURBON	B	10157	17503	28755	41758
ld_10_2	BOURBON	B	10117	17424	28770	42976
ld_11_1	BOURBON	B	10633	18459	26580	32642
ld_11_2	BOURBON	B	10155	17498	28754	41956
ld_11_3	BOURBON	B	10113	17416	28768	42984
ld_12_1	BOURBON	B	10124	17431	28771	42966
ld_12_2	BOURBON	B	10119	17425	28769	42975
ld_13_1	BOURBON	B	10120	17428	28773	43175
ld_13_2	BOURBON	B	10115	17417	28768	42970
ld_13_3	BOURBON	B	10153	17488	28780	42142
ld_14_1	BOURBON	B	10128	17439	28772	42934

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
ld_14_2	BOURBON	B	10124	17433	28770	42955
ld_14_3	BOURBON	B	10155	17496	28753	42127
ld_14_4	BOURBON	B	10106	17404	28765	43201
ld_14_5	BOURBON	B	10122	17429	28769	42957
ld_14_6	BOURBON	B	10119	17426	28769	42971
ld_15_1	BOURBON	B	10302	17794	28653	35315
ld_15_2	BOURBON	B	10124	17433	28770	42955
ld_15_3	BOURBON	B	10140	17447	28773	43151
ld_15_4	BOURBON	B	10170	17534	28757	39977
ld_15_5	BOURBON	B	10157	17502	28753	41377
ld_15_6	BOURBON	B	10120	17427	28769	42944
ld_16_1	BOURBON	B	10151	17487	28780	41994
ld_16_2	BOURBON	B	10124	17433	28770	42955
ld_16_3	BOURBON	B	10150	17485	28780	42158
ld_16_4	BOURBON	B	10156	17500	28754	41761
ld_16_5	BOURBON	B	10124	17433	28770	42955
ld_16_6	BOURBON	B	10153	17494	28753	41883
ld_17_1	BOURBON	B	10116	17420	28769	43165
ld_17_2	BOURBON	B	10124	17433	28770	42955
ld_17_3	BOURBON	B	10124	17433	28770	42955
ld_17_4	BOURBON	B	10142	17453	28775	43134
ld_17_5	BOURBON	B	10124	17433	28770	42955
ld_17_6	BOURBON	B	10154	17495	28753	42111
ld_18_1	BOURBON	B	10042	17304	28772	43042
ld_18_2	BOURBON	B	10124	17433	28770	42955
ld_18_3	BOURBON	B	10121	17428	28769	42956
ld_18_4	BOURBON	B	10105	17403	28765	43107
ld_18_5	BOURBON	B	10156	17502	28753	41337
ld_18_6	BOURBON	B	10155	17495	28753	42105
ld_19_1	BOURBON	B	10166	17589	28624	33050
ld_19_2	BOURBON	B	10108	17408	28767	43195
ld_19_3	BOURBON	B	10109	17409	28766	43104
ld_19_4	BOURBON	B	10117	17429	28770	42506
ld_19_5	BOURBON	B	10124	17433	28770	42955
ld_19_6	BOURBON	B	10135	17442	28773	43144
ld_20_1	BOURBON	B	10373	17932	28685	35189
ld_20_2	BOURBON	B	10155	17475	28784	43199
ld_20_3	BOURBON	B	10120	17428	28770	42970
ld_20_4	BOURBON	B	10120	17426	28768	43185
ld_20_5	BOURBON	B	10119	17429	28768	42509
ld_20_6	BOURBON	B	10162	17509	28787	42312
base	BULLION	WP	6493	* ----	----	----
kh_01_1	BULLION	WP	6496	----	----	----
kh_06_1	BULLION	WP	6518	----	----	----
kh_06_2	BULLION	WP	6494	----	----	----
kh_06_3	BULLION	WP	6517	----	----	----
kh_07_1	BULLION	WP	6490	----	----	----

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
kh_07_2	BULLION	WP	6505	----	----	----
kh_07_3	BULLION	WP	6492	----	----	----
kh_07_4	BULLION	WP	6498	----	----	----
kh_07_5	BULLION	WP	6385	----	----	----
kh_07_6	BULLION	WP	6496	----	----	----
kh_07_7	BULLION	WP	6403	----	----	----
kh_07_8	BULLION	WP	6482	----	----	----
kh_07_9	BULLION	WP	6487	----	----	----
kh_08_1	BULLION	WP	6529	----	----	----
kh_09_1	BULLION	WP	6505	----	----	----
kh_10_1	BULLION	WP	6495	----	----	----
kh_10_2	BULLION	WP	6511	----	----	----
kh_11_1	BULLION	WP	6338	----	----	----
kh_11_2	BULLION	WP	6504	----	----	----
kh_11_3	BULLION	WP	6845	38303	----	----
kh_12_1	BULLION	WP	6788	37950	39182	----
kh_12_2	BULLION	WP	6511	----	----	----
kh_13_1	BULLION	WP	6424	----	----	----
kh_13_2	BULLION	WP	6497	----	----	----
kh_13_3	BULLION	WP	6507	----	----	----
kh_14_1	BULLION	WP	6391	----	----	----
kh_14_2	BULLION	WP	6493	----	----	----
kh_14_3	BULLION	WP	6507	----	----	----
kh_14_4	BULLION	WP	6506	----	----	----
kh_14_5	BULLION	WP	6509	----	----	----
kh_14_6	BULLION	WP	6493	----	----	----
kh_15_1	BULLION	WP	6399	----	----	----
kh_15_2	BULLION	WP	6493	----	----	----
kh_15_3	BULLION	WP	6494	----	----	----
kh_15_4	BULLION	WP	6510	----	----	----
kh_15_5	BULLION	WP	6512	----	----	----
kh_15_6	BULLION	WP	6505	----	----	----
kh_16_1	BULLION	WP	6306	----	----	----
kh_16_2	BULLION	WP	6493	----	----	----
kh_16_3	BULLION	WP	6513	----	----	----
kh_16_4	BULLION	WP	6507	----	----	----
kh_16_5	BULLION	WP	6493	----	----	----
kh_16_6	BULLION	WP	6507	----	----	----
kh_17_1	BULLION	WP	6505	----	----	----
kh_17_2	BULLION	WP	6493	----	----	----
kh_17_3	BULLION	WP	6493	----	----	----
kh_17_4	BULLION	WP	6511	----	----	----
kh_17_5	BULLION	WP	6493	----	----	----
kh_17_6	BULLION	WP	6511	----	----	----
kh_18_1	BULLION	WP	19419	----	----	----
kh_18_2	BULLION	WP	6493	----	----	----
kh_18_3	BULLION	WP	6530	----	----	----

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
kh_18_4	BULLION	WP	6667	----	----	----
kh_18_5	BULLION	WP	6530	----	----	----
kh_18_6	BULLION	WP	6503	----	----	----
kh_19_1	BULLION	WP	5651	38781	----	----
kh_19_2	BULLION	WP	6674	----	----	----
kh_19_3	BULLION	WP	6959	----	----	----
kh_19_4	BULLION	WP	7391	----	----	----
kh_19_5	BULLION	WP	6493	----	----	----
kh_19_6	BULLION	WP	6443	----	----	----
kh_20_1	BULLION	WP	6641	----	----	----
kh_20_2	BULLION	WP	6499	----	----	----
kh_20_3	BULLION	WP	6507	----	----	----
kh_20_4	BULLION	WP	6498	----	----	----
kh_20_5	BULLION	WP	6510	----	----	----
kh_20_6	BULLION	WP	6488	----	----	----
ld_01_1	BULLION	WP	6494	----	----	----
ld_06_1	BULLION	WP	6515	----	----	----
ld_06_2	BULLION	WP	6495	----	----	----
ld_06_3	BULLION	WP	6517	----	----	----
ld_07_1	BULLION	WP	6487	----	----	----
ld_07_2	BULLION	WP	6496	----	----	----
ld_07_3	BULLION	WP	6510	----	----	----
ld_07_4	BULLION	WP	6487	----	----	----
ld_07_5	BULLION	WP	6464	----	----	----
ld_07_6	BULLION	WP	6492	----	----	----
ld_07_7	BULLION	WP	6436	----	----	----
ld_07_8	BULLION	WP	6495	----	----	----
ld_07_9	BULLION	WP	6483	----	----	----
ld_08_1	BULLION	WP	6500	----	----	----
ld_09_1	BULLION	WP	6498	----	----	----
ld_10_1	BULLION	WP	6510	----	----	----
ld_10_2	BULLION	WP	6495	----	----	----
ld_11_1	BULLION	WP	6429	----	----	----
ld_11_2	BULLION	WP	6508	----	----	----
ld_11_3	BULLION	WP	6525	----	----	----
ld_12_1	BULLION	WP	6602	38751	----	----
ld_12_2	BULLION	WP	6494	----	----	----
ld_13_1	BULLION	WP	6514	----	----	----
ld_13_2	BULLION	WP	6508	----	----	----
ld_13_3	BULLION	WP	6508	----	----	----
ld_14_1	BULLION	WP	6419	----	----	----
ld_14_2	BULLION	WP	6499	----	----	----
ld_14_3	BULLION	WP	6510	----	----	----
ld_14_4	BULLION	WP	6491	----	----	----
ld_14_5	BULLION	WP	6496	----	----	----
ld_14_6	BULLION	WP	6496	----	----	----
ld_15_1	BULLION	WP	6428	----	----	----

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
ld_15_2	BULLION	WP	6499	----	----	----
ld_15_3	BULLION	WP	6505	----	----	----
ld_15_4	BULLION	WP	6512	----	----	----
ld_15_5	BULLION	WP	6511	----	----	----
ld_15_6	BULLION	WP	6495	----	----	----
ld_16_1	BULLION	WP	6368	----	----	----
ld_16_2	BULLION	WP	6499	----	----	----
ld_16_3	BULLION	WP	6510	----	----	----
ld_16_4	BULLION	WP	6510	----	----	----
ld_16_5	BULLION	WP	6499	----	----	----
ld_16_6	BULLION	WP	6508	----	----	----
ld_17_1	BULLION	WP	6489	----	----	----
ld_17_2	BULLION	WP	6499	----	----	----
ld_17_3	BULLION	WP	6499	----	----	----
ld_17_4	BULLION	WP	6507	----	----	----
ld_17_5	BULLION	WP	6499	----	----	----
ld_17_6	BULLION	WP	6510	----	----	----
ld_18_1	BULLION	WP	7593	----	----	----
ld_18_2	BULLION	WP	6499	----	----	----
ld_18_3	BULLION	WP	6509	----	----	----
ld_18_4	BULLION	WP	6613	----	----	----
ld_18_5	BULLION	WP	6520	----	----	----
ld_18_6	BULLION	WP	6505	----	----	----
ld_19_1	BULLION	WP	6047	----	----	----
ld_19_2	BULLION	WP	6597	----	----	----
ld_19_3	BULLION	WP	6688	----	----	----
ld_19_4	BULLION	WP	6852	----	----	----
ld_19_5	BULLION	WP	6499	----	----	----
ld_19_6	BULLION	WP	6484	----	----	----
ld_20_1	BULLION	WP	6498	----	----	----
ld_20_2	BULLION	WP	6507	----	----	----
ld_20_3	BULLION	WP	6494	----	----	----
ld_20_4	BULLION	WP	6507	----	----	----
ld_20_5	BULLION	WP	6496	----	----	----
ld_20_6	BULLION	WP	6511	----	----	----
base	CLEARWATER	WT	1042	1206	1546	2336
kh_01_1	CLEARWATER	WT	1032	1197	1534	2315
kh_06_1	CLEARWATER	WT	1042	1213	1570	2413
kh_06_2	CLEARWATER	WT	1033	1195	1532	2315
kh_06_3	CLEARWATER	WT	1045	1210	1554	2357
kh_07_1	CLEARWATER	WT	1036	1199	1537	2321
kh_07_2	CLEARWATER	WT	1068	1238	1593	2417
kh_07_3	CLEARWATER	WT	954	1125	1474	2281
kh_07_4	CLEARWATER	WT	1033	1197	1534	2316
kh_07_5	CLEARWATER	WT	1043	1207	1549	2338
kh_07_6	CLEARWATER	WT	1022	1192	1525	2302
kh_07_7	CLEARWATER	WT	1043	1208	1550	2344

* ---- Particle has discharged

Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).

Parameter	Test Name	Starting Location	Distance Traveled (meters)			200 years
			25 years	50 years	100 years	
kh_07_8	CLEARWATER	WT	1041	1205	1546	2337
kh_07_9	CLEARWATER	WT	1029	1196	1531	2310
kh_08_1	CLEARWATER	WT	1018	1182	1514	2298
kh_09_1	CLEARWATER	WT	1067	1235	1584	2393
kh_10_1	CLEARWATER	WT	1035	1198	1534	2318
kh_10_2	CLEARWATER	WT	1045	1210	1554	2357
kh_11_1	CLEARWATER	WT	1035	1199	1533	2309
kh_11_2	CLEARWATER	WT	1048	1214	1559	2364
kh_11_3	CLEARWATER	WT	1052	1225	1586	2433
kh_12_1	CLEARWATER	WT	1054	1230	1597	2468
kh_12_2	CLEARWATER	WT	1048	1214	1559	2364
kh_13_1	CLEARWATER	WT	1020	1195	1526	2293
kh_13_2	CLEARWATER	WT	1031	1198	1535	2317
kh_13_3	CLEARWATER	WT	1048	1214	1559	2363
kh_14_1	CLEARWATER	WT	1042	1234	1642	2644
kh_14_2	CLEARWATER	WT	1042	1206	1546	2336
kh_14_3	CLEARWATER	WT	1065	1234	1585	2401
kh_14_4	CLEARWATER	WT	1050	1217	1562	2365
kh_14_5	CLEARWATER	WT	1063	1233	1585	2404
kh_14_6	CLEARWATER	WT	1034	1196	1532	2315
kh_15_1	CLEARWATER	WT	1068	1240	1599	2425
kh_15_2	CLEARWATER	WT	1042	1206	1546	2336
kh_15_3	CLEARWATER	WT	975	1154	1520	2362
kh_15_4	CLEARWATER	WT	1045	1210	1554	2356
kh_15_5	CLEARWATER	WT	1045	1210	1554	2357
kh_15_6	CLEARWATER	WT	1050	1217	1562	2368
kh_16_1	CLEARWATER	WT	961	1136	1496	2336
kh_16_2	CLEARWATER	WT	1042	1206	1546	2336
kh_16_3	CLEARWATER	WT	1045	1211	1554	2358
kh_16_4	CLEARWATER	WT	1051	1217	1562	2363
kh_16_5	CLEARWATER	WT	1042	1206	1546	2336
kh_16_6	CLEARWATER	WT	1045	1210	1554	2356
kh_17_1	CLEARWATER	WT	1048	1214	1558	2362
kh_17_2	CLEARWATER	WT	1042	1206	1546	2336
kh_17_3	CLEARWATER	WT	1042	1206	1546	2336
kh_17_4	CLEARWATER	WT	1045	1210	1554	2357
kh_17_5	CLEARWATER	WT	1042	1206	1546	2336
kh_17_6	CLEARWATER	WT	1048	1214	1559	2364
kh_18_1	CLEARWATER	WT	945	1106	1434	2174
kh_18_2	CLEARWATER	WT	1042	1206	1546	2336
kh_18_3	CLEARWATER	WT	1046	1212	1556	2360
kh_18_4	CLEARWATER	WT	1041	1206	1549	2350
kh_18_5	CLEARWATER	WT	1046	1212	1557	2365
kh_18_6	CLEARWATER	WT	1046	1212	1555	2358
kh_19_1	CLEARWATER	WT	1041	1206	1548	2347
kh_19_2	CLEARWATER	WT	1044	1211	1559	2374
kh_19_3	CLEARWATER	WT	1051	1223	1582	2425

* — Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
kh_19_4	CLEARWATER	WT	1056	1227	1583	2409
kh_19_5	CLEARWATER	WT	1042	1206	1546	2336
kh_19_6	CLEARWATER	WT	1029	1197	1533	2312
kh_20_1	CLEARWATER	WT	956	1128	1481	2303
kh_20_2	CLEARWATER	WT	1033	1197	1534	2318
kh_20_3	CLEARWATER	WT	1065	1235	1586	2402
kh_20_4	CLEARWATER	WT	986	1178	1500	2258
kh_20_5	CLEARWATER	WT	1048	1214	1559	2363
kh_20_6	CLEARWATER	WT	1029	1193	1527	2306
ld_01_1	CLEARWATER	WT	1037	1199	1536	2321
ld_06_1	CLEARWATER	WT	1017	1179	1514	2307
ld_06_2	CLEARWATER	WT	1032	1194	1531	2313
ld_06_3	CLEARWATER	WT	1045	1211	1555	2358
ld_07_1	CLEARWATER	WT	1037	1200	1537	2321
ld_07_2	CLEARWATER	WT	1040	1203	1544	2334
ld_07_3	CLEARWATER	WT	1045	1210	1554	2356
ld_07_4	CLEARWATER	WT	1036	1199	1538	2324
ld_07_5	CLEARWATER	WT	1036	1198	1534	2317
ld_07_6	CLEARWATER	WT	953	1124	1472	2279
ld_07_7	CLEARWATER	WT	1037	1201	1539	2322
ld_07_8	CLEARWATER	WT	1028	1196	1531	2311
ld_07_9	CLEARWATER	WT	953	1123	1471	2277
ld_08_1	CLEARWATER	WT	1019	1187	1520	2295
ld_09_1	CLEARWATER	WT	1068	1237	1587	2390
ld_10_1	CLEARWATER	WT	1045	1210	1554	2356
ld_10_2	CLEARWATER	WT	1032	1197	1534	2315
ld_11_1	CLEARWATER	WT	1036	1198	1534	2314
ld_11_2	CLEARWATER	WT	1048	1214	1559	2363
ld_11_3	CLEARWATER	WT	954	1126	1476	2288
ld_12_1	CLEARWATER	WT	1070	1244	1605	2451
ld_12_2	CLEARWATER	WT	1040	1204	1544	2333
ld_13_1	CLEARWATER	WT	1037	1200	1538	2328
ld_13_2	CLEARWATER	WT	1064	1234	1586	2406
ld_13_3	CLEARWATER	WT	1045	1210	1553	2355
ld_14_1	CLEARWATER	WT	1041	1218	1587	2464
ld_14_2	CLEARWATER	WT	1051	1217	1561	2362
ld_14_3	CLEARWATER	WT	1045	1210	1554	2356
ld_14_4	CLEARWATER	WT	1040	1206	1544	2329
ld_14_5	CLEARWATER	WT	1028	1196	1531	2311
ld_14_6	CLEARWATER	WT	1032	1198	1534	2316
ld_15_1	CLEARWATER	WT	1051	1220	1571	2384
ld_15_2	CLEARWATER	WT	1051	1217	1561	2362
ld_15_3	CLEARWATER	WT	1065	1234	1585	2400
ld_15_4	CLEARWATER	WT	1045	1210	1551	2349
ld_15_5	CLEARWATER	WT	1045	1210	1554	2357
ld_15_6	CLEARWATER	WT	1025	1194	1528	2306
ld_16_1	CLEARWATER	WT	946	1116	1463	2278

* ---- Particle has discharged

Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
ld_16_2	CLEARWATER	WT	1051	1217	1561	2362
ld_16_3	CLEARWATER	WT	1045	1210	1554	2356
ld_16_4	CLEARWATER	WT	1049	1215	1560	2363
ld_16_5	CLEARWATER	WT	1051	1217	1561	2362
ld_16_6	CLEARWATER	WT	1045	1210	1554	2356
ld_17_1	CLEARWATER	WT	1034	1197	1532	2315
ld_17_2	CLEARWATER	WT	1051	1217	1561	2362
ld_17_3	CLEARWATER	WT	1051	1217	1561	2362
ld_17_4	CLEARWATER	WT	1066	1235	1586	2402
ld_17_5	CLEARWATER	WT	1051	1217	1561	2362
ld_17_6	CLEARWATER	WT	1046	1212	1555	2358
ld_18_1	CLEARWATER	WT	1015	1198	1526	2276
ld_18_2	CLEARWATER	WT	1051	1217	1561	2362
ld_18_3	CLEARWATER	WT	1034	1198	1535	2318
ld_18_4	CLEARWATER	WT	1043	1208	1551	2349
ld_18_5	CLEARWATER	WT	1048	1215	1561	2368
ld_18_6	CLEARWATER	WT	1048	1214	1559	2363
ld_19_1	CLEARWATER	WT	1045	1211	1556	2359
ld_19_2	CLEARWATER	WT	1041	1206	1549	2349
ld_19_3	CLEARWATER	WT	1041	1207	1551	2358
ld_19_4	CLEARWATER	WT	1044	1209	1553	2355
ld_19_5	CLEARWATER	WT	1051	1217	1561	2362
ld_19_6	CLEARWATER	WT	1067	1238	1591	2413
ld_20_1	CLEARWATER	WT	948	1117	1462	2263
ld_20_2	CLEARWATER	WT	1066	1237	1590	2412
ld_20_3	CLEARWATER	WT	1037	1201	1540	2327
ld_20_4	CLEARWATER	WT	1063	1233	1584	2403
ld_20_5	CLEARWATER	WT	1037	1200	1539	2327
ld_20_6	CLEARWATER	WT	1045	1210	1554	2357
base	CORDUROY	WP	11694	19159	29843	73520
kh_01_1	CORDUROY	WP	11709	19178	29867	73569
kh_06_1	CORDUROY	WP	12071	19743	30904	74718
kh_06_2	CORDUROY	WP	11717	19190	29857	73481
kh_06_3	CORDUROY	WP	11760	19249	29925	74237
kh_07_1	CORDUROY	WP	11875	19415	30248	83736
kh_07_2	CORDUROY	WP	11842	19407	30332	80279
kh_07_3	CORDUROY	WP	11696	19156	29820	73922
kh_07_4	CORDUROY	WP	11767	19286	30064	75668
kh_07_5	CORDUROY	WP	12007	19609	30589	77125
kh_07_6	CORDUROY	WP	11694	19158	29833	73508
kh_07_7	CORDUROY	WP	11684	19143	29812	73477
kh_07_8	CORDUROY	WP	11469	18851	29345	73814
kh_07_9	CORDUROY	WP	11735	19224	29937	74952
kh_08_1	CORDUROY	WP	11852	19384	30189	73834
kh_09_1	CORDUROY	WP	11734	19211	29907	73527
kh_10_1	CORDUROY	WP	11710	19181	29871	73565
kh_10_2	CORDUROY	WP	11758	19245	29921	73646

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
kh_11_1	CORDUROY	WP	13151	21169	33010	75276
kh_11_2	CORDUROY	WP	11753	19236	29904	73399
kh_11_3	CORDUROY	WP	11679	19132	29787	73197
kh_12_1	CORDUROY	WP	11711	19178	29888	71109
kh_12_2	CORDUROY	WP	11759	19244	29915	73395
kh_13_1	CORDUROY	WP	11705	19168	29821	73761
kh_13_2	CORDUROY	WP	11679	19155	29793	73267
kh_13_3	CORDUROY	WP	11758	19243	29903	73548
kh_14_1	CORDUROY	WP	11705	19172	29855	73466
kh_14_2	CORDUROY	WP	11694	19159	29843	73520
kh_14_3	CORDUROY	WP	11744	19220	29907	73632
kh_14_4	CORDUROY	WP	11759	19244	29925	73451
kh_14_5	CORDUROY	WP	11736	19208	29898	73633
kh_14_6	CORDUROY	WP	11699	19163	29844	73534
kh_15_1	CORDUROY	WP	11997	19596	30529	74401
kh_15_2	CORDUROY	WP	11694	19159	29843	73520
kh_15_3	CORDUROY	WP	11693	19157	29840	73601
kh_15_4	CORDUROY	WP	11754	19237	29908	73407
kh_15_5	CORDUROY	WP	11749	19231	29896	73378
kh_15_6	CORDUROY	WP	11746	19226	29910	73452
kh_16_1	CORDUROY	WP	11832	19360	30161	74053
kh_16_2	CORDUROY	WP	11694	19159	29843	73520
kh_16_3	CORDUROY	WP	11755	19239	29914	73381
kh_16_4	CORDUROY	WP	11753	19236	29907	73403
kh_16_5	CORDUROY	WP	11694	19159	29843	73520
kh_16_6	CORDUROY	WP	11751	19233	29898	73378
kh_17_1	CORDUROY	WP	11750	19230	29901	73416
kh_17_2	CORDUROY	WP	11694	19159	29843	73520
kh_17_3	CORDUROY	WP	11694	19159	29843	73520
kh_17_4	CORDUROY	WP	11752	19234	29906	73411
kh_17_5	CORDUROY	WP	11694	19159	29843	73520
kh_17_6	CORDUROY	WP	11759	19245	29914	73392
kh_18_1	CORDUROY	WP	11564	18994	29552	72731
kh_18_2	CORDUROY	WP	11694	19159	29843	73520
kh_18_3	CORDUROY	WP	11748	19228	29893	73381
kh_18_4	CORDUROY	WP	11684	19142	29811	73487
kh_18_5	CORDUROY	WP	11756	19241	29915	73350
kh_18_6	CORDUROY	WP	11752	19235	29904	73400
kh_19_1	CORDUROY	WP	11688	19166	29912	73509
kh_19_2	CORDUROY	WP	11692	19154	29824	73547
kh_19_3	CORDUROY	WP	11692	19155	29824	73545
kh_19_4	CORDUROY	WP	11679	19140	29819	73508
kh_19_5	CORDUROY	WP	11694	19159	29843	73520
kh_19_6	CORDUROY	WP	11706	19174	29859	73541
kh_20_1	CORDUROY	WP	12284	20027	31212	78847
kh_20_2	CORDUROY	WP	11836	19413	30342	74441
kh_20_3	CORDUROY	WP	11741	19215	29900	73673

* --- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
kh_20_4	CORDUROY	WP	11719	19185	29892	73598
kh_20_5	CORDUROY	WP	11759	19247	29959	73266
kh_20_6	CORDUROY	WP	11759	19264	30009	75418
ld_01_1	CORDUROY	WP	11707	19176	29863	73589
ld_06_1	CORDUROY	WP	11925	19508	30456	74294
ld_06_2	CORDUROY	WP	11720	19193	29866	73463
ld_06_3	CORDUROY	WP	11751	19234	29901	73612
ld_07_1	CORDUROY	WP	10603	17703	27306	63787
ld_07_2	CORDUROY	WP	11735	19229	29977	70086
ld_07_3	CORDUROY	WP	11750	19230	29897	73493
ld_07_4	CORDUROY	WP	11722	19201	29901	74422
ld_07_5	CORDUROY	WP	11779	19277	30035	74241
ld_07_6	CORDUROY	WP	11690	19151	29827	73518
ld_07_7	CORDUROY	WP	11693	19155	29833	73518
ld_07_8	CORDUROY	WP	11650	19094	29745	74105
ld_07_9	CORDUROY	WP	11713	19187	29884	74121
ld_08_1	CORDUROY	WP	11743	19229	29961	73726
ld_09_1	CORDUROY	WP	11693	19158	29842	73560
ld_10_1	CORDUROY	WP	11756	19240	29909	73400
ld_10_2	CORDUROY	WP	11706	19175	29862	73630
ld_11_1	CORDUROY	WP	12299	20045	31215	75211
ld_11_2	CORDUROY	WP	11754	19237	29906	73400
ld_11_3	CORDUROY	WP	11701	19168	29853	73539
ld_12_1	CORDUROY	WP	11715	19184	29888	73338
ld_12_2	CORDUROY	WP	11710	19179	29865	73582
ld_13_1	CORDUROY	WP	11708	19178	29865	73461
ld_13_2	CORDUROY	WP	11697	19167	29849	73537
ld_13_3	CORDUROY	WP	11752	19234	29902	73461
ld_14_1	CORDUROY	WP	11719	19193	29889	73619
ld_14_2	CORDUROY	WP	11715	19187	29874	73557
ld_14_3	CORDUROY	WP	11754	19237	29907	73400
ld_14_4	CORDUROY	WP	11693	19157	29842	73597
ld_14_5	CORDUROY	WP	11712	19183	29871	73559
ld_14_6	CORDUROY	WP	11709	19179	29868	73565
ld_15_1	CORDUROY	WP	11922	19487	30348	74153
ld_15_2	CORDUROY	WP	11715	19187	29874	73557
ld_15_3	CORDUROY	WP	11742	19216	29902	73618
ld_15_4	CORDUROY	WP	11771	19262	29941	73398
ld_15_5	CORDUROY	WP	11756	19239	29910	73397
ld_15_6	CORDUROY	WP	11710	19180	29870	73558
ld_16_1	CORDUROY	WP	11741	19228	29961	73736
ld_16_2	CORDUROY	WP	11715	19187	29874	73557
ld_16_3	CORDUROY	WP	11748	19229	29893	73376
ld_16_4	CORDUROY	WP	11754	19238	29910	73412
ld_16_5	CORDUROY	WP	11715	19187	29874	73557
ld_16_6	CORDUROY	WP	11752	19234	29899	73374
ld_17_1	CORDUROY	WP	11706	19174	29859	73563

* --- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
ld_17_2	CORDUROY	WP	11715	19187	29874	73557
ld_17_3	CORDUROY	WP	11715	19187	29874	73557
ld_17_4	CORDUROY	WP	11744	19220	29907	73627
ld_17_5	CORDUROY	WP	11715	19187	29874	73557
ld_17_6	CORDUROY	WP	11753	19236	29906	73400
ld_18_1	CORDUROY	WP	11609	19047	29669	73188
ld_18_2	CORDUROY	WP	11715	19187	29874	73557
ld_18_3	CORDUROY	WP	11711	19181	29869	73553
ld_18_4	CORDUROY	WP	11692	19154	29829	73524
ld_18_5	CORDUROY	WP	11755	19239	29913	73372
ld_18_6	CORDUROY	WP	11754	19237	29906	73397
ld_19_1	CORDUROY	WP	11732	19236	30069	73769
ld_19_2	CORDUROY	WP	11697	19161	29838	73530
ld_19_3	CORDUROY	WP	11698	19162	29841	73527
ld_19_4	CORDUROY	WP	11702	19172	29877	73585
ld_19_5	CORDUROY	WP	11715	19187	29874	73557
ld_19_6	CORDUROY	WP	11737	19208	29885	73578
ld_20_1	CORDUROY	WP	12006	19610	30547	74790
ld_20_2	CORDUROY	WP	11755	19240	29944	73845
ld_20_3	CORDUROY	WP	11711	19181	29868	73589
ld_20_4	CORDUROY	WP	11721	19190	29887	73721
ld_20_5	CORDUROY	WP	11707	19177	29871	73506
ld_20_6	CORDUROY	WP	11760	19248	29927	73759
base	COULOMMIERS	B	950	2468	8000	15473
kh_01_1	COULOMMIERS	B	957	2483	8009	15685
kh_06_1	COULOMMIERS	B	998	2647	8241	18733
kh_06_2	COULOMMIERS	B	960	2488	8012	16661
kh_06_3	COULOMMIERS	B	980	2531	8040	17302
kh_07_1	COULOMMIERS	B	990	2619	8348	20833
kh_07_2	COULOMMIERS	B	984	2571	8150	18530
kh_07_3	COULOMMIERS	B	955	2476	8002	15495
kh_07_4	COULOMMIERS	B	968	2530	8112	17908
kh_07_5	COULOMMIERS	B	995	2624	8144	17235
kh_07_6	COULOMMIERS	B	954	2473	8001	15683
kh_07_7	COULOMMIERS	B	954	2472	7998	15538
kh_07_8	COULOMMIERS	B	931	2380	7906	14109
kh_07_9	COULOMMIERS	B	963	2504	8084	17340
kh_08_1	COULOMMIERS	B	994	2579	8148	18594
kh_09_1	COULOMMIERS	B	960	2490	8025	18338
kh_10_1	COULOMMIERS	B	957	2484	8010	15723
kh_10_2	COULOMMIERS	B	979	2528	8037	17202
kh_11_1	COULOMMIERS	B	1142	3155	9866	23000
kh_11_2	COULOMMIERS	B	978	2524	8034	17152
kh_11_3	COULOMMIERS	B	953	2468	7995	15432
kh_12_1	COULOMMIERS	B	946	2460	8166	20193
kh_12_2	COULOMMIERS	B	980	2528	8037	17238
kh_13_1	COULOMMIERS	B	957	2484	8009	15649

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
kh_13_2	COULOMMIERS	B	942	2448	7980	14952
kh_13_3	COULOMMIERS	B	980	2528	8037	17235
kh_14_1	COULOMMIERS	B	960	2486	8008	15765
kh_14_2	COULOMMIERS	B	950	2468	8000	15473
kh_14_3	COULOMMIERS	B	971	2514	8029	15950
kh_14_4	COULOMMIERS	B	978	2526	8036	17134
kh_14_5	COULOMMIERS	B	967	2506	8025	15786
kh_14_6	COULOMMIERS	B	955	2478	8004	15608
kh_15_1	COULOMMIERS	B	993	2622	8146	17542
kh_15_2	COULOMMIERS	B	950	2468	8000	15473
kh_15_3	COULOMMIERS	B	949	2465	7999	15457
kh_15_4	COULOMMIERS	B	978	2525	8034	17142
kh_15_5	COULOMMIERS	B	978	2523	8032	17132
kh_15_6	COULOMMIERS	B	974	2519	8031	16966
kh_16_1	COULOMMIERS	B	969	2536	8064	16410
kh_16_2	COULOMMIERS	B	950	2468	8000	15473
kh_16_3	COULOMMIERS	B	978	2525	8034	17157
kh_16_4	COULOMMIERS	B	977	2524	8034	17138
kh_16_5	COULOMMIERS	B	950	2468	8000	15473
kh_16_6	COULOMMIERS	B	978	2524	8033	17155
kh_17_1	COULOMMIERS	B	977	2522	8032	17071
kh_17_2	COULOMMIERS	B	950	2468	8000	15473
kh_17_3	COULOMMIERS	B	950	2468	8000	15473
kh_17_4	COULOMMIERS	B	978	2523	8033	17123
kh_17_5	COULOMMIERS	B	950	2468	8000	15473
kh_17_6	COULOMMIERS	B	980	2528	8037	17237
kh_18_1	COULOMMIERS	B	945	2425	7949	16111
kh_18_2	COULOMMIERS	B	950	2468	8000	15473
kh_18_3	COULOMMIERS	B	977	2521	8031	17094
kh_18_4	COULOMMIERS	B	954	2471	7998	15511
kh_18_5	COULOMMIERS	B	978	2526	8035	17172
kh_18_6	COULOMMIERS	B	977	2523	8033	17128
kh_19_1	COULOMMIERS	B	956	2470	7998	16800
kh_19_2	COULOMMIERS	B	955	2475	8002	15585
kh_19_3	COULOMMIERS	B	956	2476	8001	15648
kh_19_4	COULOMMIERS	B	952	2467	7995	15569
kh_19_5	COULOMMIERS	B	950	2468	8000	15473
kh_19_6	COULOMMIERS	B	957	2482	8008	15686
kh_20_1	COULOMMIERS	B	1032	2764	8285	19174
kh_20_2	COULOMMIERS	B	980	2574	8217	19873
kh_20_3	COULOMMIERS	B	970	2512	8028	15901
kh_20_4	COULOMMIERS	B	980	2528	7938	13258
kh_20_5	COULOMMIERS	B	979	2528	8037	17224
kh_20_6	COULOMMIERS	B	970	2524	8102	17667
ld_01_1	COULOMMIERS	B	956	2482	8008	15661
ld_06_1	COULOMMIERS	B	983	2583	8170	17805
ld_06_2	COULOMMIERS	B	962	2492	8014	16753

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
ld_06_3	COULOMMIERS	B	978	2525	8034	17174
ld_07_1	COULOMMIERS	B	835	2007	7496	12591
ld_07_2	COULOMMIERS	B	961	2499	8082	17298
ld_07_3	COULOMMIERS	B	977	2522	8032	17071
ld_07_4	COULOMMIERS	B	960	2494	8019	15949
ld_07_5	COULOMMIERS	B	966	2515	8040	16034
ld_07_6	COULOMMIERS	B	954	2473	8000	15532
ld_07_7	COULOMMIERS	B	955	2476	8002	15616
ld_07_8	COULOMMIERS	B	950	2457	7982	15173
ld_07_9	COULOMMIERS	B	957	2486	8013	15802
ld_08_1	COULOMMIERS	B	962	2503	8028	16019
ld_09_1	COULOMMIERS	B	953	2471	8001	15797
ld_10_1	COULOMMIERS	B	979	2526	8035	17188
ld_10_2	COULOMMIERS	B	957	2483	8008	15719
ld_11_1	COULOMMIERS	B	1034	2768	8290	19287
ld_11_2	COULOMMIERS	B	978	2525	8034	17157
ld_11_3	COULOMMIERS	B	956	2479	8005	15627
ld_12_1	COULOMMIERS	B	952	2475	8076	17819
ld_12_2	COULOMMIERS	B	957	2483	8009	15693
ld_13_1	COULOMMIERS	B	956	2478	8006	15835
ld_13_2	COULOMMIERS	B	951	2472	8001	15377
ld_13_3	COULOMMIERS	B	977	2523	8033	17104
ld_14_1	COULOMMIERS	B	958	2488	8014	15773
ld_14_2	COULOMMIERS	B	958	2486	8012	15766
ld_14_3	COULOMMIERS	B	978	2525	8035	17143
ld_14_4	COULOMMIERS	B	950	2467	7999	15460
ld_14_5	COULOMMIERS	B	958	2485	8011	15721
ld_14_6	COULOMMIERS	B	957	2483	8009	15689
ld_15_1	COULOMMIERS	B	985	2587	8110	17164
ld_15_2	COULOMMIERS	B	958	2486	8012	15766
ld_15_3	COULOMMIERS	B	969	2512	8028	15895
ld_15_4	COULOMMIERS	B	982	2534	8042	17324
ld_15_5	COULOMMIERS	B	978	2526	8035	17170
ld_15_6	COULOMMIERS	B	957	2483	8009	15697
ld_16_1	COULOMMIERS	B	960	2496	8023	15927
ld_16_2	COULOMMIERS	B	958	2486	8012	15766
ld_16_3	COULOMMIERS	B	977	2523	8032	17109
ld_16_4	COULOMMIERS	B	978	2525	8035	17159
ld_16_5	COULOMMIERS	B	958	2486	8012	15766
ld_16_6	COULOMMIERS	B	978	2524	8033	17157
ld_17_1	COULOMMIERS	B	956	2481	8008	15658
ld_17_2	COULOMMIERS	B	958	2486	8012	15766
ld_17_3	COULOMMIERS	B	958	2486	8012	15766
ld_17_4	COULOMMIERS	B	971	2514	8029	15954
ld_17_5	COULOMMIERS	B	958	2486	8012	15766
ld_17_6	COULOMMIERS	B	977	2523	8033	17129
ld_18_1	COULOMMIERS	B	946	2440	7967	15126

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
ld_18_2	COULOMMIERS	B	958	2486	8012	15766
ld_18_3	COULOMMIERS	B	957	2484	8010	15716
ld_18_4	COULOMMIERS	B	955	2475	8001	15592
ld_18_5	COULOMMIERS	B	978	2525	8035	17161
ld_18_6	COULOMMIERS	B	978	2525	8035	17146
ld_19_1	COULOMMIERS	B	957	2486	8017	16115
ld_19_2	COULOMMIERS	B	956	2478	8004	15625
ld_19_3	COULOMMIERS	B	955	2477	8004	15603
ld_19_4	COULOMMIERS	B	955	2478	8005	15672
ld_19_5	COULOMMIERS	B	958	2486	8012	15766
ld_19_6	COULOMMIERS	B	970	2511	8026	15935
ld_20_1	COULOMMIERS	B	999	2631	8149	17658
ld_20_2	COULOMMIERS	B	974	2524	8038	16208
ld_20_3	COULOMMIERS	B	957	2484	8010	15722
ld_20_4	COULOMMIERS	B	971	2512	7961	14156
ld_20_5	COULOMMIERS	B	957	2482	8008	15729
ld_20_6	COULOMMIERS	B	979	2530	8039	17256
base	CUMARIN	B	6292	11611	20112	65774
kh_01_1	CUMARIN	B	6304	11626	20248	65794
kh_06_1	CUMARIN	B	6588	11946	23211	66128
kh_06_2	CUMARIN	B	6340	11651	20584	65826
kh_06_3	CUMARIN	B	6361	11672	20567	65230
kh_07_1	CUMARIN	B	6370	11660	20140	66655
kh_07_2	CUMARIN	B	6398	11731	22482	54414
kh_07_3	CUMARIN	B	6292	11609	19540	65789
kh_07_4	CUMARIN	B	6354	11667	20362	65408
kh_07_5	CUMARIN	B	6465	11783	20260	65717
kh_07_6	CUMARIN	B	6298	11618	20161	65778
kh_07_7	CUMARIN	B	6293	11612	20080	65779
kh_07_8	CUMARIN	B	6169	11459	17261	63426
kh_07_9	CUMARIN	B	6335	11653	20304	64967
kh_08_1	CUMARIN	B	6435	11743	21991	65842
kh_09_1	CUMARIN	B	6304	11626	19991	65748
kh_10_1	CUMARIN	B	6307	11628	20253	65770
kh_10_2	CUMARIN	B	6360	11672	20654	65664
kh_11_1	CUMARIN	B	7216	12938	27394	66478
kh_11_2	CUMARIN	B	6360	11671	20674	65798
kh_11_3	CUMARIN	B	6286	11603	19932	65978
kh_12_1	CUMARIN	B	6279	11609	20509	66649
kh_12_2	CUMARIN	B	6372	11679	20759	65801
kh_13_1	CUMARIN	B	6296	11610	19079	65502
kh_13_2	CUMARIN	B	6382	11678	21580	65856
kh_13_3	CUMARIN	B	6368	11676	20654	65605
kh_14_1	CUMARIN	B	6309	11632	20355	65771
kh_14_2	CUMARIN	B	6292	11611	20112	65774
kh_14_3	CUMARIN	B	6292	11611	19953	65766
kh_14_4	CUMARIN	B	6353	11669	20661	65795

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location.	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
kh_14_5	CUMARIN	B	6281	11599	19887	65754
kh_14_6	CUMARIN	B	6298	11618	20138	65777
kh_15_1	CUMARIN	B	6483	11784	22167	65942
kh_15_2	CUMARIN	B	6292	11611	20112	65774
kh_15_3	CUMARIN	B	6293	11612	20096	65780
kh_15_4	CUMARIN	B	6354	11668	20614	65794
kh_15_5	CUMARIN	B	6358	11669	20668	65797
kh_15_6	CUMARIN	B	6336	11657	20534	65790
kh_16_1	CUMARIN	B	6359	11688	20904	65815
kh_16_2	CUMARIN	B	6292	11611	20112	65774
kh_16_3	CUMARIN	B	6360	11672	20713	65795
kh_16_4	CUMARIN	B	6359	11671	20673	65799
kh_16_5	CUMARIN	B	6292	11611	20112	65774
kh_16_6	CUMARIN	B	6359	11670	20643	65797
kh_17_1	CUMARIN	B	6345	11662	20560	65813
kh_17_2	CUMARIN	B	6292	11611	20112	65774
kh_17_3	CUMARIN	B	6292	11611	20112	65774
kh_17_4	CUMARIN	B	6355	11668	20654	65795
kh_17_5	CUMARIN	B	6292	11611	20112	65774
kh_17_6	CUMARIN	B	6372	11679	20752	65801
kh_18_1	CUMARIN	B	6268	11582	19940	65782
kh_18_2	CUMARIN	B	6292	11611	20112	65774
kh_18_3	CUMARIN	B	6352	11665	20585	65818
kh_18_4	CUMARIN	B	6291	11609	20032	65766
kh_18_5	CUMARIN	B	6362	11673	20717	65899
kh_18_6	CUMARIN	B	6356	11669	20623	65796
kh_19_1	CUMARIN	B	6345	11675	21692	65829
kh_19_2	CUMARIN	B	6296	11615	20062	65801
kh_19_3	CUMARIN	B	6306	11625	20206	65704
kh_19_4	CUMARIN	B	6298	11620	20261	65830
kh_19_5	CUMARIN	B	6292	11611	20112	65774
kh_19_6	CUMARIN	B	6304	11625	20234	65781
kh_20_1	CUMARIN	B	6680	11947	23447	65461
kh_20_2	CUMARIN	B	6430	11741	21998	66678
kh_20_3	CUMARIN	B	6289	11607	19854	65772
kh_20_4	CUMARIN	B	6384	11668	20598	65838
kh_20_5	CUMARIN	B	6372	11685	20944	65938
kh_20_6	CUMARIN	B	6349	11667	20486	64890
ld_01_1	CUMARIN	B	6302	11623	20213	65776
ld_06_1	CUMARIN	B	6476	11784	22582	65957
ld_06_2	CUMARIN	B	6319	11640	20412	65788
ld_06_3	CUMARIN	B	6358	11670	20626	65678
ld_07_1	CUMARIN	B	5528	10603	16454	37173
ld_07_2	CUMARIN	B	6343	11669	20987	65789
ld_07_3	CUMARIN	B	6345	11661	20505	65818
ld_07_4	CUMARIN	B	6318	11637	20209	65481
ld_07_5	CUMARIN	B	6336	11661	20196	65803

* --- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
Id_07_6	CUMARIN	B	6292	11611	20105	65774
Id_07_7	CUMARIN	B	6302	11623	20233	65806
Id_07_8	CUMARIN	B	6272	11588	18907	65650
Id_07_9	CUMARIN	B	6311	11632	20267	65484
Id_08_1	CUMARIN	B	6320	11646	20512	65787
Id_09_1	CUMARIN	B	6299	11620	20177	65769
Id_10_1	CUMARIN	B	6365	11675	20706	65801
Id_10_2	CUMARIN	B	6308	11630	20288	65713
Id_11_1	CUMARIN	B	6705	12059	24340	66182
Id_11_2	CUMARIN	B	6360	11672	20682	65799
Id_11_3	CUMARIN	B	6302	11623	20221	65771
Id_12_1	CUMARIN	B	6280	11602	20142	65967
Id_12_2	CUMARIN	B	6304	11625	20232	65782
Id_13_1	CUMARIN	B	6308	11630	20038	65827
Id_13_2	CUMARIN	B	6304	11625	20441	65787
Id_13_3	CUMARIN	B	6348	11663	20546	65720
Id_14_1	CUMARIN	B	6311	11633	20328	65779
Id_14_2	CUMARIN	B	6311	11632	20266	65783
Id_14_3	CUMARIN	B	6354	11667	20615	65795
Id_14_4	CUMARIN	B	6291	11611	20077	65776
Id_14_5	CUMARIN	B	6306	11627	20252	65773
Id_14_6	CUMARIN	B	6304	11626	20258	65795
Id_15_1	CUMARIN	B	6453	11755	21890	65962
Id_15_2	CUMARIN	B	6311	11632	20266	65783
Id_15_3	CUMARIN	B	6287	11603	19860	65762
Id_15_4	CUMARIN	B	6383	11688	20865	65806
Id_15_5	CUMARIN	B	6362	11673	20716	65799
Id_15_6	CUMARIN	B	6305	11627	20294	65773
Id_16_1	CUMARIN	B	6325	11652	20624	65804
Id_16_2	CUMARIN	B	6311	11632	20266	65783
Id_16_3	CUMARIN	B	6350	11664	20577	65794
Id_16_4	CUMARIN	B	6361	11672	20698	65799
Id_16_5	CUMARIN	B	6311	11632	20266	65783
Id_16_6	CUMARIN	B	6359	11670	20653	65798
Id_17_1	CUMARIN	B	6302	11623	20183	65780
Id_17_2	CUMARIN	B	6311	11632	20266	65783
Id_17_3	CUMARIN	B	6311	11632	20266	65783
Id_17_4	CUMARIN	B	6293	11612	19971	65768
Id_17_5	CUMARIN	B	6311	11632	20266	65783
Id_17_6	CUMARIN	B	6356	11669	20629	65797
Id_18_1	CUMARIN	B	6261	11576	19828	65769
Id_18_2	CUMARIN	B	6311	11632	20266	65783
Id_18_3	CUMARIN	B	6307	11628	20260	65783
Id_18_4	CUMARIN	B	6297	11617	20140	65774
Id_18_5	CUMARIN	B	6360	11672	20705	65785
Id_18_6	CUMARIN	B	6355	11667	20618	65795
Id_19_1	CUMARIN	B	6370	11705	22324	65976

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	<i>Distance Traveled (meters)</i>			
			25 years	50 years	100 years	200 years
ld_19_2	CUMARIN	B	6299	11619	20130	65788
ld_19_3	CUMARIN	B	6299	11620	20177	65789
ld_19_4	CUMARIN	B	6306	11632	20472	65793
ld_19_5	CUMARIN	B	6311	11632	20266	65783
ld_19_6	CUMARIN	B	6290	11607	19901	65775
ld_20_1	CUMARIN	B	6512	11803	22241	65805
ld_20_2	CUMARIN	B	6305	11624	20065	65888
ld_20_3	CUMARIN	B	6308	11630	20274	65787
ld_20_4	CUMARIN	B	6305	11615	19937	65772
ld_20_5	CUMARIN	B	6311	11635	20429	65782
ld_20_6	CUMARIN	B	6365	11676	20690	65601
base	DARWIN	B	4947	----	----	----
kh_01_1	DARWIN	B	4947	----	----	----
kh_06_1	DARWIN	B	4864	----	----	----
kh_06_2	DARWIN	B	4947	----	----	----
kh_06_3	DARWIN	B	4952	----	----	----
kh_07_1	DARWIN	B	4946	----	----	----
kh_07_2	DARWIN	B	4949	----	----	----
kh_07_3	DARWIN	B	4947	----	----	----
kh_07_4	DARWIN	B	4948	----	----	----
kh_07_5	DARWIN	B	4920	----	----	----
kh_07_6	DARWIN	B	4947	----	----	----
kh_07_7	DARWIN	B	4911	----	----	----
kh_07_8	DARWIN	B	4944	----	----	----
kh_07_9	DARWIN	B	4946	----	----	----
kh_08_1	DARWIN	B	4952	----	----	----
kh_09_1	DARWIN	B	4949	----	----	----
kh_10_1	DARWIN	B	4947	----	----	----
kh_10_2	DARWIN	B	4950	----	----	----
kh_11_1	DARWIN	B	4832	----	----	----
kh_11_2	DARWIN	B	4947	----	----	----
kh_11_3	DARWIN	B	5238	32646	32840	33216
kh_12_1	DARWIN	B	4910	33588	33768	34107
kh_12_2	DARWIN	B	4949	----	----	----
kh_13_1	DARWIN	B	4935	----	----	----
kh_13_2	DARWIN	B	4948	----	----	----
kh_13_3	DARWIN	B	4949	----	----	----
kh_14_1	DARWIN	B	4847	----	----	----
kh_14_2	DARWIN	B	4947	----	----	----
kh_14_3	DARWIN	B	4949	----	----	----
kh_14_4	DARWIN	B	4949	----	----	----
kh_14_5	DARWIN	B	4949	----	----	----
kh_14_6	DARWIN	B	4947	----	----	----
kh_15_1	DARWIN	B	4842	----	----	----
kh_15_2	DARWIN	B	4947	----	----	----
kh_15_3	DARWIN	B	4947	----	----	----
kh_15_4	DARWIN	B	4949	----	----	----

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
kh_15_5	DARWIN	B	4950	----	----	----
kh_15_6	DARWIN	B	4954	----	----	----
kh_16_1	DARWIN	B	4907	----	----	----
kh_16_2	DARWIN	B	4947	----	----	----
kh_16_3	DARWIN	B	4950	----	----	----
kh_16_4	DARWIN	B	4949	----	----	----
kh_16_5	DARWIN	B	4947	----	----	----
kh_16_6	DARWIN	B	4882	----	----	----
kh_17_1	DARWIN	B	4949	----	----	----
kh_17_2	DARWIN	B	4947	----	----	----
kh_17_3	DARWIN	B	4947	----	----	----
kh_17_4	DARWIN	B	4949	----	----	----
kh_17_5	DARWIN	B	4947	----	----	----
kh_17_6	DARWIN	B	4949	----	----	----
kh_18_1	DARWIN	B	4655	----	----	----
kh_18_2	DARWIN	B	4947	----	----	----
kh_18_3	DARWIN	B	4949	----	----	----
kh_18_4	DARWIN	B	4872	----	----	----
kh_18_5	DARWIN	B	4953	----	----	----
kh_18_6	DARWIN	B	4925	----	----	----
kh_19_1	DARWIN	B	16250	----	----	----
kh_19_2	DARWIN	B	4871	----	----	----
kh_19_3	DARWIN	B	6901	----	----	----
kh_19_4	DARWIN	B	12678	----	----	----
kh_19_5	DARWIN	B	4947	----	----	----
kh_19_6	DARWIN	B	4941	----	----	----
kh_20_1	DARWIN	B	4985	33153	33290	----
kh_20_2	DARWIN	B	4948	----	----	----
kh_20_3	DARWIN	B	4949	----	----	----
kh_20_4	DARWIN	B	4948	----	----	----
kh_20_5	DARWIN	B	4949	----	----	----
kh_20_6	DARWIN	B	4946	----	----	----
ld_01_1	DARWIN	B	4947	----	----	----
ld_06_1	DARWIN	B	4860	----	----	----
ld_06_2	DARWIN	B	4947	----	----	----
ld_06_3	DARWIN	B	4951	----	----	----
ld_07_1	DARWIN	B	4946	----	----	----
ld_07_2	DARWIN	B	4947	----	----	----
ld_07_3	DARWIN	B	4949	----	----	----
ld_07_4	DARWIN	B	4945	----	----	----
ld_07_5	DARWIN	B	4940	----	----	----
ld_07_6	DARWIN	B	4947	----	----	----
ld_07_7	DARWIN	B	4926	----	----	----
ld_07_8	DARWIN	B	4947	----	----	----
ld_07_9	DARWIN	B	4945	----	----	----
ld_08_1	DARWIN	B	4948	----	----	----
ld_09_1	DARWIN	B	4948	----	----	----

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
ld_10_1	DARWIN	B	4949	----	----	----
ld_10_2	DARWIN	B	4947	----	----	----
ld_11_1	DARWIN	B	4847	----	----	----
ld_11_2	DARWIN	B	4949	----	----	----
ld_11_3	DARWIN	B	4956	----	----	----
ld_12_1	DARWIN	B	4967	----	----	----
ld_12_2	DARWIN	B	4947	----	----	----
ld_13_1	DARWIN	B	4950	----	----	----
ld_13_2	DARWIN	B	4949	----	----	----
ld_13_3	DARWIN	B	4949	----	----	----
ld_14_1	DARWIN	B	4940	----	----	----
ld_14_2	DARWIN	B	4948	----	----	----
ld_14_3	DARWIN	B	4949	----	----	----
ld_14_4	DARWIN	B	4946	----	----	----
ld_14_5	DARWIN	B	4947	----	----	----
ld_14_6	DARWIN	B	4948	----	----	----
ld_15_1	DARWIN	B	4937	----	----	----
ld_15_2	DARWIN	B	4948	----	----	----
ld_15_3	DARWIN	B	4949	----	----	----
ld_15_4	DARWIN	B	4950	----	----	----
ld_15_5	DARWIN	B	4950	----	----	----
ld_15_6	DARWIN	B	4950	----	----	----
ld_16_1	DARWIN	B	4921	----	----	----
ld_16_2	DARWIN	B	4948	----	----	----
ld_16_3	DARWIN	B	4949	----	----	----
ld_16_4	DARWIN	B	4949	----	----	----
ld_16_5	DARWIN	B	4948	----	----	----
ld_16_6	DARWIN	B	4869	----	----	----
ld_17_1	DARWIN	B	4946	----	----	----
ld_17_2	DARWIN	B	4948	----	----	----
ld_17_3	DARWIN	B	4948	----	----	----
ld_17_4	DARWIN	B	4949	----	----	----
ld_17_5	DARWIN	B	4948	----	----	----
ld_17_6	DARWIN	B	4949	----	----	----
ld_18_1	DARWIN	B	4666	----	----	----
ld_18_2	DARWIN	B	4948	----	----	----
ld_18_3	DARWIN	B	4947	----	----	----
ld_18_4	DARWIN	B	4866	----	----	----
ld_18_5	DARWIN	B	4951	----	----	----
ld_18_6	DARWIN	B	4938	----	----	----
ld_19_1	DARWIN	B	6741	32989	33141	----
ld_19_2	DARWIN	B	4865	----	----	----
ld_19_3	DARWIN	B	4874	----	----	----
ld_19_4	DARWIN	B	7714	----	----	----
ld_19_5	DARWIN	B	4948	----	----	----
ld_19_6	DARWIN	B	4951	----	----	----
ld_20_1	DARWIN	B	4947	----	----	----

* ---- Particle has discharged

Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
ld_20_2	DARWIN	B	4949	----	----	----
ld_20_3	DARWIN	B	4947	----	----	----
ld_20_4	DARWIN	B	4949	----	----	----
ld_20_5	DARWIN	B	4947	----	----	----
ld_20_6	DARWIN	B	4950	----	----	----
base	DILUTED WATER	B	10	20	40	81
kh_01_1	DILUTED WATER	B	10	20	41	81
kh_06_1	DILUTED WATER	B	10	21	41	83
kh_06_2	DILUTED WATER	B	10	20	41	81
kh_06_3	DILUTED WATER	B	10	20	41	81
kh_07_1	DILUTED WATER	B	5	11	22	43
kh_07_2	DILUTED WATER	B	10	21	41	82
kh_07_3	DILUTED WATER	B	10	20	41	82
kh_07_4	DILUTED WATER	B	10	20	41	82
kh_07_5	DILUTED WATER	B	11	21	42	84
kh_07_6	DILUTED WATER	B	10	20	41	81
kh_07_7	DILUTED WATER	B	10	20	41	81
kh_07_8	DILUTED WATER	B	11	21	43	85
kh_07_9	DILUTED WATER	B	10	20	41	81
kh_08_1	DILUTED WATER	B	10	20	41	81
kh_09_1	DILUTED WATER	B	10	20	41	81
kh_10_1	DILUTED WATER	B	10	20	41	81
kh_10_2	DILUTED WATER	B	10	20	41	81
kh_11_1	DILUTED WATER	B	11	21	42	85
kh_11_2	DILUTED WATER	B	10	20	41	81
kh_11_3	DILUTED WATER	B	10	20	40	81
kh_12_1	DILUTED WATER	B	10	20	41	82
kh_12_2	DILUTED WATER	B	10	20	41	81
kh_13_1	DILUTED WATER	B	10	20	40	80
kh_13_2	DILUTED WATER	B	10	20	41	81
kh_13_3	DILUTED WATER	B	10	20	41	81
kh_14_1	DILUTED WATER	B	10	20	41	81
kh_14_2	DILUTED WATER	B	10	20	40	81
kh_14_3	DILUTED WATER	B	10	20	41	81
kh_14_4	DILUTED WATER	B	10	20	41	81
kh_14_5	DILUTED WATER	B	10	20	41	81
kh_14_6	DILUTED WATER	B	10	20	41	81
kh_15_1	DILUTED WATER	B	10	20	41	82
kh_15_2	DILUTED WATER	B	10	20	40	81
kh_15_3	DILUTED WATER	B	10	20	40	81
kh_15_4	DILUTED WATER	B	10	20	41	81
kh_15_5	DILUTED WATER	B	10	20	41	81
kh_15_6	DILUTED WATER	B	10	20	41	81
kh_16_1	DILUTED WATER	B	10	20	41	81
kh_16_2	DILUTED WATER	B	10	20	40	81
kh_16_3	DILUTED WATER	B	10	20	41	81
kh_16_4	DILUTED WATER	B	10	20	41	81

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
kh_16_5	DILUTED WATER	B	10	20	40	81
kh_16_6	DILUTED WATER	B	10	20	41	81
kh_17_1	DILUTED WATER	B	10	20	41	81
kh_17_2	DILUTED WATER	B	10	20	40	81
kh_17_3	DILUTED WATER	B	10	20	40	81
kh_17_4	DILUTED WATER	B	10	20	41	81
kh_17_5	DILUTED WATER	B	10	20	40	81
kh_17_6	DILUTED WATER	B	10	20	41	81
kh_18_1	DILUTED WATER	B	10	20	40	81
kh_18_2	DILUTED WATER	B	10	20	40	81
kh_18_3	DILUTED WATER	B	10	20	41	81
kh_18_4	DILUTED WATER	B	10	20	41	81
kh_18_5	DILUTED WATER	B	10	20	41	81
kh_18_6	DILUTED WATER	B	10	20	41	81
kh_19_1	DILUTED WATER	B	10	20	41	81
kh_19_2	DILUTED WATER	B	10	20	40	81
kh_19_3	DILUTED WATER	B	10	20	41	81
kh_19_4	DILUTED WATER	B	10	20	41	81
kh_19_5	DILUTED WATER	B	10	20	40	81
kh_19_6	DILUTED WATER	B	10	20	41	81
kh_20_1	DILUTED WATER	B	10	21	42	84
kh_20_2	DILUTED WATER	B	10	21	41	83
kh_20_3	DILUTED WATER	B	10	20	41	81
kh_20_4	DILUTED WATER	B	10	20	40	81
kh_20_5	DILUTED WATER	B	19	38	76	152
kh_20_6	DILUTED WATER	B	10	20	41	82
ld_01_1	DILUTED WATER	B	10	20	41	81
ld_06_1	DILUTED WATER	B	10	20	41	82
ld_06_2	DILUTED WATER	B	10	20	41	81
ld_06_3	DILUTED WATER	B	10	20	41	81
ld_07_1	DILUTED WATER	B	8	16	32	63
ld_07_2	DILUTED WATER	B	10	20	41	81
ld_07_3	DILUTED WATER	B	10	20	41	81
ld_07_4	DILUTED WATER	B	10	20	41	81
ld_07_5	DILUTED WATER	B	10	20	41	82
ld_07_6	DILUTED WATER	B	10	20	41	81
ld_07_7	DILUTED WATER	B	10	20	41	81
ld_07_8	DILUTED WATER	B	10	21	41	82
ld_07_9	DILUTED WATER	B	10	20	41	81
ld_08_1	DILUTED WATER	B	10	20	41	81
ld_09_1	DILUTED WATER	B	10	20	41	81
ld_10_1	DILUTED WATER	B	10	20	41	81
ld_10_2	DILUTED WATER	B	10	20	41	81
ld_11_1	DILUTED WATER	B	10	21	41	83
ld_11_2	DILUTED WATER	B	10	20	41	81
ld_11_3	DILUTED WATER	B	10	20	41	81
ld_12_1	DILUTED WATER	B	10	20	41	81

* ---- Particle has discharged

Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
ld_12_2	DILUTED WATER	B	10	20	41	81
ld_13_1	DILUTED WATER	B	10	20	40	81
ld_13_2	DILUTED WATER	B	10	20	40	81
ld_13_3	DILUTED WATER	B	10	20	41	81
ld_14_1	DILUTED WATER	B	10	20	41	81
ld_14_2	DILUTED WATER	B	10	20	41	81
ld_14_3	DILUTED WATER	B	10	20	41	81
ld_14_4	DILUTED WATER	B	10	20	40	81
ld_14_5	DILUTED WATER	B	10	20	41	81
ld_14_6	DILUTED WATER	B	10	20	41	81
ld_15_1	DILUTED WATER	B	10	20	41	82
ld_15_2	DILUTED WATER	B	10	20	41	81
ld_15_3	DILUTED WATER	B	10	20	41	81
ld_15_4	DILUTED WATER	B	10	20	41	81
ld_15_5	DILUTED WATER	B	10	20	41	81
ld_15_6	DILUTED WATER	B	10	20	41	81
ld_16_1	DILUTED WATER	B	10	20	41	81
ld_16_2	DILUTED WATER	B	10	20	41	81
ld_16_3	DILUTED WATER	B	10	20	41	81
ld_16_4	DILUTED WATER	B	10	20	41	81
ld_16_5	DILUTED WATER	B	10	20	41	81
ld_16_6	DILUTED WATER	B	10	20	41	81
ld_17_1	DILUTED WATER	B	10	20	41	81
ld_17_2	DILUTED WATER	B	10	20	41	81
ld_17_3	DILUTED WATER	B	10	20	41	81
ld_17_4	DILUTED WATER	B	10	20	41	81
ld_17_5	DILUTED WATER	B	10	20	41	81
ld_17_6	DILUTED WATER	B	10	20	41	81
ld_18_1	DILUTED WATER	B	10	20	40	81
ld_18_2	DILUTED WATER	B	10	20	41	81
ld_18_3	DILUTED WATER	B	10	20	41	81
ld_18_4	DILUTED WATER	B	10	20	41	81
ld_18_5	DILUTED WATER	B	10	20	41	81
ld_18_6	DILUTED WATER	B	10	20	41	81
ld_19_1	DILUTED WATER	B	10	20	41	82
ld_19_2	DILUTED WATER	B	10	20	41	81
ld_19_3	DILUTED WATER	B	10	20	41	81
ld_19_4	DILUTED WATER	B	10	20	41	81
ld_19_5	DILUTED WATER	B	10	20	41	81
ld_19_6	DILUTED WATER	B	10	20	41	81
ld_20_1	DILUTED WATER	B	10	21	41	82
ld_20_2	DILUTED WATER	B	10	20	41	81
ld_20_3	DILUTED WATER	B	10	20	41	81
ld_20_4	DILUTED WATER	B	10	20	41	81
ld_20_5	DILUTED WATER	B	13	26	52	103
ld_20_6	DILUTED WATER	B	10	20	41	81
base	GUMDROP	WT	47	126	312	837

* ---- Particle has discharged

Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
kh_01_1	GUMDROP	WT	82	167	334	614
kh_06_1	GUMDROP	WT	4	7	15	35
kh_06_2	GUMDROP	WT	8	16	31	62
kh_06_3	GUMDROP	WT	4	8	15	38
kh_07_1	GUMDROP	WT	577	626	719	879
kh_07_2	GUMDROP	WT	2	5	10	20
kh_07_3	GUMDROP	WT	107	371	927	2220
kh_07_4	GUMDROP	WT	133	279	574	1237
kh_07_5	GUMDROP	WT	17	34	71	142
kh_07_6	GUMDROP	WT	10	20	43	91
kh_07_7	GUMDROP	WT	3	7	14	33
kh_07_8	GUMDROP	WT	2	5	10	23
kh_07_9	GUMDROP	WT	175	492	1129	2259
kh_08_1	GUMDROP	WT	9034	13144	19250	43403
kh_09_1	GUMDROP	WT	12	24	52	107
kh_10_1	GUMDROP	WT	127	265	552	1139
kh_10_2	GUMDROP	WT	4	8	15	38
kh_11_1	GUMDROP	WT	13	27	54	106
kh_11_2	GUMDROP	WT	5	10	19	42
kh_11_3	GUMDROP	WT	68	185	521	1149
kh_12_1	GUMDROP	WT	4	7	14	28
kh_12_2	GUMDROP	WT	152	370	642	1187
kh_13_1	GUMDROP	WT	160	330	681	1516
kh_13_2	GUMDROP	WT	187	220	288	412
kh_13_3	GUMDROP	WT	152	371	643	1188
kh_14_1	GUMDROP	WT	208	563	1266	2401
kh_14_2	GUMDROP	WT	47	126	312	837
kh_14_3	GUMDROP	WT	2	5	10	20
kh_14_4	GUMDROP	WT	4	8	16	31
kh_14_5	GUMDROP	WT	106	213	416	746
kh_14_6	GUMDROP	WT	15	31	64	130
kh_15_1	GUMDROP	WT	10	21	42	82
kh_15_2	GUMDROP	WT	47	126	312	837
kh_15_3	GUMDROP	WT	57	149	450	1008
kh_15_4	GUMDROP	WT	11	22	44	87
kh_15_5	GUMDROP	WT	5	10	19	42
kh_15_6	GUMDROP	WT	211	504	877	1652
kh_16_1	GUMDROP	WT	135	283	582	1299
kh_16_2	GUMDROP	WT	47	126	312	837
kh_16_3	GUMDROP	WT	104	209	408	734
kh_16_4	GUMDROP	WT	4	9	17	35
kh_16_5	GUMDROP	WT	47	126	312	837
kh_16_6	GUMDROP	WT	4	9	17	34
kh_17_1	GUMDROP	WT	34	68	183	415
kh_17_2	GUMDROP	WT	47	126	312	837
kh_17_3	GUMDROP	WT	47	126	312	837
kh_17_4	GUMDROP	WT	2	5	10	19

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
kh_17_5	GUMDROP	WT	47	126	312	837
kh_17_6	GUMDROP	WT	152	370	642	1187
kh_18_1	GUMDROP	WT	22	45	92	181
kh_18_2	GUMDROP	WT	47	126	312	837
kh_18_3	GUMDROP	WT	4	9	17	34
kh_18_4	GUMDROP	WT	3	5	10	26
kh_18_5	GUMDROP	WT	227	281	383	567
kh_18_6	GUMDROP	WT	2	5	10	19
kh_19_1	GUMDROP	WT	294	640	1216	2657
kh_19_2	GUMDROP	WT	110	226	468	961
kh_19_3	GUMDROP	WT	18	38	77	154
kh_19_4	GUMDROP	WT	2	5	10	23
kh_19_5	GUMDROP	WT	47	126	312	837
kh_19_6	GUMDROP	WT	2	5	10	25
kh_20_1	GUMDROP	WT	65	189	549	1206
kh_20_2	GUMDROP	WT	177	494	1132	2261
kh_20_3	GUMDROP	WT	4	9	17	34
kh_20_4	GUMDROP	WT	244	325	472	722
kh_20_5	GUMDROP	WT	4	9	17	35
kh_20_6	GUMDROP	WT	417	479	594	793
ld_01_1	GUMDROP	WT	4	8	16	39
ld_06_1	GUMDROP	WT	266	367	567	961
ld_06_2	GUMDROP	WT	76	156	336	783
ld_06_3	GUMDROP	WT	4	8	16	31
ld_07_1	GUMDROP	WT	12	24	53	109
ld_07_2	GUMDROP	WT	116	336	770	1595
ld_07_3	GUMDROP	WT	65	148	418	996
ld_07_4	GUMDROP	WT	378	833	1806	3193
ld_07_5	GUMDROP	WT	407	466	576	767
ld_07_6	GUMDROP	WT	2	5	10	19
ld_07_7	GUMDROP	WT	241	663	1548	2999
ld_07_8	GUMDROP	WT	102	210	432	864
ld_07_9	GUMDROP	WT	273	546	1099	2636
ld_08_1	GUMDROP	WT	5	11	22	43
ld_09_1	GUMDROP	WT	22	45	91	180
ld_10_1	GUMDROP	WT	2	5	10	19
ld_10_2	GUMDROP	WT	151	378	760	1245
ld_11_1	GUMDROP	WT	94	190	379	686
ld_11_2	GUMDROP	WT	2	5	10	19
ld_11_3	GUMDROP	WT	133	278	571	1266
ld_12_1	GUMDROP	WT	140	405	964	2264
ld_12_2	GUMDROP	WT	3	6	11	23
ld_13_1	GUMDROP	WT	273	633	1266	2530
ld_13_2	GUMDROP	WT	211	568	1262	2361
ld_13_3	GUMDROP	WT	57	145	361	874
ld_14_1	GUMDROP	WT	54	139	327	823
ld_14_2	GUMDROP	WT	4	7	14	28

* --- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
ld_14_3	GUMDROP	WT	11	22	45	87
ld_14_4	GUMDROP	WT	17	36	74	147
ld_14_5	GUMDROP	WT	3	7	13	26
ld_14_6	GUMDROP	WT	4	7	14	28
ld_15_1	GUMDROP	WT	94	191	381	690
ld_15_2	GUMDROP	WT	4	7	14	28
ld_15_3	GUMDROP	WT	19	39	77	152
ld_15_4	GUMDROP	WT	180	397	726	1413
ld_15_5	GUMDROP	WT	4	8	16	31
ld_15_6	GUMDROP	WT	89	181	360	655
ld_16_1	GUMDROP	WT	238	313	451	690
ld_16_2	GUMDROP	WT	4	7	14	28
ld_16_3	GUMDROP	WT	12	23	46	91
ld_16_4	GUMDROP	WT	2	5	10	19
ld_16_5	GUMDROP	WT	4	7	14	28
ld_16_6	GUMDROP	WT	4	9	17	34
ld_17_1	GUMDROP	WT	12	25	50	98
ld_17_2	GUMDROP	WT	4	7	14	28
ld_17_3	GUMDROP	WT	4	7	14	28
ld_17_4	GUMDROP	WT	2	5	10	19
ld_17_5	GUMDROP	WT	4	7	14	28
ld_17_6	GUMDROP	WT	3	6	11	29
ld_18_1	GUMDROP	WT	143	304	635	1650
ld_18_2	GUMDROP	WT	4	7	14	28
ld_18_3	GUMDROP	WT	51	115	264	521
ld_18_4	GUMDROP	WT	4	9	17	42
ld_18_5	GUMDROP	WT	4	8	17	34
ld_18_6	GUMDROP	WT	3	7	13	33
ld_19_1	GUMDROP	WT	3	7	13	26
ld_19_2	GUMDROP	WT	14	28	55	109
ld_19_3	GUMDROP	WT	12	25	53	110
ld_19_4	GUMDROP	WT	135	285	587	1378
ld_19_5	GUMDROP	WT	4	7	14	28
ld_19_6	GUMDROP	WT	3	6	11	28
ld_20_1	GUMDROP	WT	153	401	919	1914
ld_20_2	GUMDROP	WT	3	6	11	28
ld_20_3	GUMDROP	WT	60	160	371	962
ld_20_4	GUMDROP	WT	105	212	417	753
ld_20_5	GUMDROP	WT	128	366	838	1767
ld_20_6	GUMDROP	WT	2	5	10	19
base	HOUSTON	B	5098	38979	42344	44573
kh_01_1	HOUSTON	B	5096	39097	42449	43925
kh_06_1	HOUSTON	B	5015	35407	37491	40770
kh_06_2	HOUSTON	B	5092	39110	42465	44009
kh_06_3	HOUSTON	B	5123	39282	42704	44663
kh_07_1	HOUSTON	B	5085	39136	42477	43703
kh_07_2	HOUSTON	B	5120	39138	42490	43853

* ---- Particle has discharged

Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
kh_07_3	HOUSTON	B	5093	39036	42393	44234
kh_07_4	HOUSTON	B	5096	39146	42486	43671
kh_07_5	HOUSTON	B	4968	38901	42275	44752
kh_07_6	HOUSTON	B	5095	39101	42451	43875
kh_07_7	HOUSTON	B	5029	38929	42243	43711
kh_07_8	HOUSTON	B	5081	39041	42392	44099
kh_07_9	HOUSTON	B	5085	39071	42489	44953
kh_08_1	HOUSTON	B	5123	39543	41127	42318
kh_09_1	HOUSTON	B	5113	39245	42573	43544
kh_10_1	HOUSTON	B	5097	39060	42415	44093
kh_10_2	HOUSTON	B	5118	39335	42492	43680
kh_11_1	HOUSTON	B	4805	39078	42298	43541
kh_11_2	HOUSTON	B	5112	39314	42518	43623
kh_11_3	HOUSTON	B	5381	43653	45559	50850
kh_12_1	HOUSTON	B	5383	32609	36221	39288
kh_12_2	HOUSTON	B	5117	39334	42498	43686
kh_13_1	HOUSTON	B	5017	46398	48239	48897
kh_13_2	HOUSTON	B	5098	39105	42457	43894
kh_13_3	HOUSTON	B	5113	39320	42693	43931
kh_14_1	HOUSTON	B	4219	38449	41903	44526
kh_14_2	HOUSTON	B	5098	38979	42344	44573
kh_14_3	HOUSTON	B	5120	39169	42514	43702
kh_14_4	HOUSTON	B	5089	39291	42598	43542
kh_14_5	HOUSTON	B	5124	39187	42530	43664
kh_14_6	HOUSTON	B	5095	39034	42393	44265
kh_15_1	HOUSTON	B	4933	38872	42195	43969
kh_15_2	HOUSTON	B	5098	38979	42344	44573
kh_15_3	HOUSTON	B	5107	38949	42314	44682
kh_15_4	HOUSTON	B	5117	39310	42572	43596
kh_15_5	HOUSTON	B	5118	39327	42504	43693
kh_15_6	HOUSTON	B	5113	39267	42600	43547
kh_16_1	HOUSTON	B	4662	44969	47622	48401
kh_16_2	HOUSTON	B	5098	38979	42344	44573
kh_16_3	HOUSTON	B	5121	39373	42396	43757
kh_16_4	HOUSTON	B	5093	39255	42594	43550
kh_16_5	HOUSTON	B	5098	38979	42344	44573
kh_16_6	HOUSTON	B	5115	39312	42564	43587
kh_17_1	HOUSTON	B	5103	39299	42612	43555
kh_17_2	HOUSTON	B	5098	38979	42344	44573
kh_17_3	HOUSTON	B	5098	38979	42344	44573
kh_17_4	HOUSTON	B	5118	39340	42486	43673
kh_17_5	HOUSTON	B	5098	38979	42344	44573
kh_17_6	HOUSTON	B	5118	39334	42498	43686
kh_18_1	HOUSTON	B	11976	40266	41796	42786
kh_18_2	HOUSTON	B	5098	38979	42344	44573
kh_18_3	HOUSTON	B	5139	39225	42545	43485
kh_18_4	HOUSTON	B	5789	40791	43640	44694

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
kh_18_5	HOUSTON	B	5140	39274	40997	42141
kh_18_6	HOUSTON	B	5112	39288	42598	43542
kh_19_1	HOUSTON	B	4582	37126	39210	41799
kh_19_2	HOUSTON	B	5357	37026	40325	42965
kh_19_3	HOUSTON	B	5627	41720	44167	46995
kh_19_4	HOUSTON	B	5844	39743	42847	45332
kh_19_5	HOUSTON	B	5098	38979	42344	44573
kh_19_6	HOUSTON	B	5058	39047	42371	43673
kh_20_1	HOUSTON	B	5232	39132	42574	45098
kh_20_2	HOUSTON	B	5097	39186	42520	43542
kh_20_3	HOUSTON	B	5120	39163	42509	43729
kh_20_4	HOUSTON	B	5095	39104	42458	43719
kh_20_5	HOUSTON	B	5116	39304	42586	43611
kh_20_6	HOUSTON	B	5086	39088	42501	44965
ld_01_1	HOUSTON	B	5096	39068	42422	44052
ld_06_1	HOUSTON	B	5079	38397	40360	42225
ld_06_2	HOUSTON	B	5094	39096	42454	44094
ld_06_3	HOUSTON	B	5124	39326	42553	43657
ld_07_1	HOUSTON	B	5085	39013	42378	44542
ld_07_2	HOUSTON	B	5097	39074	42427	44014
ld_07_3	HOUSTON	B	5117	39306	42594	43620
ld_07_4	HOUSTON	B	5088	39067	42487	45043
ld_07_5	HOUSTON	B	5063	38978	42352	44803
ld_07_6	HOUSTON	B	5095	39045	42399	44130
ld_07_7	HOUSTON	B	5053	38978	42311	44010
ld_07_8	HOUSTON	B	5095	39109	42458	43852
ld_07_9	HOUSTON	B	5085	39100	42516	45030
ld_08_1	HOUSTON	B	5096	39243	42577	43506
ld_09_1	HOUSTON	B	5100	39112	42459	43767
ld_10_1	HOUSTON	B	5117	39313	42561	43584
ld_10_2	HOUSTON	B	5095	39068	42423	44080
ld_11_1	HOUSTON	B	4975	39085	42412	43512
ld_11_2	HOUSTON	B	5115	39318	42532	43637
ld_11_3	HOUSTON	B	5127	39039	42496	45088
ld_12_1	HOUSTON	B	5232	35374	37574	41065
ld_12_2	HOUSTON	B	5095	39043	42401	44216
ld_13_1	HOUSTON	B	5118	39344	41670	43028
ld_13_2	HOUSTON	B	5124	39154	42501	43726
ld_13_3	HOUSTON	B	5114	39286	42637	43671
ld_14_1	HOUSTON	B	4644	38587	42000	44556
ld_14_2	HOUSTON	B	5107	39096	42447	43914
ld_14_3	HOUSTON	B	5116	39301	42599	43625
ld_14_4	HOUSTON	B	5085	38980	42346	44550
ld_14_5	HOUSTON	B	5096	39085	42438	43994
ld_14_6	HOUSTON	B	5096	39098	42449	43919
ld_15_1	HOUSTON	B	4982	38989	42313	43715
ld_15_2	HOUSTON	B	5107	39096	42447	43914

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
ld_15_3	HOUSTON	B	5118	39128	42479	43819
ld_15_4	HOUSTON	B	5117	39364	42417	43687
ld_15_5	HOUSTON	B	5118	39327	42501	43690
ld_15_6	HOUSTON	B	5095	39110	42460	43857
ld_16_1	HOUSTON	B	4809	43737	45543	49540
ld_16_2	HOUSTON	B	5107	39096	42447	43914
ld_16_3	HOUSTON	B	5116	39301	42603	43628
ld_16_4	HOUSTON	B	5110	39323	42489	43677
ld_16_5	HOUSTON	B	5107	39096	42447	43914
ld_16_6	HOUSTON	B	5116	39311	42568	43591
ld_17_1	HOUSTON	B	5085	39032	42391	44273
ld_17_2	HOUSTON	B	5107	39096	42447	43914
ld_17_3	HOUSTON	B	5107	39096	42447	43914
ld_17_4	HOUSTON	B	5120	39161	42507	43711
ld_17_5	HOUSTON	B	5107	39096	42447	43914
ld_17_6	HOUSTON	B	5117	39290	42623	43581
ld_18_1	HOUSTON	B	6052	40072	43079	44083
ld_18_2	HOUSTON	B	5107	39096	42447	43914
ld_18_3	HOUSTON	B	5109	39031	42376	44030
ld_18_4	HOUSTON	B	5387	39541	43029	43929
ld_18_5	HOUSTON	B	5127	39421	41518	42706
ld_18_6	HOUSTON	B	5112	39296	42587	43614
ld_19_1	HOUSTON	B	4797	35841	37916	41157
ld_19_2	HOUSTON	B	5250	37751	41140	43650
ld_19_3	HOUSTON	B	5330	39374	42648	45178
ld_19_4	HOUSTON	B	5378	39315	42537	44906
ld_19_5	HOUSTON	B	5107	39096	42447	43914
ld_19_6	HOUSTON	B	5104	39133	42469	43671
ld_20_1	HOUSTON	B	5100	39074	42431	44046
ld_20_2	HOUSTON	B	5121	39167	42511	43698
ld_20_3	HOUSTON	B	5097	39047	42404	44196
ld_20_4	HOUSTON	B	5122	39153	42500	43731
ld_20_5	HOUSTON	B	5099	39070	42425	44073
ld_20_6	HOUSTON	B	5118	39331	42492	43681
base	PILEDRIIVER	WT	8954	12721	15446	42881
kh_01_1	PILEDRIIVER	WT	8950	12908	15578	43008
kh_06_1	PILEDRIIVER	WT	9851	13377	22017	43669
kh_06_2	PILEDRIIVER	WT	8945	12908	15584	43037
kh_06_3	PILEDRIIVER	WT	8965	13019	16826	43162
kh_07_1	PILEDRIIVER	WT	9826	13050	17191	43099
kh_07_2	PILEDRIIVER	WT	9868	13094	16814	43127
kh_07_3	PILEDRIIVER	WT	8934	12918	15585	43021
kh_07_4	PILEDRIIVER	WT	9874	13076	15976	43047
kh_07_5	PILEDRIIVER	WT	9234	13049	16879	43336
kh_07_6	PILEDRIIVER	WT	8935	12896	15565	42993
kh_07_7	PILEDRIIVER	WT	8929	12891	15558	42982
kh_07_8	PILEDRIIVER	WT	8724	12804	15463	43199

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			200 years
			25 years	50 years	100 years	
kh_07_9	PILEDRIIVER	WT	9018	12731	15456	42905
kh_09_1	PILEDRIIVER	WT	8947	12906	15658	43068
kh_10_1	PILEDRIIVER	WT	8955	12906	15576	43006
kh_10_2	PILEDRIIVER	WT	8947	13035	17000	43189
kh_11_1	PILEDRIIVER	WT	9859	13503	23858	44110
kh_11_2	PILEDRIIVER	WT	8934	13004	16787	43177
kh_11_3	PILEDRIIVER	WT	8922	12898	15563	42982
kh_12_1	PILEDRIIVER	WT	8911	12882	15566	43052
kh_12_2	PILEDRIIVER	WT	8936	13004	16848	43188
kh_13_1	PILEDRIIVER	WT	8964	12900	15569	42994
kh_13_2	PILEDRIIVER	WT	8931	12872	15543	42976
kh_13_3	PILEDRIIVER	WT	8939	13037	17083	43199
kh_14_1	PILEDRIIVER	WT	8934	12897	15574	43029
kh_14_2	PILEDRIIVER	WT	8954	12721	15446	42881
kh_14_3	PILEDRIIVER	WT	8958	13018	16561	43126
kh_14_4	PILEDRIIVER	WT	8944	13010	16787	43177
kh_14_5	PILEDRIIVER	WT	8958	12909	15693	43053
kh_14_6	PILEDRIIVER	WT	8944	12902	15570	42996
kh_15_1	PILEDRIIVER	WT	9248	13021	17912	43288
kh_15_2	PILEDRIIVER	WT	8954	12721	15446	42881
kh_15_3	PILEDRIIVER	WT	8958	12724	15446	42877
kh_15_4	PILEDRIIVER	WT	8936	13005	16789	43175
kh_15_5	PILEDRIIVER	WT	8930	13002	16771	43173
kh_15_6	PILEDRIIVER	WT	8942	13010	16681	43159
kh_16_1	PILEDRIIVER	WT	9076	12824	15562	43018
kh_16_2	PILEDRIIVER	WT	8954	12721	15446	42881
kh_16_3	PILEDRIIVER	WT	8936	13005	16793	43178
kh_16_4	PILEDRIIVER	WT	8936	13005	16765	43174
kh_16_5	PILEDRIIVER	WT	8954	12721	15446	42881
kh_16_6	PILEDRIIVER	WT	8931	13002	16789	43175
kh_17_1	PILEDRIIVER	WT	8935	13005	16733	43167
kh_17_2	PILEDRIIVER	WT	8954	12721	15446	42881
kh_17_3	PILEDRIIVER	WT	8954	12721	15446	42881
kh_17_4	PILEDRIIVER	WT	8934	13005	16769	43174
kh_17_5	PILEDRIIVER	WT	8954	12721	15446	42881
kh_17_6	PILEDRIIVER	WT	8936	13004	16851	43187
kh_18_1	PILEDRIIVER	WT	8794	12959	15616	43002
kh_18_2	PILEDRIIVER	WT	8954	12721	15446	42881
kh_18_3	PILEDRIIVER	WT	8932	13002	16732	43167
kh_18_4	PILEDRIIVER	WT	8930	12893	15559	42983
kh_18_5	PILEDRIIVER	WT	8935	13006	16821	43182
kh_18_6	PILEDRIIVER	WT	8936	13005	16757	43172
kh_19_1	PILEDRIIVER	WT	8878	12988	16125	43115
kh_19_2	PILEDRIIVER	WT	8939	12896	15564	42988
kh_19_3	PILEDRIIVER	WT	8937	12892	15562	42987
kh_19_4	PILEDRIIVER	WT	8924	12888	15553	42978
kh_19_5	PILEDRIIVER	WT	8954	12721	15446	42881

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
kh_19_6	PILEDRIIVER	WT	8948	12905	15575	43005
kh_20_1	PILEDRIIVER	WT	9549	12962	16440	43350
kh_20_2	PILEDRIIVER	WT	9850	13051	16384	43081
kh_20_3	PILEDRIIVER	WT	8956	13021	16556	43128
kh_20_4	PILEDRIIVER	WT	8960	13021	16451	43097
kh_20_5	PILEDRIIVER	WT	8937	13004	16827	43185
kh_20_6	PILEDRIIVER	WT	9058	12878	15550	42983
ld_01_1	PILEDRIIVER	WT	8951	12907	15576	43004
ld_06_1	PILEDRIIVER	WT	9096	13072	18376	43330
ld_06_2	PILEDRIIVER	WT	8941	12899	15639	43042
ld_06_3	PILEDRIIVER	WT	8939	13031	16974	43184
ld_07_1	PILEDRIIVER	WT	8981	12484	19292	45714
ld_07_2	PILEDRIIVER	WT	9000	12751	15471	42929
ld_07_3	PILEDRIIVER	WT	8933	13007	16765	43171
ld_07_4	PILEDRIIVER	WT	8994	12755	15472	42916
ld_07_5	PILEDRIIVER	WT	9017	12970	15723	43103
ld_07_6	PILEDRIIVER	WT	8936	12897	15563	42987
ld_07_7	PILEDRIIVER	WT	8935	12896	15565	42993
ld_07_8	PILEDRIIVER	WT	8892	12897	15560	42997
ld_07_9	PILEDRIIVER	WT	8970	12891	15561	42989
ld_08_1	PILEDRIIVER	WT	8982	12886	15661	43031
ld_09_1	PILEDRIIVER	WT	8936	12898	15564	42994
ld_10_1	PILEDRIIVER	WT	8936	13004	16807	43180
ld_10_2	PILEDRIIVER	WT	8952	12902	15572	43003
ld_11_1	PILEDRIIVER	WT	9557	13198	19667	43543
ld_11_2	PILEDRIIVER	WT	8934	13004	16793	43178
ld_11_3	PILEDRIIVER	WT	8946	12904	15572	42999
ld_12_1	PILEDRIIVER	WT	8947	12753	15479	42933
ld_12_2	PILEDRIIVER	WT	8954	12908	15578	43007
ld_13_1	PILEDRIIVER	WT	8945	12903	15574	43013
ld_13_2	PILEDRIIVER	WT	8950	12900	15566	42985
ld_13_3	PILEDRIIVER	WT	8938	13004	16739	43167
ld_14_1	PILEDRIIVER	WT	8961	12916	15586	43021
ld_14_2	PILEDRIIVER	WT	8959	12912	15583	43015
ld_14_3	PILEDRIIVER	WT	8937	13005	16787	43175
ld_14_4	PILEDRIIVER	WT	8952	12722	15447	42883
ld_14_5	PILEDRIIVER	WT	8955	12909	15580	43011
ld_14_6	PILEDRIIVER	WT	8953	12908	15578	43008
ld_15_1	PILEDRIIVER	WT	9163	12968	17278	43234
ld_15_2	PILEDRIIVER	WT	8959	12912	15583	43015
ld_15_3	PILEDRIIVER	WT	8961	13019	16514	43121
ld_15_4	PILEDRIIVER	WT	8945	13010	16934	43201
ld_15_5	PILEDRIIVER	WT	8936	13005	16799	43179
ld_15_6	PILEDRIIVER	WT	8953	12909	15579	43008
ld_16_1	PILEDRIIVER	WT	8977	12928	15601	43044
ld_16_2	PILEDRIIVER	WT	8959	12912	15583	43015
ld_16_3	PILEDRIIVER	WT	8931	13002	16761	43170

* ---- Particle has discharged

Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
ld_16_4	PILEDRIIVER	WT	8935	13005	16802	43179
ld_16_5	PILEDRIIVER	WT	8959	12912	15583	43015
ld_16_6	PILEDRIIVER	WT	8932	13002	16790	43175
ld_17_1	PILEDRIIVER	WT	8951	12907	15576	43004
ld_17_2	PILEDRIIVER	WT	8959	12912	15583	43015
ld_17_3	PILEDRIIVER	WT	8959	12912	15583	43015
ld_17_4	PILEDRIIVER	WT	8959	13019	16565	43126
ld_17_5	PILEDRIIVER	WT	8959	12912	15583	43015
ld_17_6	PILEDRIIVER	WT	8937	13005	16759	43172
ld_18_1	PILEDRIIVER	WT	8863	12841	15502	42906
ld_18_2	PILEDRIIVER	WT	8959	12912	15583	43015
ld_18_3	PILEDRIIVER	WT	8953	12908	15579	43009
ld_18_4	PILEDRIIVER	WT	8936	12897	15565	42991
ld_18_5	PILEDRIIVER	WT	8935	13005	16801	43179
ld_18_6	PILEDRIIVER	WT	8936	13005	16789	43175
ld_19_1	PILEDRIIVER	WT	8924	12918	15691	43090
ld_19_2	PILEDRIIVER	WT	8942	12899	15569	42996
ld_19_3	PILEDRIIVER	WT	8945	12900	15568	42992
ld_19_4	PILEDRIIVER	WT	8941	12902	15571	43005
ld_19_5	PILEDRIIVER	WT	8959	12912	15583	43015
ld_19_6	PILEDRIIVER	WT	8948	13012	16541	43119
ld_20_1	PILEDRIIVER	WT	9232	13071	16921	43266
ld_20_2	PILEDRIIVER	WT	8985	13030	16662	43129
ld_20_3	PILEDRIIVER	WT	8953	12908	15579	43010
ld_20_4	PILEDRIIVER	WT	8959	13022	16055	43080
ld_20_5	PILEDRIIVER	WT	8949	12903	15574	43009
ld_20_6	PILEDRIIVER	WT	8952	13030	16961	43185
base	PURSE	WP	6683	----	----	----
kh_01_1	PURSE	WP	6685	----	----	----
kh_06_1	PURSE	WP	6614	----	----	----
kh_06_2	PURSE	WP	6685	----	----	----
kh_06_3	PURSE	WP	6688	----	----	----
kh_07_1	PURSE	WP	6686	----	----	----
kh_07_2	PURSE	WP	6684	----	----	----
kh_07_3	PURSE	WP	6684	----	----	----
kh_07_4	PURSE	WP	6686	----	----	----
kh_07_5	PURSE	WP	6581	----	----	----
kh_07_6	PURSE	WP	6685	----	----	----
kh_07_7	PURSE	WP	6670	----	----	----
kh_07_8	PURSE	WP	6685	----	----	----
kh_07_9	PURSE	WP	6683	----	----	----
kh_08_1	PURSE	WP	6694	----	----	----
kh_09_1	PURSE	WP	6686	----	----	----
kh_10_1	PURSE	WP	6684	----	----	----
kh_10_2	PURSE	WP	6687	----	----	----
kh_11_1	PURSE	WP	6602	----	----	----
kh_11_2	PURSE	WP	6686	----	----	----

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
kh_11_3	PURSE	WP	6794	34608	34800	35174
kh_12_1	PURSE	WP	6647	----	----	----
kh_12_2	PURSE	WP	6687	----	----	----
kh_13_1	PURSE	WP	6668	----	----	----
kh_13_2	PURSE	WP	6685	----	----	----
kh_13_3	PURSE	WP	6686	----	----	----
kh_14_1	PURSE	WP	6693	----	----	----
kh_14_2	PURSE	WP	6683	----	----	----
kh_14_3	PURSE	WP	6684	----	----	----
kh_14_4	PURSE	WP	6687	----	----	----
kh_14_5	PURSE	WP	6684	----	----	----
kh_14_6	PURSE	WP	6685	----	----	----
kh_15_1	PURSE	WP	6585	----	----	----
kh_15_2	PURSE	WP	6683	----	----	----
kh_15_3	PURSE	WP	6682	----	----	----
kh_15_4	PURSE	WP	6687	----	----	----
kh_15_5	PURSE	WP	6687	----	----	----
kh_15_6	PURSE	WP	6697	----	----	----
kh_16_1	PURSE	WP	6671	----	----	----
kh_16_2	PURSE	WP	6683	----	----	----
kh_16_3	PURSE	WP	6687	----	----	----
kh_16_4	PURSE	WP	6687	----	----	----
kh_16_5	PURSE	WP	6683	----	----	----
kh_16_6	PURSE	WP	6620	----	----	----
kh_17_1	PURSE	WP	6686	----	----	----
kh_17_2	PURSE	WP	6683	----	----	----
kh_17_3	PURSE	WP	6683	----	----	----
kh_17_4	PURSE	WP	6687	----	----	----
kh_17_5	PURSE	WP	6683	----	----	----
kh_17_6	PURSE	WP	6687	----	----	----
kh_18_1	PURSE	WP	6439	----	----	----
kh_18_2	PURSE	WP	6683	----	----	----
kh_18_3	PURSE	WP	6688	----	----	----
kh_18_4	PURSE	WP	6606	----	----	----
kh_18_5	PURSE	WP	6691	----	----	----
kh_18_6	PURSE	WP	6409	----	----	----
kh_19_1	PURSE	WP	----	----	----	----
kh_19_2	PURSE	WP	6604	----	----	----
kh_19_3	PURSE	WP	6856	----	----	----
kh_19_4	PURSE	WP	6869	----	----	----
kh_19_5	PURSE	WP	6683	----	----	----
kh_19_6	PURSE	WP	6633	----	----	----
kh_20_1	PURSE	WP	6715	----	----	----
kh_20_2	PURSE	WP	6686	----	----	----
kh_20_3	PURSE	WP	6684	----	----	----
kh_20_4	PURSE	WP	6685	----	----	----
kh_20_5	PURSE	WP	6686	----	----	----

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
kh_20_6	PURSE	WP	6684	----	----	----
ld_01_1	PURSE	WP	6684	----	----	----
ld_06_1	PURSE	WP	6703	----	----	----
ld_06_2	PURSE	WP	6684	----	----	----
ld_06_3	PURSE	WP	6688	----	----	----
ld_07_1	PURSE	WP	6684	----	----	----
ld_07_2	PURSE	WP	6684	----	----	----
ld_07_3	PURSE	WP	6686	----	----	----
ld_07_4	PURSE	WP	6682	----	----	----
ld_07_5	PURSE	WP	6684	----	----	----
ld_07_6	PURSE	WP	6684	----	----	----
ld_07_7	PURSE	WP	6675	----	----	----
ld_07_8	PURSE	WP	6685	----	----	----
ld_07_9	PURSE	WP	6682	----	----	----
ld_08_1	PURSE	WP	6687	----	----	----
ld_09_1	PURSE	WP	6685	----	----	----
ld_10_1	PURSE	WP	6686	----	----	----
ld_10_2	PURSE	WP	6684	----	----	----
ld_11_1	PURSE	WP	6695	----	----	----
ld_11_2	PURSE	WP	6686	----	----	----
ld_11_3	PURSE	WP	6694	----	----	----
ld_12_1	PURSE	WP	6706	----	----	----
ld_12_2	PURSE	WP	6684	----	----	----
ld_13_1	PURSE	WP	6688	----	----	----
ld_13_2	PURSE	WP	6684	----	----	----
ld_13_3	PURSE	WP	6686	----	----	----
ld_14_1	PURSE	WP	6689	----	----	----
ld_14_2	PURSE	WP	6684	----	----	----
ld_14_3	PURSE	WP	6686	----	----	----
ld_14_4	PURSE	WP	6683	----	----	----
ld_14_5	PURSE	WP	6684	----	----	----
ld_14_6	PURSE	WP	6686	----	----	----
ld_15_1	PURSE	WP	6693	----	----	----
ld_15_2	PURSE	WP	6684	----	----	----
ld_15_3	PURSE	WP	6684	----	----	----
ld_15_4	PURSE	WP	6687	----	----	----
ld_15_5	PURSE	WP	6687	----	----	----
ld_15_6	PURSE	WP	6690	----	----	----
ld_16_1	PURSE	WP	6674	----	----	----
ld_16_2	PURSE	WP	6684	----	----	----
ld_16_3	PURSE	WP	6686	----	----	----
ld_16_4	PURSE	WP	6687	----	----	----
ld_16_5	PURSE	WP	6684	----	----	----
ld_16_6	PURSE	WP	6706	----	----	----
ld_17_1	PURSE	WP	6684	----	----	----
ld_17_2	PURSE	WP	6684	----	----	----
ld_17_3	PURSE	WP	6684	----	----	----

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
ld_17_4	PURSE	WP	6684	----	----	----
ld_17_5	PURSE	WP	6684	----	----	----
ld_17_6	PURSE	WP	6686	----	----	----
ld_18_1	PURSE	WP	6435	----	----	----
ld_18_2	PURSE	WP	6684	----	----	----
ld_18_3	PURSE	WP	6686	----	----	----
ld_18_4	PURSE	WP	6588	----	----	----
ld_18_5	PURSE	WP	6689	----	----	----
ld_18_6	PURSE	WP	6647	----	----	----
ld_19_1	PURSE	WP	23306	----	----	----
ld_19_2	PURSE	WP	6700	----	----	----
ld_19_3	PURSE	WP	6607	----	----	----
ld_19_4	PURSE	WP	6860	----	----	----
ld_19_5	PURSE	WP	6684	----	----	----
ld_19_6	PURSE	WP	6671	----	----	----
ld_20_1	PURSE	WP	6684	----	----	----
ld_20_2	PURSE	WP	6684	----	----	----
ld_20_3	PURSE	WP	6684	----	----	----
ld_20_4	PURSE	WP	6684	----	----	----
ld_20_5	PURSE	WP	6684	----	----	----
ld_20_6	PURSE	WP	6687	----	----	----
base	STRAIT	B	806	4070	11809	19211
kh_01_1	STRAIT	B	806	4072	11831	19236
kh_06_1	STRAIT	B	838	4135	12812	24498
kh_06_2	STRAIT	B	807	4073	11846	19260
kh_06_3	STRAIT	B	809	4082	11896	19021
kh_07_1	STRAIT	B	819	4103	12109	19032
kh_07_2	STRAIT	B	816	4093	12174	21888
kh_07_3	STRAIT	B	806	4071	11788	19006
kh_07_4	STRAIT	B	811	4085	11933	19021
kh_07_5	STRAIT	B	834	4137	12427	19081
kh_07_6	STRAIT	B	805	4069	11798	19192
kh_07_7	STRAIT	B	804	4068	11776	19131
kh_07_8	STRAIT	B	789	3938	10777	18887
kh_07_9	STRAIT	B	808	4078	11869	19016
kh_08_1	STRAIT	B	816	4092	12163	19409
kh_09_1	STRAIT	B	807	4076	11870	19239
kh_10_1	STRAIT	B	807	4073	11834	19259
kh_10_2	STRAIT	B	809	4081	11900	19159
kh_11_1	STRAIT	B	959	4392	14318	27853
kh_11_2	STRAIT	B	809	4080	11889	19164
kh_11_3	STRAIT	B	804	4067	11758	19113
kh_12_1	STRAIT	B	804	4068	11873	19346
kh_12_2	STRAIT	B	809	4081	11901	19183
kh_13_1	STRAIT	B	806	4074	11790	19000
kh_13_2	STRAIT	B	805	4070	11785	19010
kh_13_3	STRAIT	B	809	4081	11893	19050

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
kh_14_1	STRAIT	B	806	4071	11820	19224
kh_14_2	STRAIT	B	806	4070	11809	19211
kh_14_3	STRAIT	B	809	4079	11880	19211
kh_14_4	STRAIT	B	809	4081	11906	19168
kh_14_5	STRAIT	B	808	4077	11871	19301
kh_14_6	STRAIT	B	806	4070	11808	19182
kh_15_1	STRAIT	B	832	4129	12451	19452
kh_15_2	STRAIT	B	806	4070	11809	19211
kh_15_3	STRAIT	B	806	4070	11805	19168
kh_15_4	STRAIT	B	809	4080	11892	19184
kh_15_5	STRAIT	B	808	4079	11882	19167
kh_15_6	STRAIT	B	808	4078	11884	19217
kh_16_1	STRAIT	B	817	4096	12113	19392
kh_16_2	STRAIT	B	806	4070	11809	19211
kh_16_3	STRAIT	B	809	4080	11897	19169
kh_16_4	STRAIT	B	809	4080	11890	19184
kh_16_5	STRAIT	B	806	4070	11809	19211
kh_16_6	STRAIT	B	808	4080	11885	19153
kh_17_1	STRAIT	B	808	4079	11883	19175
kh_17_2	STRAIT	B	806	4070	11809	19211
kh_17_3	STRAIT	B	806	4070	11809	19211
kh_17_4	STRAIT	B	809	4080	11889	19189
kh_17_5	STRAIT	B	806	4070	11809	19211
kh_17_6	STRAIT	B	809	4081	11901	19178
kh_18_1	STRAIT	B	794	4046	11540	18980
kh_18_2	STRAIT	B	806	4070	11809	19211
kh_18_3	STRAIT	B	808	4079	11878	19151
kh_18_4	STRAIT	B	804	4068	11775	19141
kh_18_5	STRAIT	B	809	4080	11899	19169
kh_18_6	STRAIT	B	809	4080	11889	19166
kh_19_1	STRAIT	B	803	4061	11870	19358
kh_19_2	STRAIT	B	805	4070	11789	19162
kh_19_3	STRAIT	B	805	4070	11788	19153
kh_19_4	STRAIT	B	804	4066	11779	19270
kh_19_5	STRAIT	B	806	4070	11809	19211
kh_19_6	STRAIT	B	806	4072	11824	19256
kh_20_1	STRAIT	B	858	4193	13016	19567
kh_20_2	STRAIT	B	816	4096	12126	19392
kh_20_3	STRAIT	B	809	4079	11871	19169
kh_20_4	STRAIT	B	808	4074	11833	19322
kh_20_5	STRAIT	B	809	4081	11906	19203
kh_20_6	STRAIT	B	810	4083	11920	19044
ld_01_1	STRAIT	B	806	4072	11828	19225
ld_06_1	STRAIT	B	825	4108	12446	25258
ld_06_2	STRAIT	B	807	4074	11844	19198
ld_06_3	STRAIT	B	808	4080	11883	19095
ld_07_1	STRAIT	B	754	3844	10073	20704

* --- Particle has discharged

Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
ld_07_2	STRAIT	B	808	4075	11911	19361
ld_07_3	STRAIT	B	808	4080	11882	19128
ld_07_4	STRAIT	B	807	4076	11847	19059
ld_07_5	STRAIT	B	813	4087	11966	19132
ld_07_6	STRAIT	B	805	4069	11792	19255
ld_07_7	STRAIT	B	805	4069	11796	19175
ld_07_8	STRAIT	B	802	4064	11682	18989
ld_07_9	STRAIT	B	807	4073	11838	19204
ld_08_1	STRAIT	B	809	4076	11929	19335
ld_09_1	STRAIT	B	805	4069	11804	19292
ld_10_1	STRAIT	B	809	4080	11894	19163
ld_10_2	STRAIT	B	806	4072	11824	19265
ld_11_1	STRAIT	B	859	4192	13061	23892
ld_11_2	STRAIT	B	809	4080	11891	19172
ld_11_3	STRAIT	B	806	4071	11817	19232
ld_12_1	STRAIT	B	806	4071	11864	19326
ld_12_2	STRAIT	B	807	4073	11831	19264
ld_13_1	STRAIT	B	806	4072	11828	19266
ld_13_2	STRAIT	B	806	4071	11817	19197
ld_13_3	STRAIT	B	809	4080	11887	19145
ld_14_1	STRAIT	B	807	4074	11855	19296
ld_14_2	STRAIT	B	807	4074	11840	19194
ld_14_3	STRAIT	B	809	4080	11892	19181
ld_14_4	STRAIT	B	806	4070	11805	19246
ld_14_5	STRAIT	B	807	4073	11837	19233
ld_14_6	STRAIT	B	806	4072	11832	19229
ld_15_1	STRAIT	B	825	4114	12291	19420
ld_15_2	STRAIT	B	807	4074	11840	19194
ld_15_3	STRAIT	B	809	4079	11877	19201
ld_15_4	STRAIT	B	810	4083	11927	19178
ld_15_5	STRAIT	B	809	4080	11895	19188
ld_15_6	STRAIT	B	807	4072	11835	19209
ld_16_1	STRAIT	B	809	4077	11922	19349
ld_16_2	STRAIT	B	807	4074	11840	19194
ld_16_3	STRAIT	B	808	4079	11879	19158
ld_16_4	STRAIT	B	809	4080	11893	19186
ld_16_5	STRAIT	B	807	4074	11840	19194
ld_16_6	STRAIT	B	808	4080	11886	19161
ld_17_1	STRAIT	B	806	4072	11824	19176
ld_17_2	STRAIT	B	807	4074	11840	19194
ld_17_3	STRAIT	B	807	4074	11840	19194
ld_17_4	STRAIT	B	809	4079	11880	19208
ld_17_5	STRAIT	B	807	4074	11840	19194
ld_17_6	STRAIT	B	809	4080	11890	19177
ld_18_1	STRAIT	B	799	4054	11637	19138
ld_18_2	STRAIT	B	807	4074	11840	19194
ld_18_3	STRAIT	B	807	4073	11835	19233

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
ld_18_4	STRAIT	B	805	4069	11794	19187
ld_18_5	STRAIT	B	809	4080	11896	19170
ld_18_6	STRAIT	B	809	4080	11891	19178
ld_19_1	STRAIT	B	807	4067	12068	24518
ld_19_2	STRAIT	B	805	4070	11802	19136
ld_19_3	STRAIT	B	806	4070	11805	19194
ld_19_4	STRAIT	B	806	4070	11837	19333
ld_19_5	STRAIT	B	807	4074	11840	19194
ld_19_6	STRAIT	B	808	4077	11860	19155
ld_20_1	STRAIT	B	832	4132	12455	19446
ld_20_2	STRAIT	B	809	4081	11901	19151
ld_20_3	STRAIT	B	807	4073	11833	19179
ld_20_4	STRAIT	B	808	4075	11841	19318
ld_20_5	STRAIT	B	806	4072	11831	19257
ld_20_6	STRAIT	B	809	4081	11902	19120
base	TYBO	WP	----	----	----	----
kh_01_1	TYBO	WP	----	----	----	----
kh_06_1	TYBO	WP	----	----	----	----
kh_06_2	TYBO	WP	----	----	----	----
kh_06_3	TYBO	WP	----	----	----	----
kh_07_1	TYBO	WP	----	----	----	----
kh_07_2	TYBO	WP	----	----	----	----
kh_07_3	TYBO	WP	----	----	----	----
kh_07_4	TYBO	WP	----	----	----	----
kh_07_5	TYBO	WP	----	----	----	----
kh_07_6	TYBO	WP	----	----	----	----
kh_07_7	TYBO	WP	----	----	----	----
kh_07_8	TYBO	WP	----	----	----	----
kh_07_9	TYBO	WP	----	----	----	----
kh_08_1	TYBO	WP	----	----	----	----
kh_09_1	TYBO	WP	----	----	----	----
kh_10_1	TYBO	WP	----	----	----	----
kh_10_2	TYBO	WP	----	----	----	----
kh_11_1	TYBO	WP	----	----	----	----
kh_11_2	TYBO	WP	----	----	----	----
kh_11_3	TYBO	WP	----	----	----	----
kh_12_1	TYBO	WP	----	----	----	----
kh_12_2	TYBO	WP	----	----	----	----
kh_13_1	TYBO	WP	----	----	----	----
kh_13_2	TYBO	WP	----	----	----	----
kh_13_3	TYBO	WP	----	----	----	----
kh_14_1	TYBO	WP	----	----	----	----
kh_14_2	TYBO	WP	----	----	----	----
kh_14_3	TYBO	WP	----	----	----	----
kh_14_4	TYBO	WP	----	----	----	----
kh_14_5	TYBO	WP	----	----	----	----
kh_14_6	TYBO	WP	----	----	----	----

* ---- Particle has discharged

Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).

Parameter	Test Name	Starting Location	Distance Traveled (meters)			
			25 years	50 years	100 years	200 years
kh_15_1	TYBO	WP	----	----	----	----
kh_15_2	TYBO	WP	----	----	----	----
kh_15_3	TYBO	WP	----	----	----	----
kh_15_4	TYBO	WP	----	----	----	----
kh_15_5	TYBO	WP	----	----	----	----
kh_15_6	TYBO	WP	----	----	----	----
kh_16_1	TYBO	WP	----	----	----	----
kh_16_2	TYBO	WP	----	----	----	----
kh_16_3	TYBO	WP	----	----	----	----
kh_16_4	TYBO	WP	----	----	----	----
kh_16_5	TYBO	WP	----	----	----	----
kh_16_6	TYBO	WP	----	----	----	----
kh_17_1	TYBO	WP	----	----	----	----
kh_17_2	TYBO	WP	----	----	----	----
kh_17_3	TYBO	WP	----	----	----	----
kh_17_4	TYBO	WP	----	----	----	----
kh_17_5	TYBO	WP	----	----	----	----
kh_17_6	TYBO	WP	----	----	----	----
kh_18_1	TYBO	WP	----	----	----	----
kh_18_2	TYBO	WP	----	----	----	----
kh_18_3	TYBO	WP	----	----	----	----
kh_18_4	TYBO	WP	----	----	----	----
kh_18_5	TYBO	WP	----	----	----	----
kh_18_6	TYBO	WP	----	----	----	----
kh_19_1	TYBO	WP	----	----	----	----
kh_19_2	TYBO	WP	----	----	----	----
kh_19_3	TYBO	WP	----	----	----	----
kh_19_4	TYBO	WP	----	----	----	----
kh_19_5	TYBO	WP	----	----	----	----
kh_19_6	TYBO	WP	----	----	----	----
kh_20_1	TYBO	WP	----	----	----	----
kh_20_2	TYBO	WP	----	----	----	----
kh_20_3	TYBO	WP	----	----	----	----
kh_20_4	TYBO	WP	----	----	----	----
kh_20_5	TYBO	WP	----	----	----	----
kh_20_6	TYBO	WP	----	----	----	----
ld_01_1	TYBO	WP	----	----	----	----
ld_06_1	TYBO	WP	----	----	----	----
ld_06_2	TYBO	WP	----	----	----	----
ld_06_3	TYBO	WP	----	----	----	----
ld_07_1	TYBO	WP	----	----	----	----
ld_07_2	TYBO	WP	----	----	----	----
ld_07_3	TYBO	WP	----	----	----	----
ld_07_4	TYBO	WP	----	----	----	----
ld_07_5	TYBO	WP	----	----	----	----
ld_07_6	TYBO	WP	----	----	----	----
ld_07_7	TYBO	WP	----	----	----	----

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	<i>Distance Traveled (meters)</i>			
			25 years	50 years	100 years	200 years
ld_07_8	TYBO	WP	----	----	----	----
ld_07_9	TYBO	WP	----	----	----	----
ld_08_1	TYBO	WP	----	----	----	----
ld_09_1	TYBO	WP	----	----	----	----
ld_10_1	TYBO	WP	----	----	----	----
ld_10_2	TYBO	WP	----	----	----	----
ld_11_1	TYBO	WP	----	----	----	----
ld_11_2	TYBO	WP	----	----	----	----
ld_11_3	TYBO	WP	----	----	----	----
ld_12_1	TYBO	WP	----	----	----	----
ld_12_2	TYBO	WP	----	----	----	----
ld_13_1	TYBO	WP	----	----	----	----
ld_13_2	TYBO	WP	----	----	----	----
ld_13_3	TYBO	WP	----	----	----	----
ld_14_1	TYBO	WP	----	----	----	----
ld_14_2	TYBO	WP	----	----	----	----
ld_14_3	TYBO	WP	----	----	----	----
ld_14_4	TYBO	WP	----	----	----	----
ld_14_5	TYBO	WP	----	----	----	----
ld_14_6	TYBO	WP	----	----	----	----
ld_15_1	TYBO	WP	----	----	----	----
ld_15_2	TYBO	WP	----	----	----	----
ld_15_3	TYBO	WP	----	----	----	----
ld_15_4	TYBO	WP	----	----	----	----
ld_15_5	TYBO	WP	----	----	----	----
ld_15_6	TYBO	WP	----	----	----	----
ld_16_1	TYBO	WP	----	----	----	----
ld_16_2	TYBO	WP	----	----	----	----
ld_16_3	TYBO	WP	----	----	----	----
ld_16_4	TYBO	WP	----	----	----	----
ld_16_5	TYBO	WP	----	----	----	----
ld_16_6	TYBO	WP	----	----	----	----
ld_17_1	TYBO	WP	----	----	----	----
ld_17_2	TYBO	WP	----	----	----	----
ld_17_3	TYBO	WP	----	----	----	----
ld_17_4	TYBO	WP	----	----	----	----
ld_17_5	TYBO	WP	----	----	----	----
ld_17_6	TYBO	WP	----	----	----	----
ld_18_1	TYBO	WP	----	----	----	----
ld_18_2	TYBO	WP	----	----	----	----
ld_18_3	TYBO	WP	----	----	----	----
ld_18_4	TYBO	WP	----	----	----	----
ld_18_5	TYBO	WP	----	----	----	----
ld_18_6	TYBO	WP	----	----	----	----
ld_19_1	TYBO	WP	----	----	----	----
ld_19_2	TYBO	WP	----	----	----	----
ld_19_3	TYBO	WP	----	----	----	----

* ---- Particle has discharged

**Table I-1. Travel Distances for Sensitivity Runs
(100% Increase in K_h ; 10% Decrease in Λ).**

Parameter	Test Name	Starting Location	<i>Distance Traveled (meters)</i>			
			25 years	50 years	100 years	200 years
Id_19_4	TYBO	WP	----	----	----	----
Id_19_5	TYBO	WP	----	----	----	----
Id_19_6	TYBO	WP	----	----	----	----
Id_20_1	TYBO	WP	----	----	----	----
Id_20_2	TYBO	WP	----	----	----	----
Id_20_3	TYBO	WP	----	----	----	----
Id_20_4	TYBO	WP	----	----	----	----
Id_20_5	TYBO	WP	----	----	----	----
Id_20_6	TYBO	WP	----	----	----	----

* ---- Particle has discharged

Plates

1222

Calibrated Water-Table
Contours

1044

Target Head

Contour Interval =50 Meters

N

Model
Outline
Boundary

0 15 30
Kilometers

Plate 1
Location of Active Model Grid

Calibrated Water-Table
Contours

1.2

 Weighted Residual

Contour Interval =50 Meters

Model
Outline
Boundary

Plate 2
**Elevation of the Simulated Water
Table for the Calibrated Model**

Plate 4
Elevation of the Simulated Water Table for the Calibrated Model (Episode 2)

Plate 5
Elevation of the Simulated Water Table for the Calibrated Model (Episode 3)