

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT  
SPECIAL INSTRUCTION SHEET

1. QA: QA

Page: 1 of: 1

Complete Only Applicable Items

This is a placeholder page for records that cannot be scanned or microfilmed

2. Record Date  
02/05/2001

3. Accession Number

MOL. 20010221. 0160

4. Author Name(s)  
MICHAEL T. ITAMURA

5. Author Organization  
N/A

6. Title  
ABSTRACTION OF NFE DRIFT THERMODYNAMIC ENVIRONMENT AND PERCOLATION FLUX

7. Document Number(s)  
ANL-EBS-HS-000003

8. Version  
REV 00/ICN 02

9. Document Type  
REPORT

10. Medium  
OPTIC/PAPER

11. Access Control Code  
PUB

12. Traceability Designator  
DC # 26877

13. Comments  
THIS IS A ONE-OF-A-KIND DOCUMENT DUE TO THE COLORED GRAPHS ENCLOSED AND CAN BE LOCATED THROUGH THE RPC

*Handwritten:*  
R. J. ...  
NMS07  
WM-11

**OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT**  
**ANALYSIS/MODEL COVER SHEET**  
**Complete Only Applicable Items**

1. QA: QA  
Page: 1 of 117

<p>2. <input checked="" type="checkbox"/> <b>Analysis</b>      Check all that apply</p> <table border="1" style="width:100%; border-collapse: collapse;"> <tr> <td style="width:20%;">Type of Analysis</td> <td> <input type="checkbox"/> Engineering  <input checked="" type="checkbox"/> Performance Assessment  <input type="checkbox"/> Scientific </td> </tr> <tr> <td>Intended Use of Analysis</td> <td> <input type="checkbox"/> Input to Calculation  <input checked="" type="checkbox"/> Input to another Analysis or Model  <input checked="" type="checkbox"/> Input to Technical Document  <input checked="" type="checkbox"/> Input to other Technical Products </td> </tr> </table> <p>Describe use: Abstraction of in-drift thermodynamic environment such as temperature and relative humidity and percolation flux in the near-field host rock.</p>	Type of Analysis	<input type="checkbox"/> Engineering <input checked="" type="checkbox"/> Performance Assessment <input type="checkbox"/> Scientific	Intended Use of Analysis	<input type="checkbox"/> Input to Calculation <input checked="" type="checkbox"/> Input to another Analysis or Model <input checked="" type="checkbox"/> Input to Technical Document <input checked="" type="checkbox"/> Input to other Technical Products	<p>3. <input type="checkbox"/> <b>Model</b>      Check all that apply</p> <table border="1" style="width:100%; border-collapse: collapse;"> <tr> <td style="width:20%;">Type of Model</td> <td> <input type="checkbox"/> Conceptual Model      <input type="checkbox"/> Abstraction Model  <input type="checkbox"/> Mathematical Model      <input type="checkbox"/> System Model  <input type="checkbox"/> Process Model </td> </tr> <tr> <td>Intended Use of Model</td> <td> <input type="checkbox"/> Input to Calculation  <input type="checkbox"/> Input to another Model or Analysis  <input type="checkbox"/> Input to Technical Document  <input type="checkbox"/> Input to other Technical Products </td> </tr> </table> <p>Describe use:</p>	Type of Model	<input type="checkbox"/> Conceptual Model <input type="checkbox"/> Abstraction Model <input type="checkbox"/> Mathematical Model <input type="checkbox"/> System Model <input type="checkbox"/> Process Model	Intended Use of Model	<input type="checkbox"/> Input to Calculation <input type="checkbox"/> Input to another Model or Analysis <input type="checkbox"/> Input to Technical Document <input type="checkbox"/> Input to other Technical Products
Type of Analysis	<input type="checkbox"/> Engineering <input checked="" type="checkbox"/> Performance Assessment <input type="checkbox"/> Scientific								
Intended Use of Analysis	<input type="checkbox"/> Input to Calculation <input checked="" type="checkbox"/> Input to another Analysis or Model <input checked="" type="checkbox"/> Input to Technical Document <input checked="" type="checkbox"/> Input to other Technical Products								
Type of Model	<input type="checkbox"/> Conceptual Model <input type="checkbox"/> Abstraction Model <input type="checkbox"/> Mathematical Model <input type="checkbox"/> System Model <input type="checkbox"/> Process Model								
Intended Use of Model	<input type="checkbox"/> Input to Calculation <input type="checkbox"/> Input to another Model or Analysis <input type="checkbox"/> Input to Technical Document <input type="checkbox"/> Input to other Technical Products								

## 4. Title:

Abstraction of NFE Drift Thermodynamic Environment and Percolation Flux

## 5. Document Identifier (including Rev. No. and Change No., if applicable):

ANL-EBS-HS-000003 Rev 00, ICN 02

## 6. Total Attachments:

8

## 7. Attachment Numbers - No. of Pages in Each:

Attachment I – 45, Attachment II – 12, Attachment III – 15,  
Attachment IV – 91, Attachment V – 10, Attachment VI – 13,  
Attachment VII – 10, Attachment VIII – 30

	Printed Name	Signature	Date
8. Originators	Michael T. Itamura	<i>Michael T. Itamura</i>	12/18/00
	Nicholas D. Francis	<i>Nicholas D. Francis</i>	12/18/00
9. Checker	Junghun Leem	<i>Junghun Leem</i>	12/19/00
10. Lead/Supervisor	Nicholas D. Francis	<i>Nicholas D. Francis</i>	1/4/01
11. Responsible Manager	Clifford K. Ho	<i>Clifford K. Ho</i>	1/5/01

## 12. Remarks:

Nicholas Francis is responsible for sections 1 through 5, section 6.1, 6.3.10, 6.3.11, 6.3.12, portions of 6.4.8, section 6.5, section 7, section 8, Attachments I, IV, V, VIII.

Michael T. Itamura is responsible for portions of section 6.2, section 6.3, section 6.4, and Attachments II, III, VI, VII.

Michael L. Wilson also contributed to this analysis (section 6.2).

**OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT**  
**ANALYSIS/MODEL REVISION RECORD**  
*Complete Only Applicable Items*

1. Page: 2 of: 117

2. Analysis or Model Title:

Abstraction of NFE Drift Thermodynamic Environment and Percolation Flux

3. Document Identifier (including Rev. No. and Change No., if applicable):

ANL-EBS-HS-000003 Rev 00, ICN 02

4. Revision/Change No.

5. Description of Revision/Change

Rev00

Backfill TH Abstraction Only

Rev 00, ICN 01

TH abstraction of the No Backfill Repository Design along with the abstraction of the backfill design.

Rev 00, ICN 02

TH abstraction of percolation flux for the post-10k-year climates for TSPA. Abstraction is for No Backfill Repository Design only. Also added clarification to the primary abstraction routines described in Attachments I and IV.

# CONTENTS

	PAGE
1. PURPOSE.....	13
2. QUALITY ASSURANCE.....	15
3. COMPUTER SOFTWARE AND MODEL USAGE.....	16
4. INPUTS .....	17
4.1 DATA AND PARAMETERS .....	18
4.2 CRITERIA .....	18
4.3 CODES AND STANDARDS.....	18
5. ASSUMPTIONS.....	19
5.1 TH ABSTRACTION .....	19
5.1.1 Infiltration Rate Bin Ranges .....	19
5.1.2 Infiltration Rate Bin Basis .....	20
5.1.3 Conversion Assumptions.....	20
5.1.4 Drip Shield Evaporation Rate (without backfill).....	20
6. ANALYSIS.....	21
6.1 TH ABSTRACTION ROUTINE.....	21
6.2 INFILTRATION RATE BINNING.....	39
6.3 TH ABSTRACTION RESULTS FOR THE NO BACKFILL (BASE CASE) REPOSITORY DESIGN .....	49
6.3.1 CSNF Temperature Profiles .....	50
6.3.2 CSNF and HLW Waste Package Bin Temperature Comparison .....	56
6.3.3 CSNF and HLW Waste Package Bin Relative Humidity Comparison .....	58
6.3.4 Comparison of Waste Package 3-10 mm/year Bin Averaged Temperatures and Relative Humidity for All Infiltration Flux Cases for the TSPA-SR Base Case.....	60
6.3.5 Temperature at the Top of the Drip Shield.....	64
6.3.6 Invert Thermodynamic Variables.....	64
6.3.7 Drift Wall Temperatures.....	68
6.3.8 CSNF Percolation Flux 5 Meters Above Drift.....	70
6.3.9 Pillar Temperatures in Repository.....	71
6.3.10 Drip Shield Evaporation Rate.....	73
6.3.11 Average TH Abstraction Uncertainty.....	76
6.3.12 Post-10k-Year Climates for TSPA .....	83
6.4 TH ABSTRACTION RESULTS FOR THE BACKFILLED REPOSITORY (ALTERNATIVE) DESIGN.....	84
6.4.1 CSNF Temperature Profiles .....	84
6.4.2 CSNF and HLW Waste Package Bin Temperature Comparison .....	91
6.4.3 CSNF and HLW Waste Package Bin Relative Humidity Comparison .....	93



6.4.4	Comparison of Waste Package 3-10 mm/year Bin Averaged Temperatures and Relative Humidity for All Infiltration Flux Cases .....	95
6.4.5	Temperature at the Top of the Drip Shield.....	99
6.4.6	Invert Thermodynamic Variables .....	99
6.4.7	Drift Wall Temperatures.....	103
6.4.8	CSNF Percolation Flux 5 Meters Above Drift .....	105
6.4.9	Pillar Temperatures in Repository.....	107
6.5	ANALYSIS CONFIDENCE FOR INTENDED USE .....	110
7.	CONCLUSIONS .....	111
8.	INPUTS AND REFERENCES.....	114
8.1	REFERENCES CITED.....	114
8.2	DATA INPUT, LISTED BY DATA TRACKING NUMBER.....	115
8.3	DATA OUTPUT, LISTED BY DATA TRACKING NUMBER.....	115
8.4	SOFTWARE ROUTINES .....	116
8.5	PROCEDURES .....	116
9.	ATTACHMENTS.....	117

## FIGURES

	Page
Figure 1 Percolation Flux for a TSPA Reduced Number of Time Points Based on a 2% ROC Temperature Control (with backfill results) .....	26
Figure 2 Percolation Flux for a TSPA Reduced Number of Time Points Based on a 2% ROC Percolation Flux Control (with backfill results) .....	27
Figure 3 Waste Package Surface Temperature for a TSPA Reduced Number of Time Points Based on a 2% ROC Percolation Flux Control (with backfill results) .....	28
Figure 4 Percolation Flux for a TSPA Reduced Number of Time Points Based on a 2% ROC Percolation Flux and Temperature Control (with backfill results) .....	29
Figure 5 Waste Package Surface Temperature for a TSPA Reduced Number of Time Points Based on a 2% ROC Percolation Flux and Temperature Control (with backfill results) .....	30
Figure 6 Waste Package Surface Temperature for a TSPA Reduced Number of Time Points Based on a 3% ROC Percolation Flux and Temperature Control (with backfill results) .....	31
Figure 7 Waste Package Relative Humidity for a TSPA Reduced Number of Time Points Based on a 3% ROC Percolation Flux and Temperature Control (with backfill results) .....	31
Figure 8 Invert Liquid Saturation for a TSPA Reduced Number of Time Points Based on a 3% ROC Percolation Flux and Temperature Control (with backfill results) .....	32
Figure 9 Air Mass Fraction for a TSPA Reduced Number of Time Points Based on a 3% ROC Percolation Flux and Temperature Control (with backfill results) .....	32
Figure 10 Water Vapor Flux for a TSPA Reduced Number of Time Points Based on a 3% ROC Percolation Flux and Temperature Control (with backfill results) .....	33
Figure 11 Drip Shield Evaporation Rate for a TSPA Reduced Number of Time Points Based on a 3% ROC Percolation Flux and Temperature Control (with backfill results) .....	33
Figure 12 Percolation Flux for a TSPA Reduced Number of Time Points Based on a 3% ROC Percolation Flux and Temperature Control (with backfill results) .....	34
Figure 13 Average Percolation Flux for a TSPA Reduced Number of Time Points Based on a 3% ROC (with backfill results) .....	35

## FIGURES (Continued)

	Page
Figure 14 Average Invert Evaporation Rate for a TSPA Reduced Number of Time Points Based on a 3% ROC (with backfill results) .....	36
Figure 15 Average Invert Liquid Saturation for a TSPA Reduced Number of Time Points Based on a 3% ROC (with backfill results) .....	36
Figure 16 Maximum Waste Package Surface Temperature for a TSPA Reduced Number of Time Points Based on a 3% ROC (with backfill results).....	37
Figure 17 Average Invert Relative Humidity for a TSPA Reduced Number of Time Points Based on a 3% ROC (with backfill results) .....	37
Figure 18 The Location of All of the Waste Packages in the Different Infiltration Bins for the Low Glacial Infiltration Map for TSPA-SR Base Case .....	40
Figure 19 The Location of All of the Waste Packages in the Different Infiltration Bins for the Mean Glacial Infiltration Map for TSPA-SR Base Case .....	41
Figure 20 The Location of All of the Waste Packages in the Different Infiltration Bins for the High Glacial Infiltration Map for TSPA-SR Base Case .....	41
Figure 21 Variability of Infiltration Rates Throughout the Repository for the Low Present Day Infiltration Map for TSPA-SR Base Case .....	44
Figure 22 Variability of Infiltration Rates Throughout the Repository for the Mean Present Day Infiltration Map for TSPA-SR Base Case .....	45
Figure 23 Variability of Infiltration Rates Throughout the Repository for the High Present Day Infiltration Map for TSPA-SR Base Case .....	46
Figure 24 The Location of All of the Waste Packages in the Different Infiltration Bins for the Low Glacial Infiltration Map Backfill Design Alternative .....	47
Figure 25 The Location of All of the Waste Packages in the Different Infiltration Bins for the Mean Glacial Infiltration Map Backfill Design Alternative .....	48
Figure 26 The Location of All of the Waste Packages in the Different Infiltration Bins for the High Glacial Infiltration Map Backfill Design Alternative.....	48
Figure 27 The Peak Waste Package Temperatures for All 610 Waste Package Locations for the Low Infiltration Flux TSPA-SR Base Case .....	51
Figure 28 The Peak Waste Package Temperatures for All 610 Waste Package Locations for the Mean Infiltration Flux TSPA-SR Base Case .....	52

## FIGURES (Continued)

	Page
Figure 29 The Peak Waste Package Temperatures for All 610 Waste Package Locations for the High Infiltration Flux TSPA-SR Base Case.....	52
Figure 30 The CSNF Waste Package Temperature Time Histories That Had the Lowest and Highest Peak Temperature in Each Mean Infiltration Flux Bin for the TSPA-SR Base Case .....	54
Figure 31 The Difference Between the Temperature Time Histories That Had the Highest and Lowest Peak Temperature in Each of the Infiltration Bins for the Mean Infiltration Flux Case for the TSPA-SR Base Case .....	54
Figure 32 The 170 CSNF Waste Package Temperature-Time Histories in the 10-20 mm/year Mean Infiltration Flux Bin for the TSPA-SR Base Case .....	55
Figure 33 The Average CSNF Waste Package Temperatures for the Mean Infiltration Rate Map Bins for the TSPA-SR Base Case Design.....	56
Figure 34 The Average Waste Package Temperatures for Both the CSNF and HLW in Each of the Infiltration Bins for the Mean Infiltration Flux TSPA-SR Base Case .....	57
Figure 35 The Temperature Difference Between the Average CSNF and HLW Waste Package Bin Temperatures for the Mean Infiltration Map and TSPA-SR Base Case.....	58
Figure 36 The Average Waste Package Relative Humidity for Both the CSNF and HLW in Each of the Infiltration Bins for the Mean Infiltration Flux Map and TSPA-SR Base Case .....	59
Figure 37 The Difference in Relative Humidity Between the Average CSNF and HLW Waste Package Bin Temperatures for the Mean Infiltration Maps and TSPA-SR Base Case .....	59
Figure 38 The 3-10 mm/year Infiltration Rate Average Bin Results for Waste Package and Drip Shield Temperatures for All Three Infiltration Flux Maps for the TSPA-SR Base Case .....	60
Figure 39 The 3-10 mm/year Infiltration Rate Bin Results for Waste Package and Drip Shield Relative Humidities for All Three Infiltration Flux Maps and TSPA-SR Base Case .....	61
Figure 40 The Difference Between the Mean-Low and Mean-High Infiltration Flux Case Waste Package and Drip Shield Temperatures in the 3-10 mm/year Infiltration Rate Bin and for TSPA-SR Base Case.....	62

## FIGURES (Continued)

	Page
Figure 41 The Difference Between the Mean-Low and Mean-High Infiltration Flux Waste Package and Drip Shield Relative Humidities in the 3-10 mm/year Infiltration Rate Bin and for the TSPA-SR Base Case.....	63
Figure 42 The Bin Averaged Temperatures at the Top of the Drip Shield Near CSNF Waste Packages for the Mean Infiltration Rate Map for the TSPA-SR Base Case .....	64
Figure 43 The Bin Averaged Invert Temperatures Near CSNF Waste Packages for the Mean Infiltration Rate Map for the TSPA-SR Base Case.....	65
Figure 44 The Averaged CSNF Invert Relative Humidity for the Mean Infiltration Map for the TSPA-SR Base Case .....	65
Figure 45 The Bin Averaged Evaporation Rate in the Invert Near a CSNF for the Mean Infiltration Map and TSPA-SR Base Case.....	66
Figure 46 The Bin Averaged CSNF Invert Saturations for the Mean Infiltration Map for the TSPA-SR Base Case .....	67
Figure 47 Average Percolation Flux in the Invert for a CSNF Waste Package for the Mean Infiltration Map and the TSPA-SR Base Case.....	68
Figure 48 Bin Averaged Drift Wall Temperatures Adjacent to the CSNF and HLW Waste Packages for the Mean Infiltration and TSPA-SR Base Case.....	69
Figure 49 The Difference Between the Bin Averaged Drift Wall Temperatures Adjacent to the CSNF and HLW Waste Packages for the Mean Infiltration and TSPA-SR Base Case .....	69
Figure 50 The Bin Averaged CSNF Percolation Fluxes 5 m Above the Top of the Crown for the Mean Infiltration Map for the TSPA-SR Base Case .....	70
Figure 51 Maximum Temperatures at 15.14 Meters from the Drift Centerline for the Low Infiltration Flux TSPA-SR Base Case .....	71
Figure 52 Maximum Temperatures at 22.64 Meters from the Drift Centerline for the Low Infiltration Flux TSPA-SR Base Case .....	72
Figure 53 Average CSNF Drip Shield Evaporation Rate for the No Backfill Repository Design .....	75
Figure 54 Average HLW Drip Shield Evaporation Rate for the No Backfill Repository Design .....	76

## FIGURES (Continued)

	Page
Figure 55 Average CSNF Waste Package Temperature Uncertainty Range in TSPA-SR .....	78
Figure 56 Average CSNF Waste Package Relative Humidity Uncertainty Range in TSPA-SR.....	79
Figure 57 Average CSNF Near-Field Host Rock Percolation Flux Uncertainty Range in TSPA-SR .....	80
Figure 58 Average HLW Waste Package Temperature Uncertainty Range in TSPA-SR .....	81
Figure 59 Average HLW Waste Package Relative Humidity Uncertainty Range in TSPA-SR.....	82
Figure 60 Average HLW Near-Field Host Rock Percolation Flux Uncertainty Range in TSPA-SR .....	83
Figure 61 The Peak Waste Package Temperatures for All 623 Waste Package Locations for the Low Infiltration Flux Backfill Design Alternative Case .....	86
Figure 62 The Peak Waste Package Temperatures for All 623 Waste Package Locations for the Mean Infiltration Flux Backfill Design Alternative Case .....	87
Figure 63 The Peak Waste Package Temperatures for All 623 Waste Package Locations for the High Infiltration Flux Backfill Design Alternative Case .....	88
Figure 64 The Ten Waste Package Temperature Time Histories That Had the Lowest and Highest Peak Temperature in Each Mean Infiltration Flux Bin for the Backfill Design Alternative Case.....	90
Figure 65 The Difference Between the Temperature Time Histories That Had the Highest and Lowest Peak Temperature in Each of the Infiltration Bins for the Mean Infiltration Flux Case and Backfill Design Alternative .....	90
Figure 66 The Average CSNF Waste Package Temperatures for the Mean Infiltration Rate Map Bins for the Backfill Design Alternative .....	91
Figure 67 The Average Waste Package Temperatures for Both the CSNF and HLW in Each of the Infiltration Bins for the Mean Infiltration Rate Map and Backfill Design Alternative.....	92

## FIGURES (Continued)

	Page
Figure 68 The Temperature Difference Between the Average CSNF and HLW Waste Package Bin Temperatures for the Mean Infiltration Maps and Backfill Design Alternative.....	93
Figure 69 The Average Waste Package Relative Humidity for Both the CSNF and HLW in Each of the Infiltration Bins for the Mean Infiltration Rate Map and Backfill Design Alternative .....	94
Figure 70 The Difference in Relative Humidity Between the Average CSNF and HLW Waste Package Bin Temperatures for the Mean Infiltration Maps and Backfill Design Alternative .....	94
Figure 71 The 3-10 mm/year Infiltration Rate Bin Results for Waste Package and Drip Shield Temperatures for All Three Infiltration Flux Maps and for the Backfill Design Alternative .....	95
Figure 72 The 3-10 mm/year Infiltration Rate Bin Results for Waste Package and Drip Shield Relative Humidities for All Three Infiltration Flux Maps and for the Backfill Design Alternative .....	96
Figure 73 The Difference Between the Mean-Low and Mean-High Infiltration Flux Case Waste Package and Drip Shield Temperatures in the 3-10 mm/year Infiltration Rate Bin and for the Backfill Design Alternative .....	97
Figure 74 The Difference Between the Mean-Low and Mean-High Infiltration Flux Waste Package and Drip Shield Relative Humidities in the 3-10 mm/year Infiltration Rate Bin for the Backfill Design Alternative.....	98
Figure 75 The Bin Averaged Temperatures at the Top of the Drip Shield Near CSNF Waste Packages for the Mean Infiltration Rate Map and for the Backfill Design Alternative.....	99
Figure 76 The Bin Averaged Invert Temperatures Near CSNF Waste Packages for the Mean Infiltration Rate Map and for the Backfill Design Alternative .....	100
Figure 77 The Averaged CSNF Invert Relative Humidity for the Mean Infiltration Map for the Backfill Design Alternative.....	100
Figure 78 The Bin Averaged Evaporation Rate in the Invert Near a CSNF for the Mean Infiltration Map and the Backfill Design Alternative .....	101

## FIGURES (Continued)

	Page
Figure 79 The Bin Averaged CSNF Invert Saturations for the Mean Infiltration Map for the Backfill Design Alternative .....	102
Figure 80 Average Percolation Flux in the Invert for a CSNF Waste Package for the Mean Infiltration Map and the Backfill Design Alternative .....	103
Figure 81 Bin Averaged Drift Wall Temperatures Adjacent to the CSNF and HLW Waste Packages for the Mean Infiltration and Backfill Design Alternative .....	104
Figure 82 The Difference Between the Bin Averaged Drift Wall Temperatures Adjacent to the CSNF and HLW Waste Packages for the Mean Infiltration Backfill Design Alternative.....	104
Figure 83 The Bin Averaged CSNF Percolation Fluxes 5 m Above the Top of the Crown for the Mean Infiltration Map for the Backfill Design Alternative.....	105
Figure 84 Overall Change in Percolation Flux as a Function of Changes in Temperature at 5 m Above the Emplacement Drift Crown .....	106
Figure 85 Maximum Temperatures at 15.14 Meters from the Drift Centerline for the Low Infiltration Flux Case for the Backfill Design Alternative.....	108
Figure 86 Maximum Temperatures at 22.64 Meters from the Drift Centerline for the Low Infiltration Flux Case and Backfill Design Alternative .....	109
Figure V-1 Testing the Interpolation Performed for the Average CSNF Evaporation Rate .....	V-10
Figure V-2 Testing the Interpolation Performed for the Average HLW Evaporation Rate .....	V-10



## TABLES

	Page
Table 1    Software Routine Usage.....	16
Table 2    Analysis Inputs.....	17
Table 3    TSPA Inputs Directly from Multiscale TH Model Data.....	23
Table 4    Average and Raw <sup>a</sup> Quantities used in the TSPA Model.....	24
Table 5    Distribution of Process-Level Model Results within Infiltration Bins for the TSPA-SR Base Case.....	42
Table 6    Distribution of Process-Level Model Results within Infiltration Bins for the TSPA-SR Backfill Design Alternative .....	49
Table 7    The Minimum, Mean, and Maximum of the Peak CSNF and HLW Waste Package Temperatures(°C) for All Bins for the Three Infiltration Flux Cases for the TSPA-SR Base Case .....	50
Table 8    The Difference Between the Highest and the Lowest Maximum Temperature (°C) in Each Bin for Each Infiltration Flux as well as the Overall Temperature Difference for Each Infiltration Flux TSPA-SR Base Case.....	53
Table 9    The Minimum, Mean, and Maximum of the Peak CSNF and HLW Waste Package Temperatures (°C) for All Bins for the Three Infiltration Flux Backfill Design Alternative Cases .....	85
Table 10   The Difference Between the Highest and the Lowest Maximum Temperature (°C) in Each Bin for Each Infiltration Flux as well as the Overall Temperature Difference for Each Infiltration Flux and for the Backfill Design Alternative Case.....	89
Table 11   List of Attachments.....	117

## 1. PURPOSE

The purpose of this analysis and model report (AMR) is to provide abstraction of the process-level thermal hydrology (TH) model that characterizes the in-drift thermodynamic environment. Specifically, this AMR details the abstraction of the multiscale TH model described in CRWMS M&O 2000a Sections 6.1 through 6.6 (or CRWMS M&O 2000d Sections 6.1 through 6.6). The multiscale TH model describes how repository heating effects the engineered barrier system (EBS) as well as the near-field environment (NFE) host rock. Subsequently, it provides a description of the how the temperature changes in the engineered materials and host rock, the magnitude and direction of liquid and gas phase flows (in the EBS and NFE), and how corrosive the emplacement drift environment is (e.g., by providing an estimate of the temporal variability of the relative humidity (RH) near the drip shield and waste package). The abstraction characterized by this AMR provides a simplified view of the process-level description and the data that is fed into the total system performance assessment (TSPA) model. The TSPA TH data feed will require development of appropriately averaged quantities of temperature, liquid saturation, relative humidity, evaporation rate, and percolation flux. It will also require converting certain raw values (from the process-level model) into other physical quantities: a simple example is changing the liquid water velocity (in mm/yr) in the invert to a volume flow rate ( $\text{m}^3/\text{yr}$ ) in the invert by multiplying the velocity by the appropriate flow area. In addition, the maximum and minimum temperature waste packages will be identified. Finally, the process-level model "raw" output will be rewritten into a format that is readily input into the TSPA model. It is noted that the abstraction of TH data must be able to characterize the potential variability and uncertainty in the thermal hydrologic system. Therefore, the abstraction AMR will provide not only a qualitative and quantitative description of the potential TH variability (e.g., host rock waste emplacement, edge proximity, waste type, spatial infiltration rate variability, and climate state), it will also provide an assessment of the uncertainty of the TH data based on different infiltration rate characterizations and property sets (e.g., corresponding to the low, mean, and high flux maps). This is addressed in the analysis section of this AMR.

The abstracted quantities used by TSPA will be based on a division of the repository by a specified method developed to preserve and highlight the variability and uncertainty in the TH system. In the viability assessment TSPA (CRWMS M&O 1998a, Chapter 3, Figure 3-52), this was done by subdividing the repository into six spatial regions based roughly on areas that contain similar infiltration rates that encompassed the footprint of the potential repository. Abstracted data similar to that described above were based on these six subregions. The current AMR specifies the subdivision of the repository footprint by the glacial-transition climate infiltration rate instead of the repository subregion. For this methodology, any number of infiltration rate ranges (e.g., 0 – 3, 3-10 mm/yr, ... , ranges) can be defined. The definition of the infiltration rate ranges (or "bins") will provide the basis for abstraction such that each of the abstraction quantities will be averaged based on an appropriate infiltration rate range. As an example, consider that for a given infiltration rate bin, 100 out of 610 (or 623 for the backfill repository design which is considered in this AMR as an alternative design) total waste package locations fall within the infiltration range specified for a bin. A set of TH abstractions for this bin will be based on the TH characteristics of those 100 waste package locations. In order to assemble all relevant TH data that belongs in a particular infiltration bin, a procedure is developed to sort the process-level TH results driven by the local glacial-transition infiltration rate data that had been implemented as variable boundary conditions in the

multiscale TH model.

All of the abstraction quantities described above will be computed (or reformatted) using software routines developed for this AMR. The primary routine has the capability to, based on infiltration rate binning requirements, accept input commands, and create the abstracted data file used for input into the TSPA model on a per bin basis. That is, the averaged quantities (e.g., waste package RH), maximum/minimum waste package surface temperature, and reformatted raw data will be computed (or abstracted) by the routine for each of the infiltration bins as defined by TSPA.

Finally, the abstracted TH data used by the TSPA model will be analyzed in this AMR for trends and possible indicators of potential repository performance. In particular, analysis of the resulting time-histories of temperature, liquid saturation, percolation flux, evaporation rates, and maximum and minimum waste package surface temperatures will be considered, for each infiltration bin, for both EBS materials and NFE host rock. This TH abstraction AMR is for a repository design with and without backfill emplacement at the time of repository closure (CRWMS M&O 2000a, Section 4.1.1.5 through 4.1.1.8; CRWMS M&O 2000e).

### **Caveats and Limitations**

The caveats and limitations associated with this AMR primarily stem from the assumptions made in CRWMS M&O 2000a, Sections 5.1 through 5.3 and in CRWMS M&O 2000d, Sections 5.1 through 5.3, since any assumption applied to the process model also apply to the TH abstraction as well. In addition, the abstraction itself will create averaged data that may be based on a large number of waste package results. In cases where the average values may hide the variability of the data (e.g., an average waste package surface temperature for an infiltration bin that may contain hundreds of waste packages), maximum and minimum quantities will also be abstracted in order that an appropriate range of variability will be captured in this AMR for the TSPA model.

Ultimately, the purpose of the AMR is to provide an abstraction of the TH processes in the engineered barrier system and the near-field environment host rock. It will provide an assessment of potential TH variability and uncertainty. This abstracted data will be used by the TSPA model to compute waste package and drip shield corrosion rates, in-drift geochemical environment, and the transport of radionuclides out of the EBS. The abstraction analysis for this AMR is outlined in detail in the development plan, TDP-EBS-HS-000003, (CRWMS M&O 1999a).

## 2. QUALITY ASSURANCE

This analysis was prepared in accordance with the Civilian Radioactive Waste Management System (CRWMS) Quality Assurance program. The performance assessment operations (PAO) responsible manager has evaluated this activity in accordance with QAP-2-0, *Conduct of Activities*. The QAP-2-0 activity evaluation (CRWMS M&O 1999b) determined that the development of this analysis is subject to the requirements in the *Quality Assurance Requirements and Description* (DOE 2000). The analysis was conducted and this report developed in accordance with AP-3.10Q, *Analyses and Models*. According to procedures QAP-2-3, *Classification of Permanent Items*, and NLP-2-0, *Determination of Importance Evaluations*, quality level of permanent items or the determination of importance evaluation do not apply to this abstraction AMR. With regard to the development of this AMR, the control of electronic management of data was evaluated in accordance with AP-SV.1Q, *Control of the Electronic Management of Data*. The evaluation (Andrews 2000) determined that current work processes and procedures are adequate for the control of electronic management of data for this activity.

### 3. COMPUTER SOFTWARE AND MODEL USAGE

The software routines developed for and applied in this abstraction AMR are listed in Table 1. The routines are developed and used in this abstraction AMR in accordance with Section 5.1.1 (option 1) in the administrative procedure, AP-SI.1Q, *Software Management*. All of the software routines (except evapds\_wobackfill) are developed using SUN OS FORTRAN 77 SC4.2. The operating system is SUN OS 5.7 or higher. The computer identification numbers are S819978, R431923, and R404810. It is noted that TH-msmabs\_ver\_1 and TH-msmabs\_ver\_2 were only implemented on R404810 due to its extensive memory capacity. All three computers are located at Sandia National Laboratories, Performance Assessment Department in Albuquerque, New Mexico. The software routines provide the correct results for the specified range of input parameters as shown in the figures given in the Section 6.1 of this AMR. The documentation of these routines (including the testing and verification) is included both in this technical product (e.g., Attachments I-VIII), and in the data submittals (to the technical data management system, TDMS).

Table 1. Software Routine Usage

Software Routine Name	Version	Data Tracking Number (DTN)	Computer Platform	Design Case Used In
TH-msmabs_ver_1	1.0	DTN: SN0001T0872799.006	SUN w/ UNIX OS	With Backfill
TH-msmabs_ver_2	2.0	DTN: SN0007T0872799.014	SUN w/ UNIX OS	Without Backfill
maxtwp	1.00, 1.01, 1.02	DTN: SN0001T0872799.006	SUN w/ UNIX OS	With Backfill
maxtwp	1.03, 1.04, 1.05	DTN: SN0007T0872799.014	SUN w/ UNIX OS	Without Backfill
pillart	1.00	DTN: SN0001T0872799.006	SUN w/ UNIX OS	With Backfill
pillart	1.02, 1.03, 1.04	DTN: SN0007T0872799.014	SUN w/ UNIX OS	Without Backfill
extinf	1.00, 1.01, 1.02	DTN: SN0007T0872799.014	SUN w/ UNIX OS	With Backfill
extinf	1.03, 1.04, 1.05	DTN: SN0007T0872799.014	SUN w/ UNIX OS	Without Backfill
extinf2	1.00, 1.01, 1.02	DTN: SN0007T0872799.014	SUN w/ UNIX OS	Without Backfill
evapds_wobackfill	1.0	DTN: SN0007T0872799.014	Microsoft Excel Spreadsheet for Windows PC	Without Backfill
future_cs-csnf, future_cs-hlw	1.0	DTN: SN0010T0872799.015	SUN w/ UNIX OS	Without Backfill

NOTE: The software routine source code used in this AMR is identified and included in the data submittal DTN listed in the table.

Additionally, Microsoft Excel 97 (release SR-1) is used to graphically display the results and comparisons contained within this abstraction AMR. Commercially available software for spreadsheets and visual display graphics programs, which do not have additional applications developed using them, are not subject to software quality assurance requirements per Section 2.1 of AP-SI.1Q, *Software Management*. Models were not developed or used in this development of this AMR. Output results from upstream thermal hydrology process models are used as inputs in this AMR as listed in Table 2.

## 4. INPUTS

The inputs to this abstraction AMR are results from the process-level models described in CRWMS M&O 2000a, Section 6, and CRWMS M&O 2000d, Section 6. The abstraction and comparative analysis inputs are summarized in Table 2. It is noted that the abstracted output from Rev 00 ICN 01 of this AMR is used as source input data for Rev 00 ICN 02 of this AMR.

Table 2. Analysis Inputs

Title	DTN	Status	Repository Design	Description
Multiscale Thermohydrologic Model Results CRWMS M&O 2000a	Low infiltration flux case: LL000113904242.089 Mean infiltration flux case: LL000114004242.090 High infiltration flux case: LL000114104242.091  Input file names: csnf_xA_yB_data, hlw_xA_yB_data	All Data NQ; Input Data Submitted to TDMS on January 28, 2000	With Backfill	In-drift thermodynamic environment (refer to Table 3 below) from the process-level model results for low, mean, and high infiltration flux cases.
Heat Decay Data and Repository Footprint for Thermal-Hydrologic and Conduction-Only Models for TSPA-SR. CRWMS M&O 2000c	SN9907T0872799.001	NQ; Input Data Submitted to TDMS on July 27, 1999	Without Backfill	Used individual heat decay curves to compute an average CSNF and HLW drip shield evaporation rate for the no backfill repository design.
Multiscale Thermohydrologic Model Results CRWMS M&O 2000d	Low infiltration flux case: LL000509012312.002 Mean infiltration flux case: LL000509112312.003 High infiltration flux case: LL000509212312.004  Input file names: csnf_xA_yB_data, hlw_xA_yB_data	All Data NQ; Input Data Submitted to TDMS on May 18, 2000	Without Backfill	In-drift thermodynamic environment (refer to Table 3 below) from the process-level model results for low, mean, and high infiltration flux cases.
Abstraction Results from Rev 00 ICN 01 of this AMR.	SN0007T0872799.014 Input filenames: RIP_C*_qperc_d1050100_bin0-3_low RIP_C*_qperc_d1050100_bin3-10_low RIP_C*_qperc_d1050100_bin3-10_high RIP_C*_qperc_d1050100_bin10-20_high RIP_C*_qperc_d1050100_bin20-60_high RIP_C*_qperc_d1050100_bin60-high	All Data NQ; Input Data Submitted to TDMS on July 5, 2000	Without Backfill	High infiltration flux case percolation flux time-histories in four bins are mapped into the two low infiltration flux bins.

NOTE: The wild cards A, B in the input file names represent numbered locations for different repository footprint locations. An example of this is csnf\_x23\_y19\_data which approximately represents repository easting coordinate location 171,221m and northing coordinate location 234,098m. There are 610 (or 623 with backfill case) csnf files and 610 (or 623 with backfill case) hlw files per infiltration flux case. Input file headers in both csnf\_xA\_yB\_data, hlw\_xA\_yB\_data include repository footprint location and glacial transition climate state infiltration rate (used in Figures 18, 19, and 20). The wild card C\* in the input file name represents either csnf or hlw.

## 4.1 DATA AND PARAMETERS

The input data for this AMR are listed in Table 2. The input data (applied directly into the abstraction routines developed for this AMR) are the process-level model results from the multiscale TH model (CRWMS M&O 2000a and 2000d). Each of the data inputs along with their subsequent usage in this comparative analysis are described in detail in Section 6.0 of this AMR. It is re-emphasized that this AMR is an abstraction of process-level data along with a comparative analysis. Therefore, the data inputs are typically few since they are limited to the results of the appropriate process-level models.

## 4.2 CRITERIA

Standard requirements are specified in AP-3.10Q (*Analyses and Models*) regarding the documentation, review, and records. In addition, the Engineered Barrier System Process Model Report and the TSPA-SR may use the results of this analysis. These two reports have specific criteria as follows:

The U.S. Nuclear Regulatory Commission's (NRC's) Total System Performance Assessment and Integration (TSPA&I) Issue Resolution Status Report (IRSR) (NRC 1998, 2000) establishes generic technical acceptance criteria considered by the NRC staff to be essential to a defensible, transparent, and comprehensive assessment methodology for the repository system. These regulatory acceptance criteria address five fundamental elements of the U.S. Department of Energy (DOE) TSPA model for the Yucca Mountain site, namely:

1. Data and model justification (focusing on sufficiency of data to support the conceptual basis of the process model and abstractions);
2. Data uncertainty and verification (focusing on technical basis for bounding assumptions and statistical representations of uncertainties and parameter variabilities);
3. Model uncertainty (focusing on alternative conceptual models consistent with available site data);
4. Model verification (focusing on testing of model abstractions using detailed process-level models and empirical observations); and
5. Integration (focusing on appropriate and consistent coupling of model abstractions).

## 4.3 CODES AND STANDARDS

No specific formally established standards have been identified as applying to this analysis activity.

This AMR was prepared to comply with the DOE interim guidance (Dyer 1999) which directs the use of proposed NRC high-level waste rule, 10 CFR Part 63. Relevant requirements for performance

assessment from Section 114 of that document are: “Any performance assessment used to demonstrate compliance with Sec. 113(b) shall: (a) Include data related to the geology, hydrology, and geochemistry ... used to define parameters and conceptual models used in the assessment. (b) Account for uncertainties and variabilities in parameter values and provide the technical basis for parameter ranges, probability distributions, or bounding values used in the performance assessment. ... (g) Provide the technical basis for the models used in the performance assessment such as comparisons made with outputs of detailed process-level models ... .”

## **5. ASSUMPTIONS**

The standard working assumptions for the TH process-level model detailed in CRWMS M&O 2000a and 2000d (Section 5) also apply to the TH abstraction AMR as well. There are no critical assumptions contained within the process model documentation that need additional confirmation in the abstraction AMR. The details of the assumptions given in the above document will not be repeated here. Additional assumptions applied directly to the TH abstraction analysis are the following.

### **5.1 TH ABSTRACTION**

The abstraction results can, in theory, be computed for any number of infiltration rate bins defined over the entire range of infiltration rate variability/uncertainty. The range of infiltration rate uncertainty considered in the TH process-level model, and subsequently its abstraction, is captured in the local infiltration flux by the low, mean, and high infiltration flux cases (described in CRWMS M&O 2000a and 2000d, Section 6.3.6).

#### **5.1.1 Infiltration Rate Bin Ranges**

It is assumed in this AMR that the same (variable) infiltration rate bin definitions can be applied to each of the three infiltration flux cases (low, mean, and high) considered in the multiscale TH model. With this assumption, consistent comparisons can be made across the entire range of infiltration uncertainty. The infiltration rate bins used in each case of the TH abstraction are defined as the following:

- 0 – 3 mm/yr
- 3 – 10 mm/yr
- 10 – 20 mm/yr
- 20 – 60 mm/yr
- 60+ mm/yr



This assumption is applied in Section 6.2 of the current AMR. The basis for this assumption is a result of the seepage abstraction which showed that certain ranges in percolation flux would result in different seepage rates. More detail is found in Section 6.2.

### **5.1.2 Infiltration Rate Bin Basis**

It is assumed that the five binning ranges given in Section 5.1.1, and hence the basis of the abstraction itself, is applied to the infiltration rate for the glacial transition period of the future climate state. That is, the TH abstraction is based on the infiltration rate of the climate state that is in force in the process-level TH model from  $2 \times 10^3$  years to  $10^6$  years of simulation time. This assumption is applied in Section 6.2 of this AMR. The basis for this assumption is that the infiltration flux that is used in the model will be from the glacial transition climate during the time that radionuclide transport is important to dose.

### **5.1.3 Conversion Assumptions**

The evaporation rates given in kg/yr can be converted to volume flow rates using a constant water density of  $1000 \text{ kg/m}^3$ . This assumption removes a subtle dependence of the liquid water density on temperature. This is used in Section 6.1 of this AMR. The basis for this assumption is that the density changes by only 4% from  $27^\circ\text{C}$  to  $100^\circ\text{C}$ .

### **5.1.4 Drip Shield Evaporation Rate (without backfill)**

The drip shield evaporation rate (for the no backfill case only) is computed using an energy balance with the waste package heat output and the incoming water from the abstracted seepage model. It is computed for an average commercial spent nuclear fuel (CSNF) and defense high-level waste (HLW) waste package. The fluid properties applied in the energy balance method used to determine the evaporation rates (in  $\text{m}^3/\text{yr}$ ) are evaluated using a constant average temperature. (It is shown in Section 6.3.10 that the evaporation rate at this location is fairly insensitive to the temperatures chosen to evaluate the fluid properties in the energy balance.) This abstraction method for the drip shield evaporation rate and volume water flow rate differs from the backfill case (also described in this AMR) due to limitations in the multiscale TH process model. The multiscale TH model does not currently contain a submodel that allows for dripping and flow mechanisms into and through an open emplacement drift. The lack of fracture property heterogeneity in the surrounding host rock and coarse gridding in the open drift space (not to mention the uncertainty of applying porous media flow properties to an open space) potentially results in an incomplete description of the processes that may occur at the top of the drip shield in the absence of a porous backfill material. In the case of backfill emplacement, more water (compared to dripping from seepage entering above) is brought into the drift by capillary flow where backfill material contacts fractured host rock. This flow process (into the drift) is adequately captured by the multiscale TH model (CRWMS M&O 2000a, Section 6.11.4). Therefore, the water volume flow and evaporation processes (occurring within the backfill) are adequately represented by the backfill hydrologic properties applied in the process model and is

computed directly by the process model based on flow properties and a representative conceptual flow model through a porous (backfilled) medium.

The assumption applied for the no backfill evaporation rate at the drip shield is considered conservative since it allows the available heat input to the drip shield to evaporate all incoming dripping water (thus leaving the maximum amount of precipitation on the drip shield). The incoming water used in the abstraction is specified by the seepage abstraction model.

The use of an average waste package is appropriate due to the similarity of heat outputs of waste packages of particular types (CSNF blending of fuel assemblies, average HLW in the process-level model). The use of constant fluid properties is appropriate based on a comparative analysis between the constant property result and an analysis that applied an energy balance using (time varying drip shield) temperature dependent fluid properties. The abstraction method and the application of the assumptions are described in section 6.3.10.

## **6. ANALYSIS**

The analysis section of the TH abstraction AMR is summarized as the following. In Section 6.1, the development of the TH abstraction routine is described. This section will provide the details of the routine itself including the inputs required, the calculations performed, the printing specifications, and any raw data reformatting/extracting necessary for input into the TSPA model. This section also discusses the averaged quantities necessary for the TSPA model. Section 6.2 describes the abstraction itself including the selection of the infiltration bins. This section will display the resulting subdivision of the repository footprint by infiltration bin for each of the three infiltration flux cases considered in the abstraction (low, mean, and high) for both repository designs (with or without backfill). Section 6.3 describes the details of a comparative analysis of the TH abstraction data applied in the TSPA model for the no backfill repository design (referred to as the base case repository design). Section 6.4 describes the details of a comparative analysis of the TH abstraction data applied in the TSPA model for the backfill repository design (an alternative repository design). Section 6.5 describes the confidence in the methods applied to this abstraction analysis.

### **6.1 TH ABSTRACTION ROUTINE**

The main abstraction routine computes/assembles the abstracted TH data in a format required by the TSPA model. The routine input calls for the number of infiltration bins ( $n_{inf} = 5$ , refer to Section 5.1.1) and the bin ranges (refer to Section 5.1.1). The primary TH abstraction routine (see Attachment I used for the backfill repository design or Attachment IV used for the no backfill repository design for complete source code methods) then reads the raw input files (from DTN: LL000113904242.089, LL000114004242.090, LL000114104242.091, Table 2 for the backfill repository design or LL000509012312.002, LL000509112312.003, LL000509212312.004, Table 2 for the no backfill repository design) and sorts them into the predefined infiltration rate bins based on the infiltration rate during the glacial-transition (see Section 5.1.2) of the future climate state (for waste emplacement times greater than 2000 years). Each raw data file is assigned to an infiltration

bin where it is processed/reformatted into the TSPA model data files. Each “raw” location data file (contained within an infiltration bin) represents the conditions that would be associated with either a commercial spent nuclear fuel (CSNF) waste package or a defense high-level (HLW) waste package located at its specified northing or easting coordinate (e.g., the location specifically within the repository footprint). The sum of the areas associated with the waste package locations in a particular infiltration rate bin (e.g., each waste package location file contains an area weighting factor which results in the area of the repository represented by that location) result in the total repository area represented by that bin. Due to the nature of the multiscale TH model grids, each waste package location dependent result does not represent the same sized area.

Therefore, the first set of data required by the TSPA model is taken directly from the raw data files of the results of the multiscale TH model (refer to Table 2 for file names used as abstraction inputs) and reformatted into a new file for TSPA uses. For example, a single file contains a set of time-histories for each waste package location in a particular infiltration bin. The data is unchanged from the process model results with the possible exception of unit conversion. A maximum of five files per infiltration flux case per waste package type are generated. The raw process model values used directly in the TSPA model are listed in Table 3 below. The table indicates which design TSPA potentially applies the variable to in its analyses.

Table 3. TSPA Inputs Directly from Multiscale TH Model Data

TH Variable Used in the TSPA Model	Abstraction Routine Variable Name	Used in Repository Design Analysis
Time (year)	timeyr ( <i>i</i> )	both
Waste package surface temperature (°C)	T_wp( <i>i,j</i> )	both
Drip shield temperature (°C)	T_ds( <i>i,j</i> )	both
Drift wall temperature (°C)	T_dw( <i>i,j</i> )	both
Invert temperature (°C)	T_inv( <i>i,j</i> )	both
Waste package relative humidity	RH_wp( <i>i,j</i> )	both
Drip shield relative humidity	RH_ds( <i>i,j</i> )	both
Drift wall relative humidity	RH_dw( <i>i,j</i> )	both
Backfill relative humidity	RH_bfp( <i>i,j</i> )	backfill only
Invert relative humidity	RH_inv( <i>i,j</i> )	both
Drip shield liquid saturation	SI_ds( <i>i,j</i> )	backfill only
Invert liquid saturation	SI_inv( <i>i,j</i> )	both
Drip shield air mass fraction	xa_ds( <i>i,j</i> )	both
Drift wall water vapor flux (kg/yr/m of drift)	qw_dw( <i>i,j</i> )	both
Drift wall air flux (kg/yr/m of drift)	qa_dw( <i>i,j</i> )	both
Top of drip shield evaporation rate <sup>a</sup> (m <sup>3</sup> /yr/m-drift)	qvpsT( <i>i,j</i> )/rho	backfill only <sup>d</sup>
Backfill evaporation rate <sup>a</sup> (m <sup>3</sup> /yr/m-drift)	qvbpfp( <i>i,j</i> )/rho	backfill only
Invert evaporation rate <sup>a</sup> (m <sup>3</sup> /yr/m-drift)	qvpinv( <i>i,j</i> )/rho	both
Percolation flux at 5 m above drift crown (mm/yr)	ql_5m( <i>i,j</i> )	both
Percolation flux at 3 m above drift crown (mm/yr)	ql_3m( <i>i,j</i> )	both
Volume flow rate at top of drip shield <sup>b</sup> (m <sup>3</sup> /yr/m-drift)	ql_dsT( <i>i,j</i> )*(a_dsT/1000.)	backfill only <sup>d</sup>
Volume flow rate at invert <sup>c</sup> (m <sup>3</sup> /yr/m-drift)	ql_inv( <i>i,j</i> )*(a_inv/1000.)	both
Top of drip shield temperature (°C)	Tdstop( <i>i,j</i> )	both

NOTES:

- <sup>a</sup> - Converted from kg/yr by dividing by 1000 kg/m<sup>3</sup> (assumption 5.1.3).
- <sup>b</sup> - Converted from mm/yr by (0.57m<sup>2</sup>/1000).
- <sup>c</sup> - Converted from mm/yr by (0.92m<sup>2</sup>/1000).
- <sup>d</sup> - Refer to Sections 5.1.4 and 6.3.10 for the no backfill abstraction method for these variables.
- i* = The number of location entries in an infiltration bin (*i* varies, see Table 5).
- j* (backfill case only) = The time points (maximum possible = 442 time points for low, 352 mean, and 457 high infiltration flux cases—this number is changed in the parameter statement of the software routine TH-msmabs\_ver\_1 and re-compiled).
- j* (no backfill case only) = The time points ( = 99 for all three infiltration flux cases used in TH-msmabs\_ver\_2).

It is noted that dummy values are given in the raw data when the variable has no meaning (e.g., there can be no drip shield temperature or relative humidity during the repository preclosure period before the drip shield has been installed) and have been set to -999.9 (or in the case of backfill, -99.9). These values are not used by the TSPA model.

In addition to the raw data indicated in Table 3, the TSPA model requires infiltration bin averaged quantities for the transport model, waste form degradation model, and the in-drift geochemical models. The averaged quantities are based on the location specific (or raw) data contained within an infiltration rate bin. The average quantity (e.g., waste package surface temperature) is based on the sum of all the area factors (*f<sub>i</sub>*) contained within the infiltration bin. That is, the relative weight of a specific location contained within a particular infiltration bin (including all of its entries) is

given by:

$$f_{avg-i} = \frac{f_i}{\sum_{bin-i} f_i} \quad (\text{Eq. 1})$$

and the average is computed as the following:

$$X_{avg}(j) = \sum_{bin-i} f_{avg-i} X_i(j) \quad (\text{Eq. 2})$$

where  $X_{avg}$  is an average quantity,  $X$  is its raw value, and  $i$  and  $j$  are as defined in Table 3 above. Equations 1 and 2 are computed separately for each predefined infiltration bin. The values of  $X$  used in the TSPA model are given in Table 4 below. The infiltration bin averaged quantities given in the table below are applied to the abstraction of both the with and without backfill repository designs. Additional bin average quantities, such as temperature and relative humidity adjacent to the drift wall, are computed for the submodels of the TSPA model.

Table 4. Average and Raw<sup>a</sup> Quantities used in the TSPA Model

TH Variable Used in the TSPA Model	Abstraction Routine Variable Name
Waste package surface temperature (°C)	TavgRIP(k,j)
Invert liquid saturation	S_lavgRIP(k,j)
Percolation flux at 5 m above the drift crown (mm/yr)	ql_5mavgRIP(k,j)
Maximum <sup>a</sup> waste package surface temperature (°C)	Tmaxrip(k,j)
Minimum <sup>a</sup> waste package surface temperature (°C)	Tminrip(k,j)
Invert temperature (°C)	TavgRIPinv(k,j)
Invert relative humidity	RHavgRIPin(k,j)
Invert evaporation rate (m <sup>3</sup> /yr/m-drift)	qvpavgRIPinv(k,j)
Top drip shield temperature (°C)	TavgRIPdstop(k,j)
Invert volume flow rate (m <sup>3</sup> /yr/m-drift)	ql_invavgRIP(k,j)*(a_inv/1000.)
Absolute invert volume flow rate <sup>b</sup> (m <sup>3</sup> /yr/m-drift)	ql_invavgabs(k,j)*(a_inv/1000.)
Drift wall relative humidity	RHavgRIPdw(k,j)
Drift wall temperature (°C)	TavgRIPdw(k,j)

NOTES: <sup>a</sup>-The raw quantities don't use the Equations 1 and 2 defined above. The max/min waste package surface temperature curves correspond to the time histories for the waste packages with the highest and lowest peak waste package temperature for each bin.

<sup>b</sup>-The absolute value of the raw quantity is taken before the average.

$k$  = An infiltration bin (=5 total).

$j$  = The time point.

As indicated in Section 1.0, this abstraction will create average time-history data that may be based on a number of very different results (from the raw files obtained from the process-level TH model). In cases where variability may be averaged out (e.g., an infiltration bin that may contain hundreds of waste package locations with many different waste package surface temperatures), the location dependent "raw" files that contained the waste package locations with the maximum and minimum peak temperature values are abstracted in order that an appropriate range of variability may be defined by this AMR for the TSPA model (to compare to the bin averaged results of the abstraction). Additionally, in some cases (e.g., both for the raw and the bin-averaged data) the amount of abstraction data transferred to the TSPA model is reduced by the TH abstraction routines developed for this AMR. This is necessary because of time point restrictions in the TSPA models which required that the number of data points in the TH abstraction data be reduced for runtime purposes. It is noted that the process-level data applied to the TH abstraction of the backfill repository design contained a large number of time points in the results because of differential re-wetting times occurring in the backfill material. The re-wetting times varied depending on infiltration flux case and spatial variability of infiltration rate at each of the repository locations (e.g., 623 for the backfilled repository design). In order to resolve the differences in the re-wetting times associated with the backfill material, the number of time points reported in the raw data is on the order of hundreds of data points (refer to the note given above in Table 3). The large number of reported data needed to be reduced (for computational efficiency) to about a hundred data points before being applied by the TSPA model (the method for an efficient reduction in data points for the backfill repository design abstraction is described below). The without backfill process-level model results did not require the large number of data points required by the backfill case (e.g., no backfill to cause differences in re-wetting times). Therefore, the number of data points given in the process-level model results (99 total time points for any variable) remained unaltered in the abstraction of each infiltration flux case (refer to the note given in Table 3). The time point reduction method used in the abstraction of the backfill repository design results is described below.

The TH abstraction routine (TH-msmabs\_ver\_1, backfill case only) altered the data sets (both raw and averaged) due to requirements set forth by the TSPA model. The use of the large number of time points (denoted in the tables above as  $j$ ) given in the multiscale TH model results for the backfill repository design would result in very long runtimes in the TSPA model. A method has been developed to reduce the number of time points while still maintaining the time varying nature of the data. This is done by only printing variables when any one of two key TSPA variables (waste package temperature and percolation flux at 5 meters into near-field host rock) changes by some predetermined fraction. The rate-of-change (ROC) parameter is defined in general as:

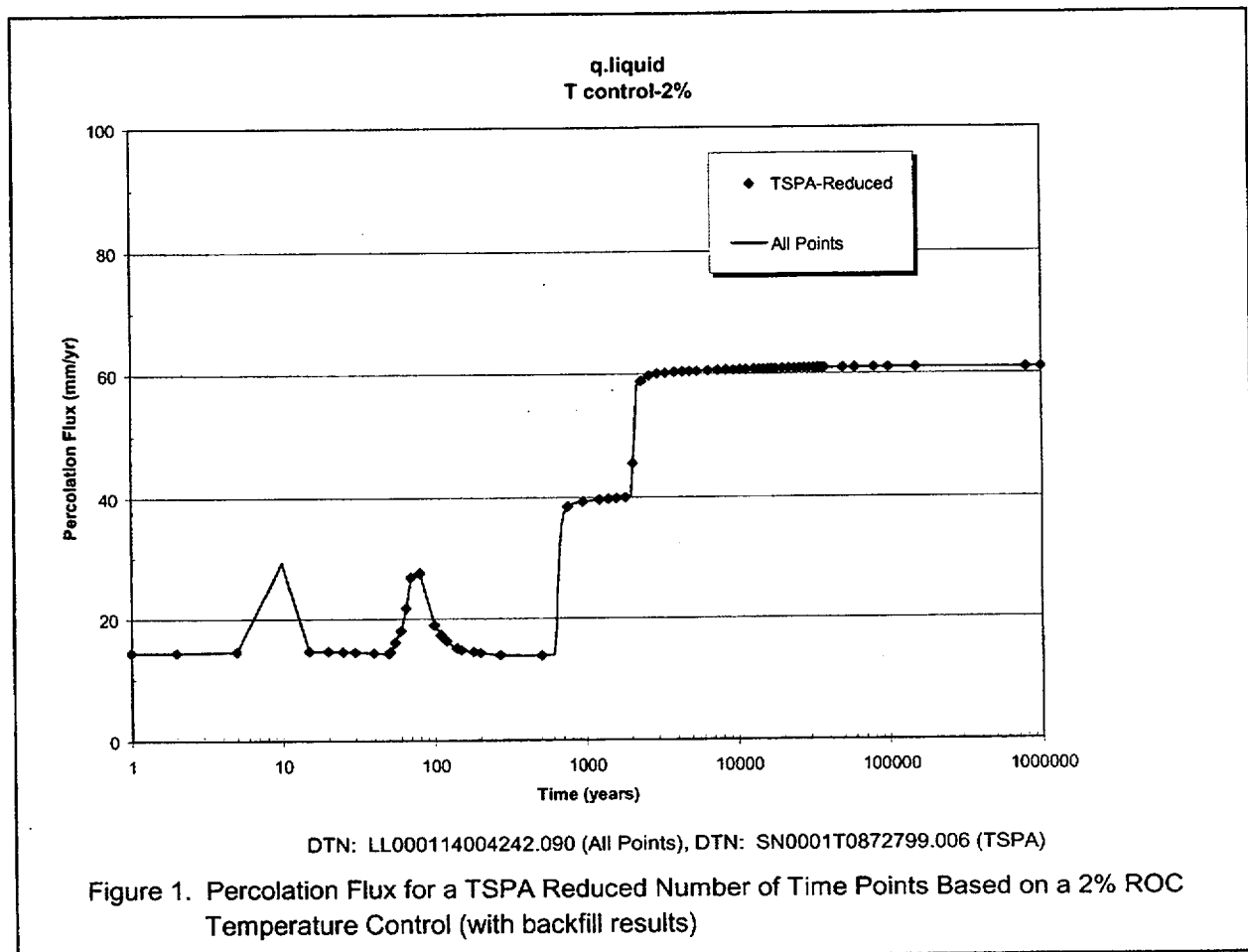
$$ROC = \frac{X_j - X_r}{X_r} \quad (\text{Eq. 3})$$

where  $X_r$ , the last retained value (the last value printed), is not in general  $j-1$ . Since much of the TSPA input data, as given in Table 3, is applied to the waste package degradation model, the total number of time points is reduced but kept identical for each variable listed in the table (e.g., each of the variables given in Table 3 had the same total number of  $j$ 's and at identical time points). Since both flux and state variable dependence can be used to maintain the integrity of the data, the time rate of change of the waste package surface temperature and the liquid flux 5 m above the crown of

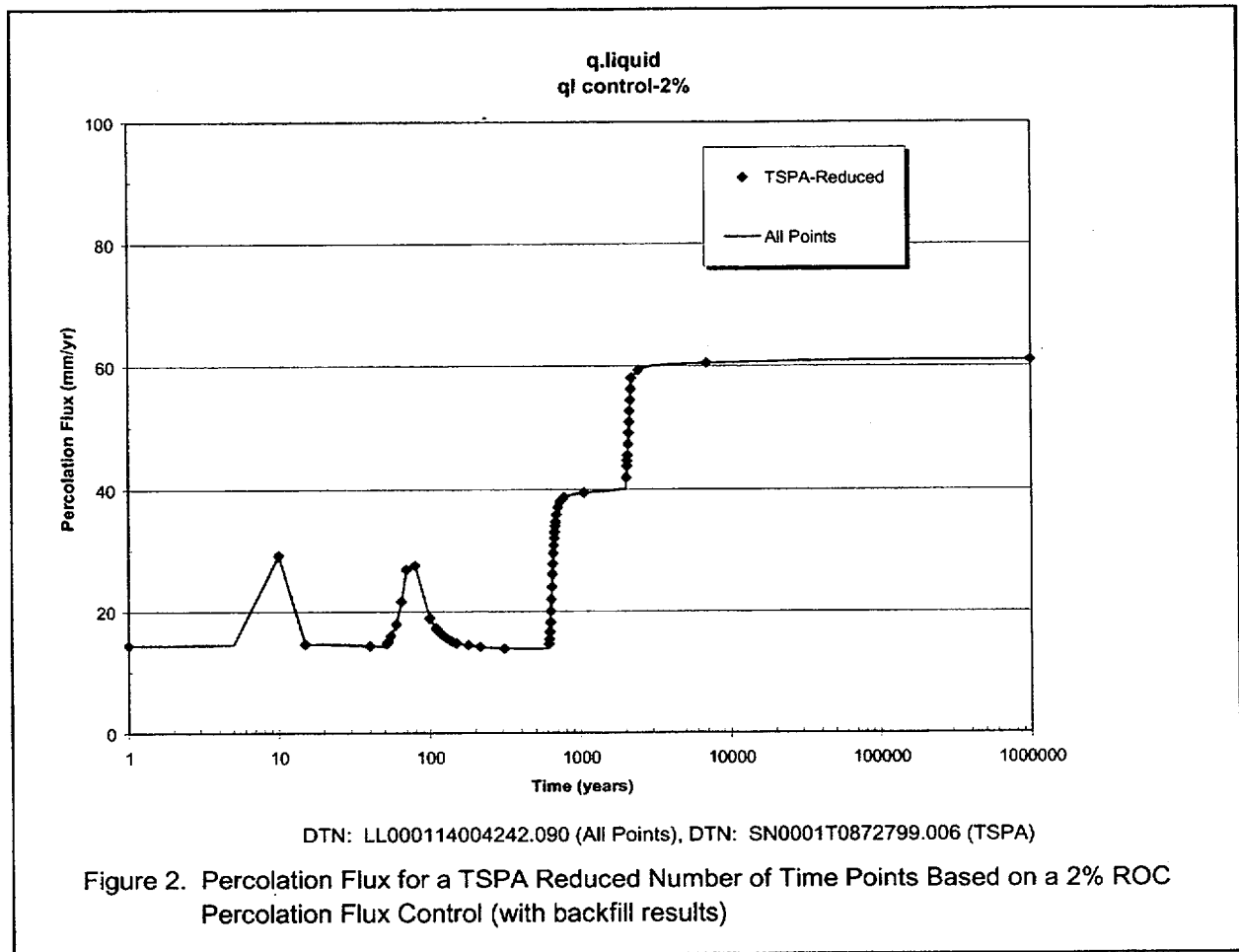
the drift are used as the controlling parameters.

The software routine (TH-msmabs\_ver\_1, backfill case only) test cases and results are described as the following. In order to determine the best method of time print control, three methods are considered. The first uses a temperature rate of change only, the second uses percolation flux change only, and the third uses both (this is the method chosen for the abstraction). The results of each method are shown in the following figures. In the time print control study, rates of change are selected in the range of 3 to 5%. For changes in the control variables that are less than this range, the value would not be retained as TSPA input and the  $j^{\text{th}}$  time point (from the raw data) is discarded (for all the variables listed in Table 3). For changes greater than or equal this range, the values are saved in the TSPA input files.

For temperature control, one need only look at the time-histories of the liquid flux variable to conclude that this control parameter is insufficient by itself. Figure 1 contains the full and reduced percolation flux time history for an actual waste package location using the mean infiltration flux map. The reduction is based on a print out for a 2% change in waste package surface temperature.



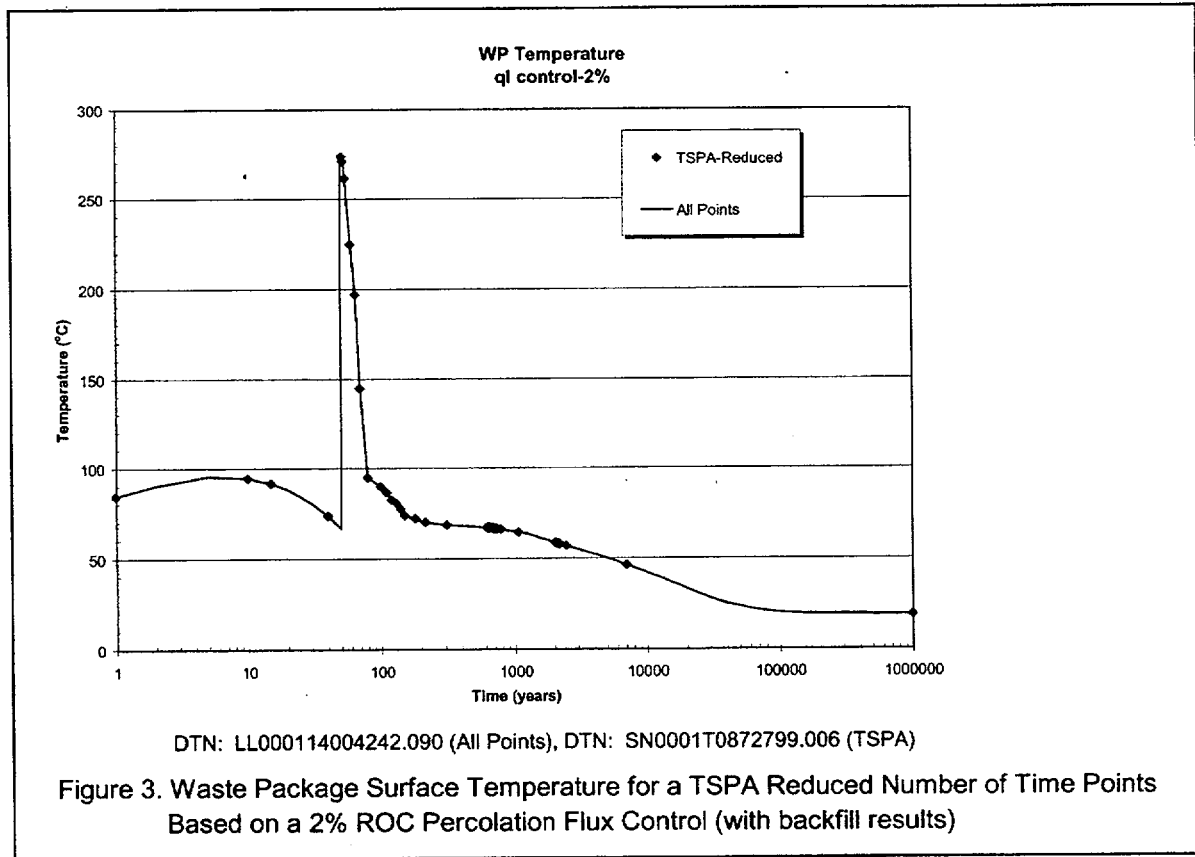
From Figure 1 it is evident that at 10 years the initial pulse of liquid water (e.g., during initial heat-up and moisture movement period) above the crown of the emplacement drift is not captured when a changing waste package surface temperature is used to determine the time print data for use in the TSPA model. Therefore, using only the waste package surface temperature to control the time print outs is not sufficient to capture the variability in the percolation flux. Figures 2 and 3 show the percolation flux and waste package temperature for the same waste package location when a 2% change in percolation flux is used as the controlling parameter.

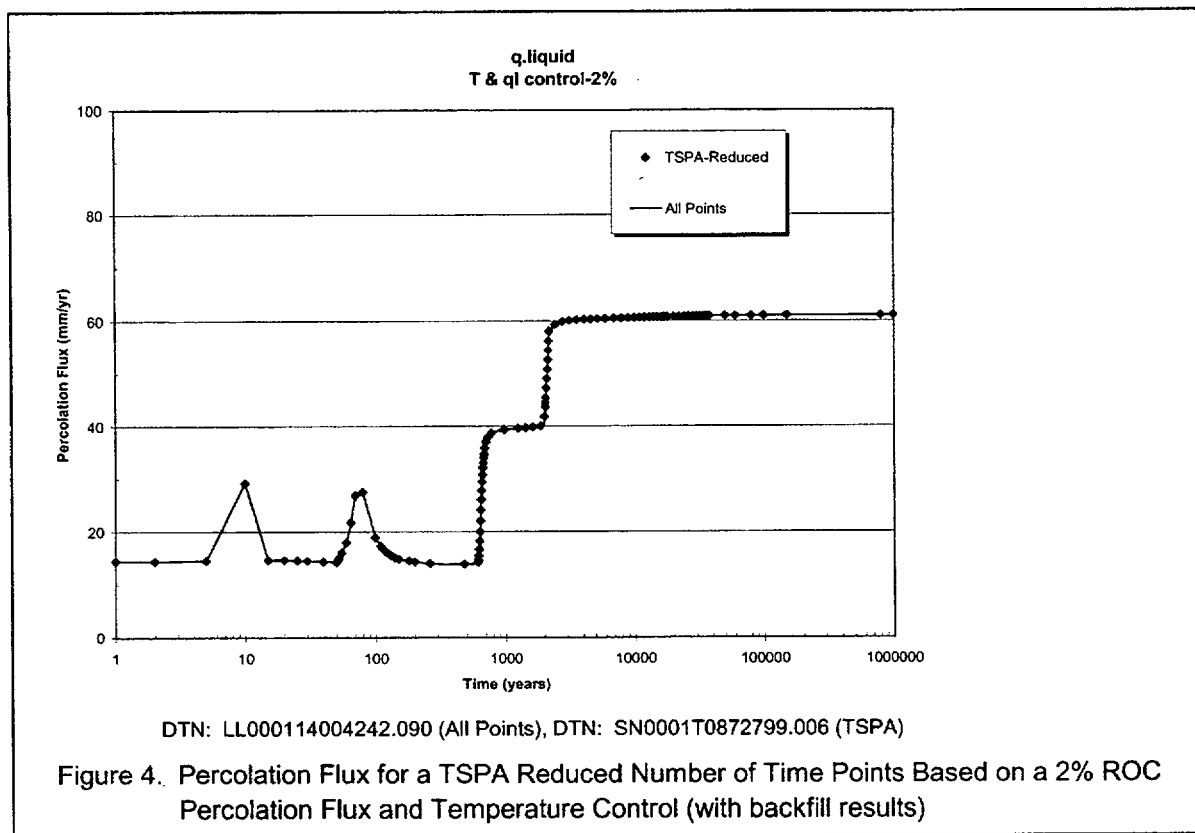


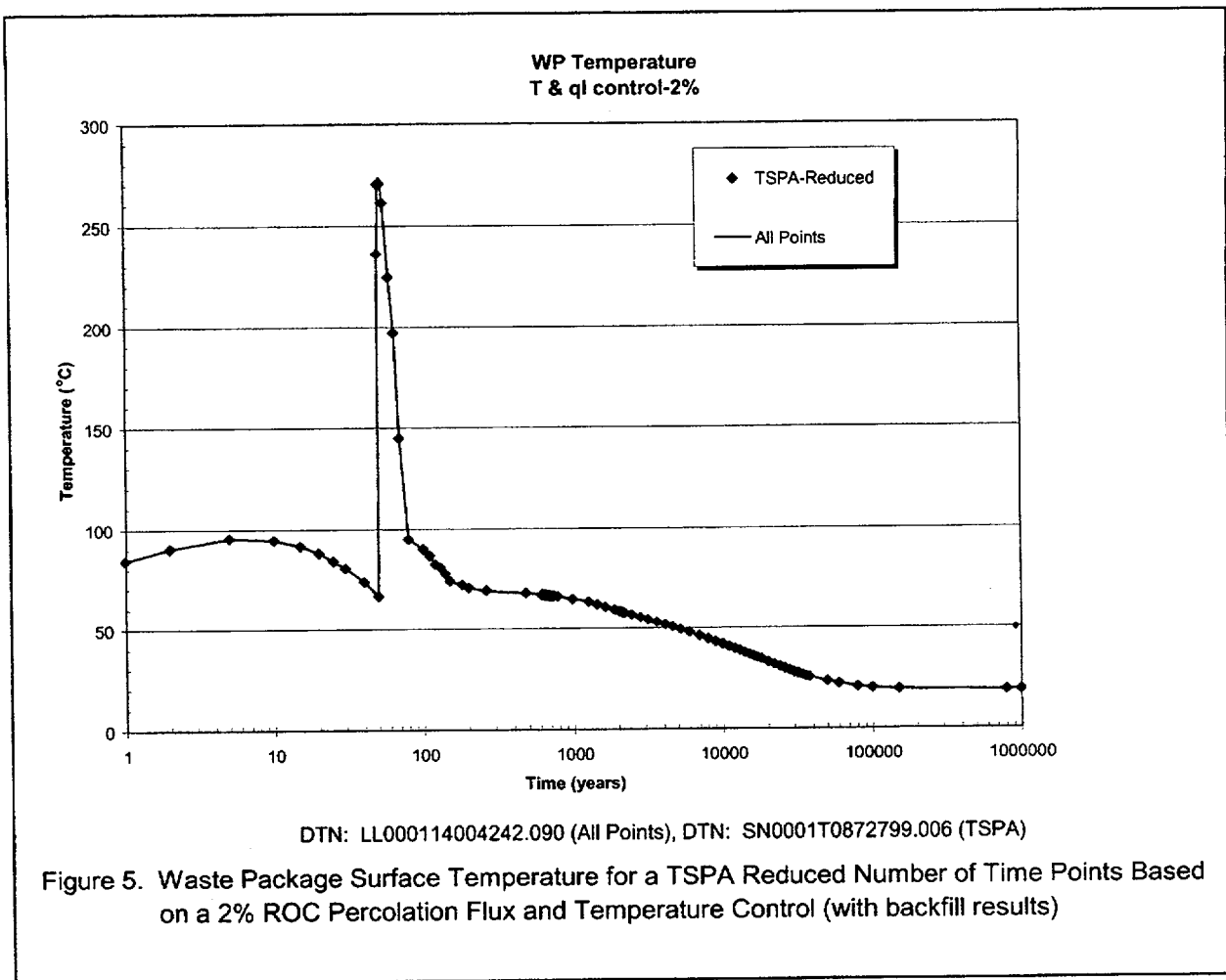
In Figure 2, the initial pulse (at 10 years) of water at the crown of the emplacement drift is captured in the reduced files. From this figure and Figure 3, this method is too coarse both at late and early times for both the flux and state variables. There are no data points between 10,000 and 1,000,000 years when the percolation flux is nearly constant but the waste package surface temperature drops from approximately 40°C back to its ambient value. Alternate methods that would result in more time points in the required variables are reducing the rate-of-change factor when using the



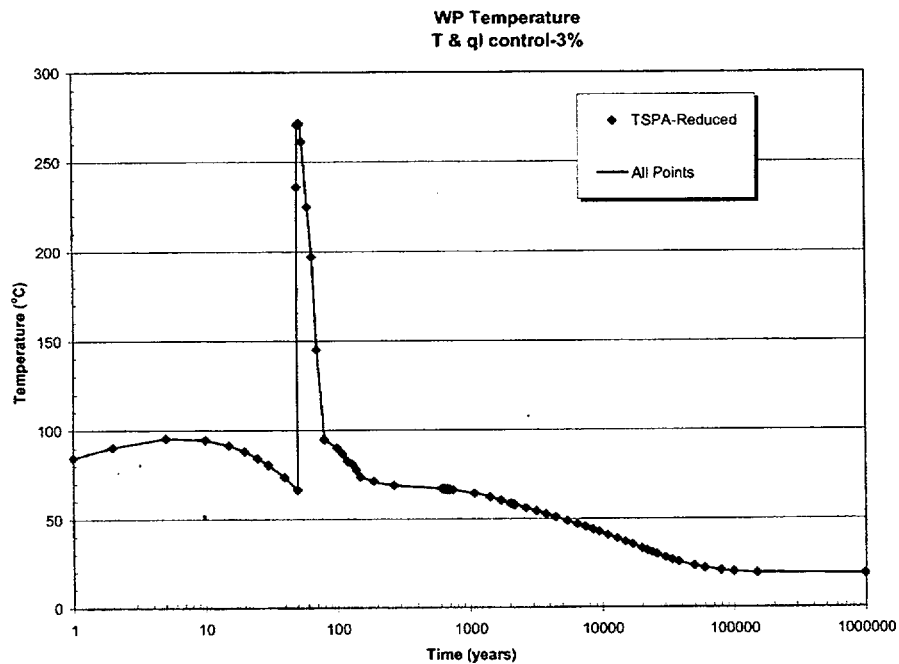
percolation flux control parameter or using both a flux and a state variable when specifying the points retained for the TSPA model. The later method is used in Figures 4 and 5 for the percolation flux and the waste package temperature, respectively.





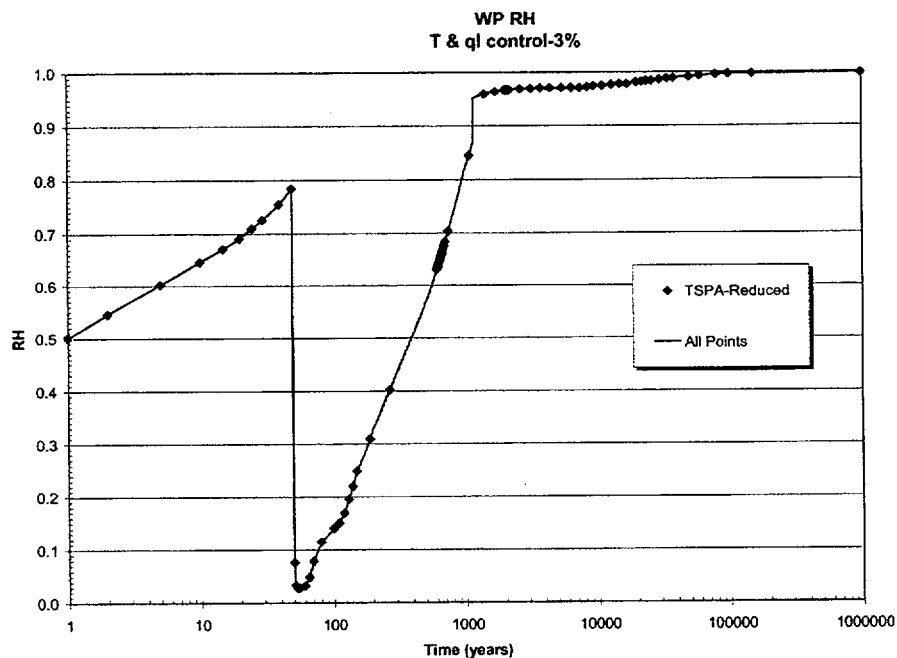


Figures 4 and 5 show the percolation flux and waste package surface temperature when a 2% rate-of-change factor is utilized for both parameters (state and flux). In order to reduce the number of time points even further, the flux and state variable control is increased to 3%. For this case, the number of time print outs is reduced from 102 for 2% change to 83 for a 3% change. This represents about 25% of the original data while still maintaining the integrity of the data and its trends. The results of this specification are shown in the following figures. Figures 6 through 12 indicate both flux and state variables based on a combination of temperature and percolation flux rate of changes specified as 3%. The results are for an arbitrary waste package location within an infiltration bin as defined above. This criteria is selected for the abstraction. (Note: for the low infiltration rate case, the ROC criteria is specified as 5% to minimize the number of data points passed to the TSPA model since a 3% reduction did not remove a sufficient number of points for the TSPA model.)



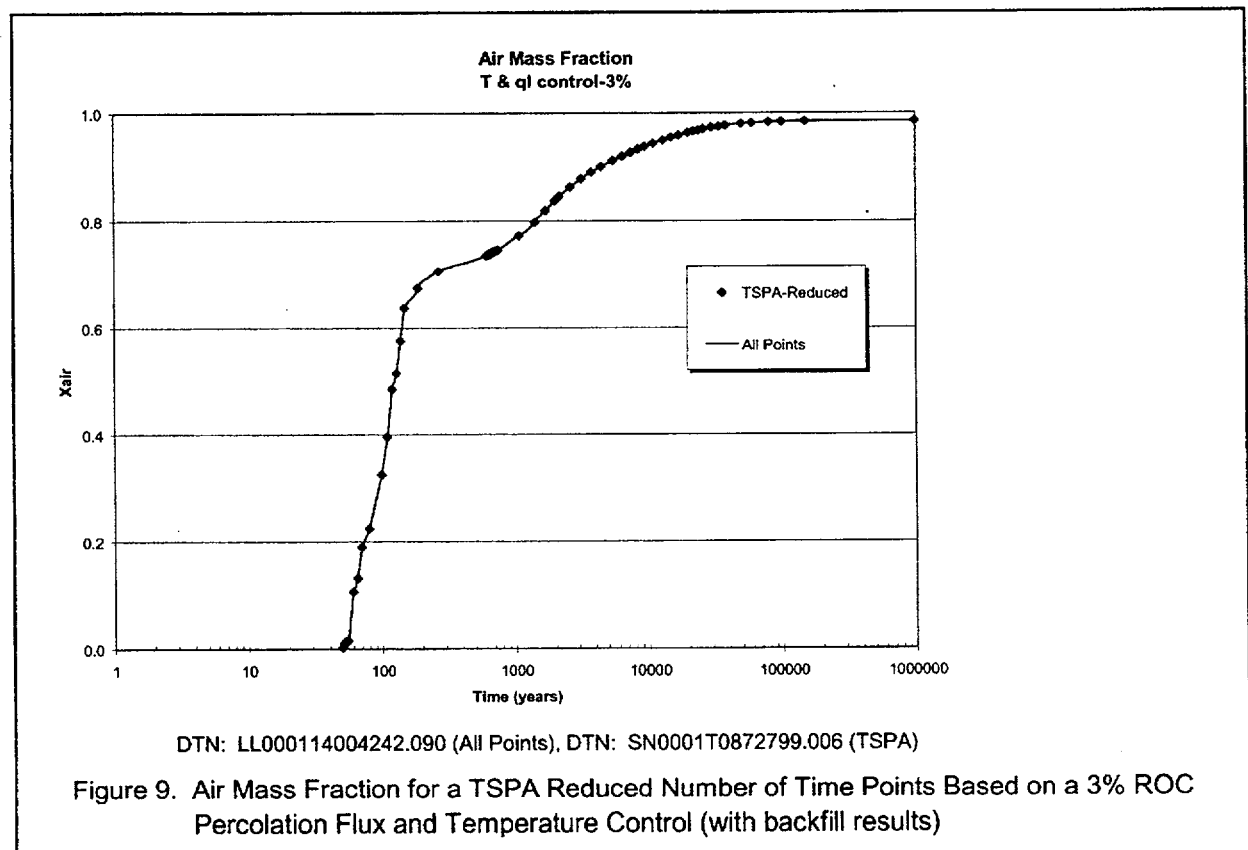
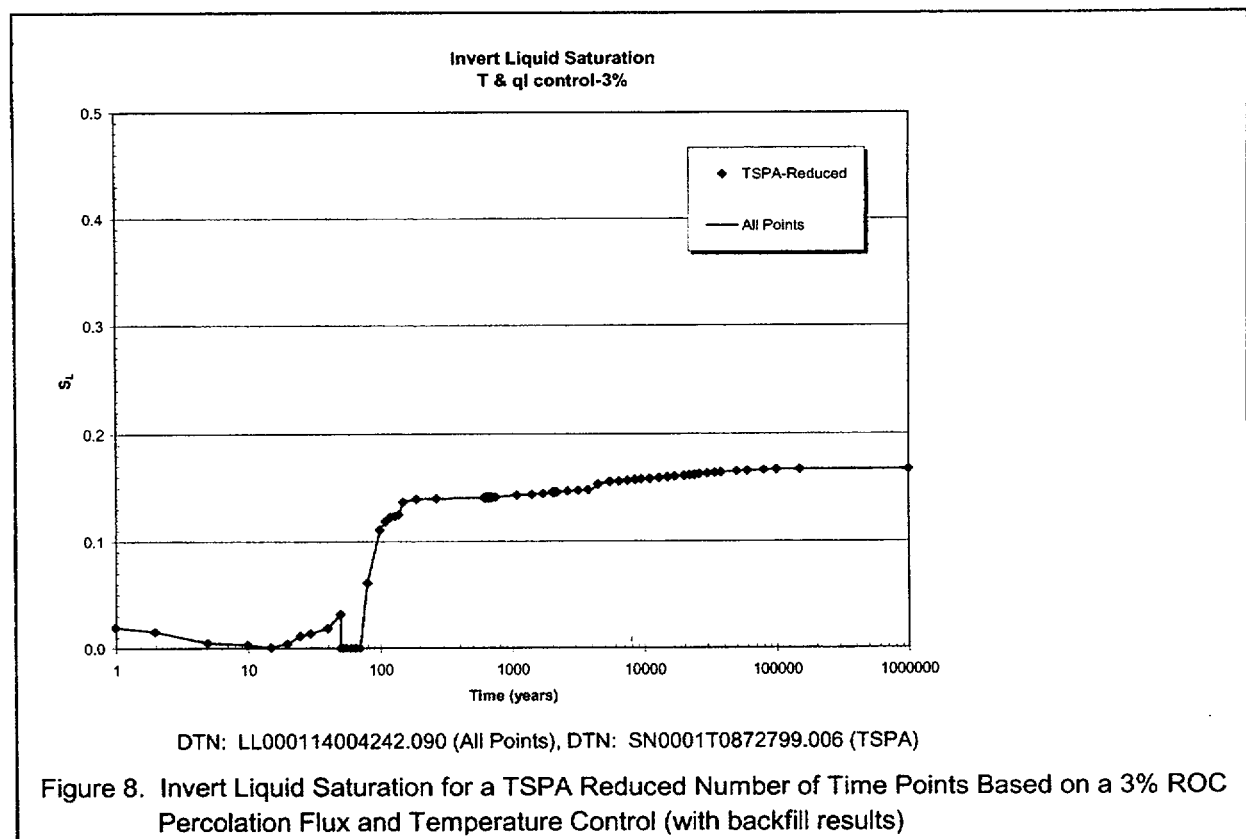
DTN: LL000114004242.090 (All Points), DTN: SN0001T0872799.006 (TSPA)

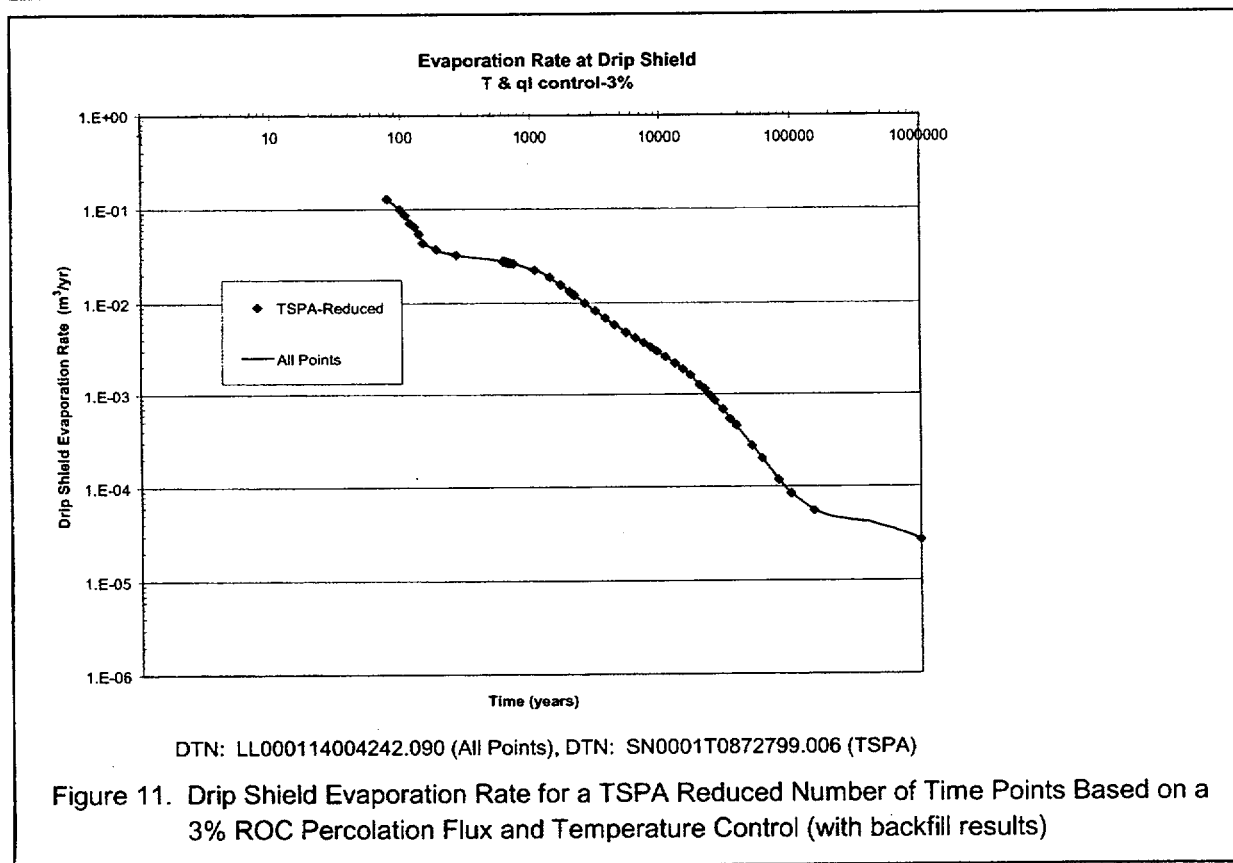
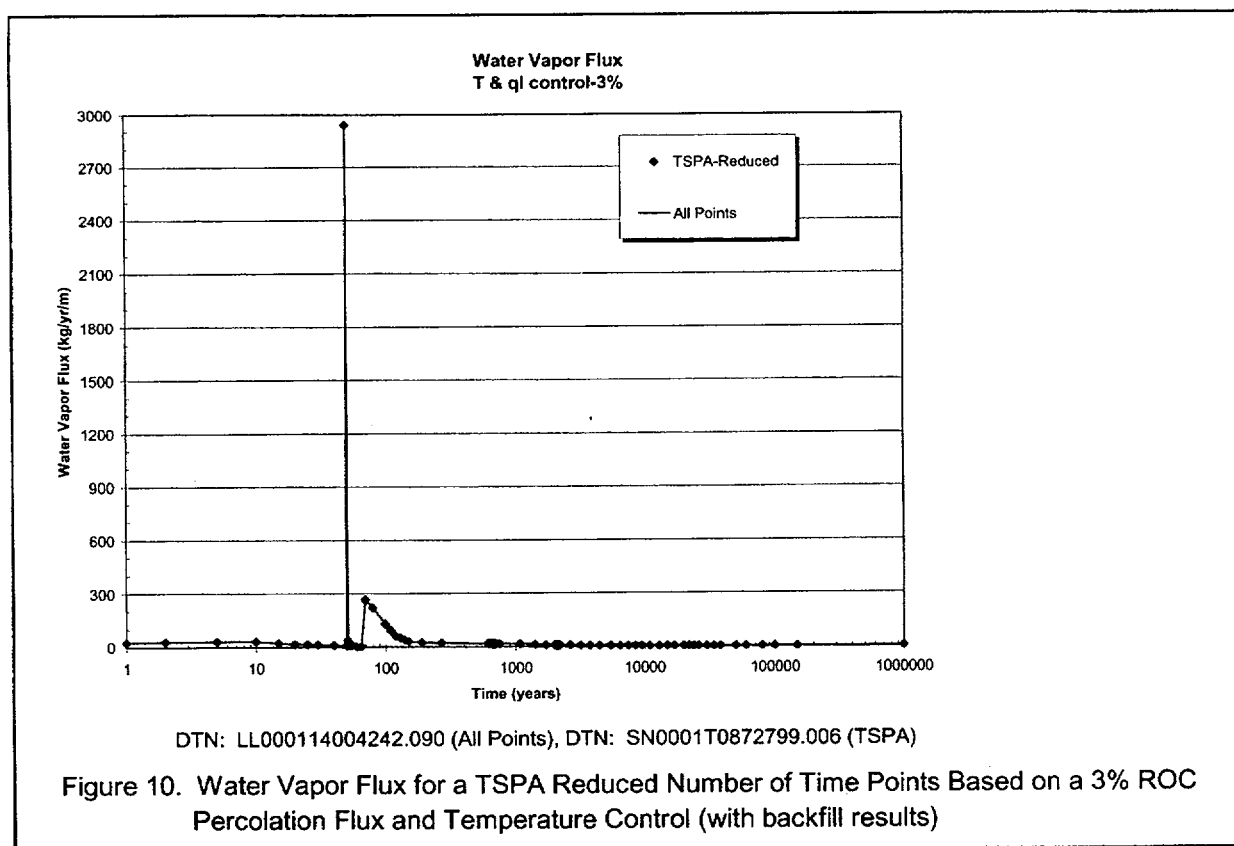
Figure 6. Waste Package Surface Temperature for a TSPA Reduced Number of Time Points Based on a 3% ROC Percolation Flux and Temperature Control (with backfill results)

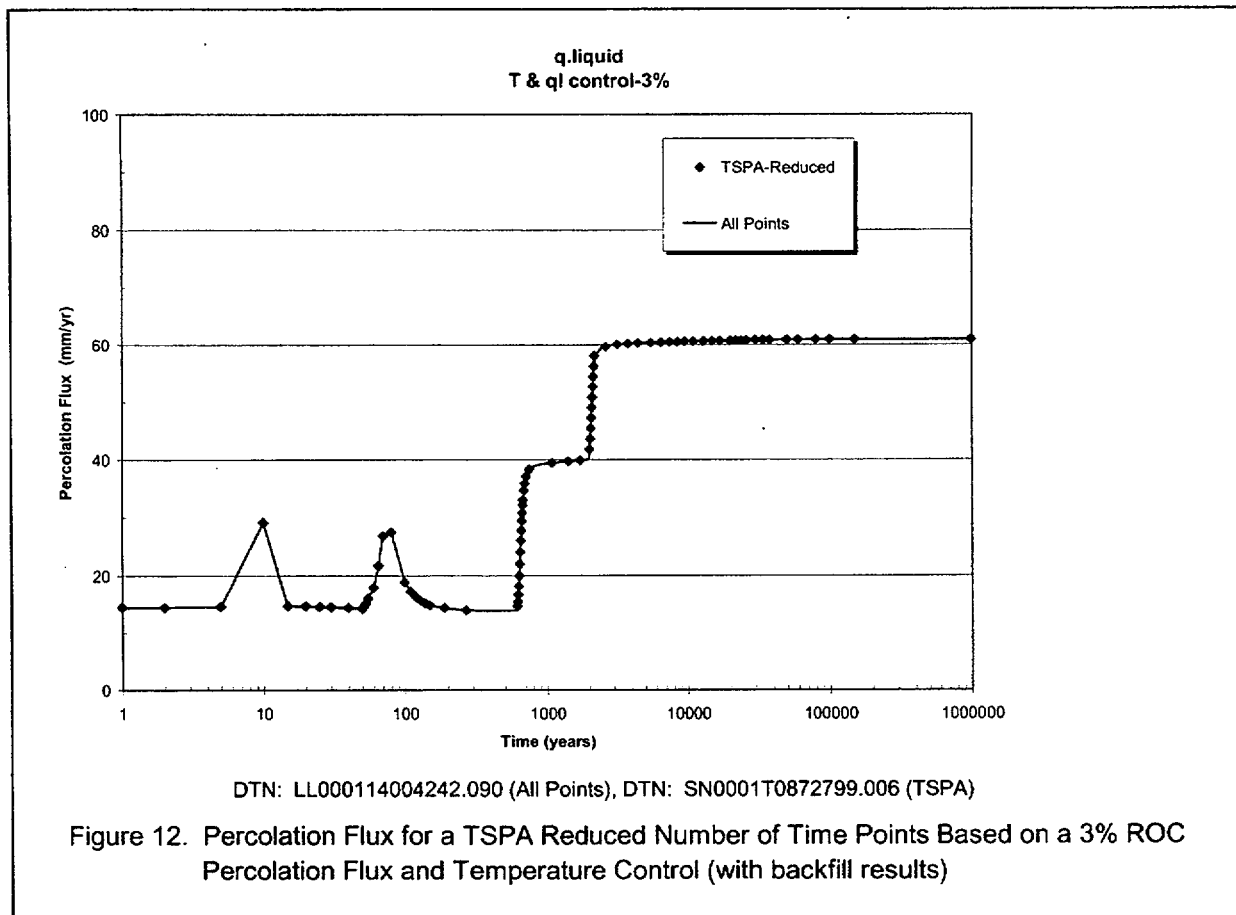


DTN: LL000114004242.090 (All Points), DTN: SN0001T0872799.006 (TSPA)

Figure 7. Waste Package Relative Humidity for a TSPA Reduced Number of Time Points Based on a 3% ROC Percolation Flux and Temperature Control (with backfill results)

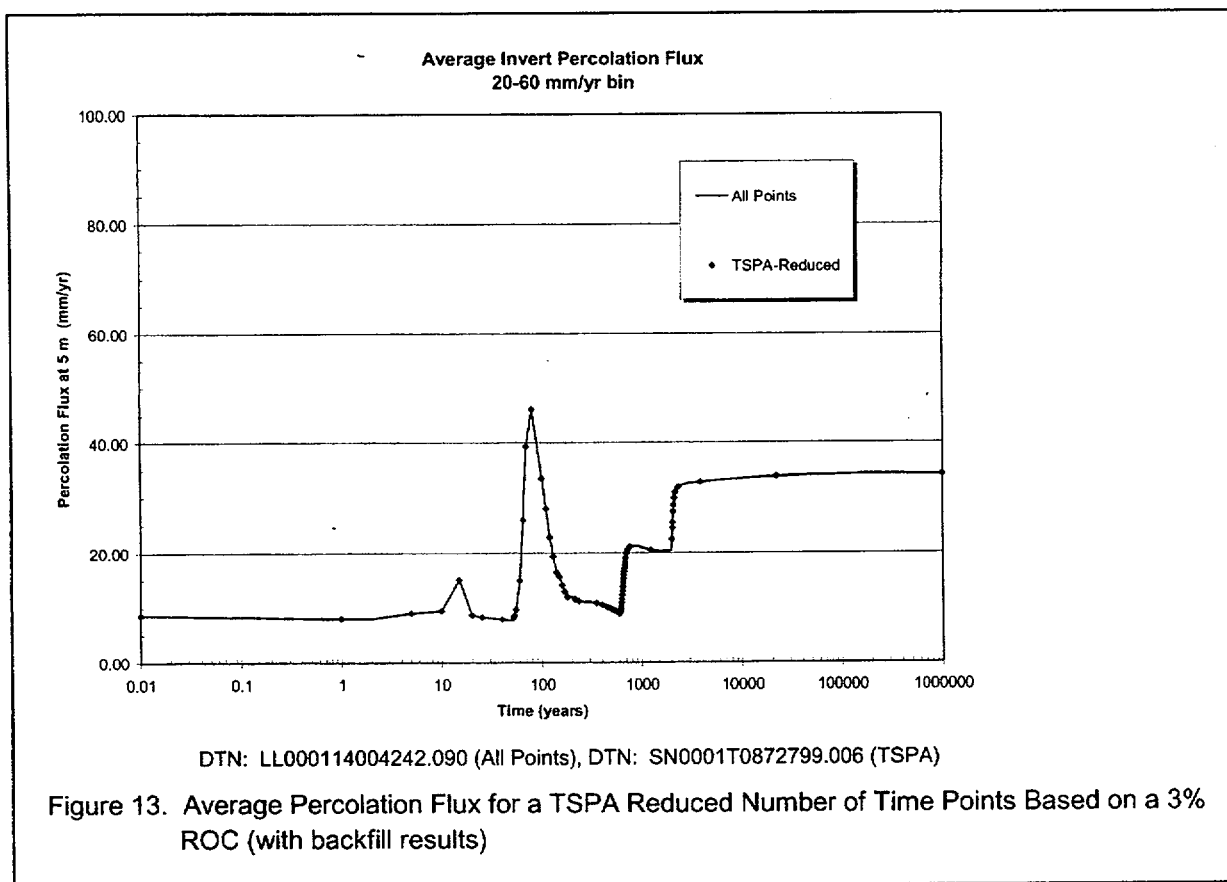




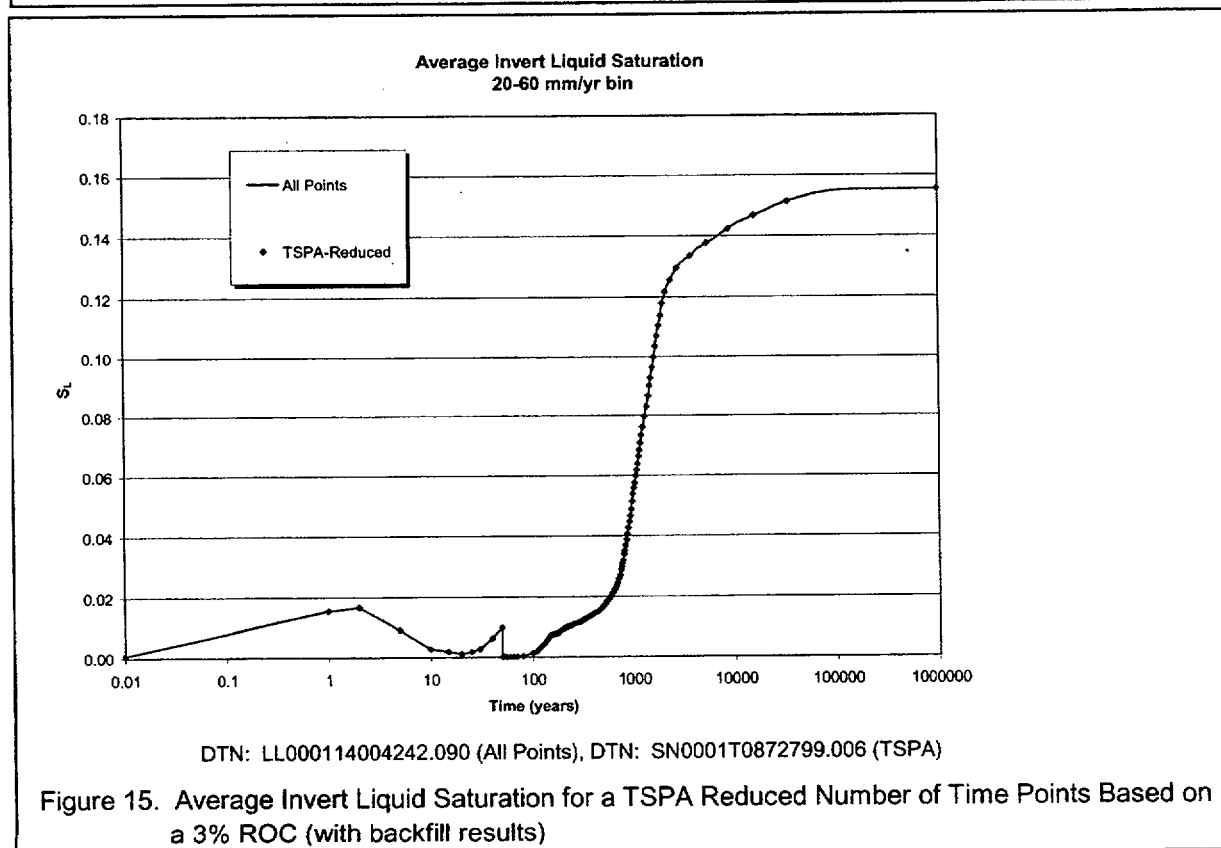
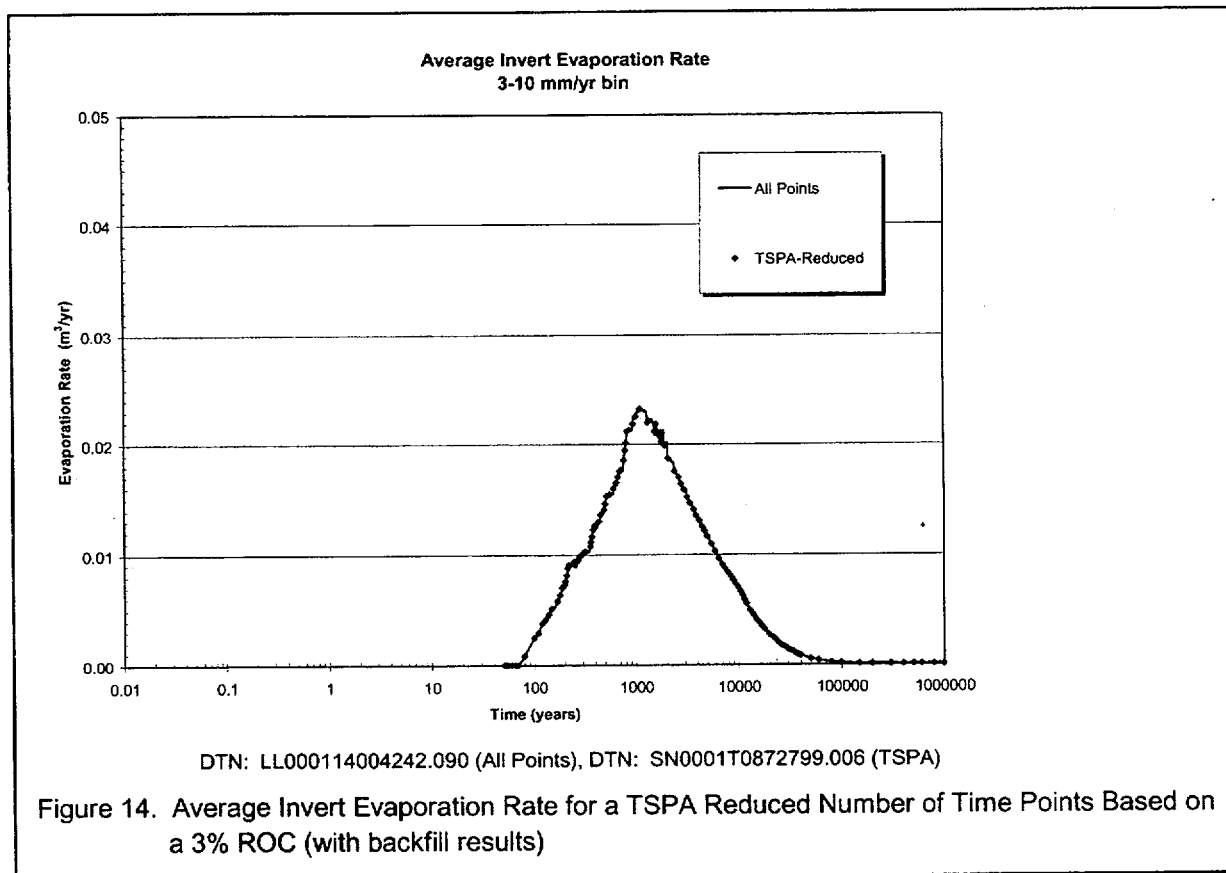


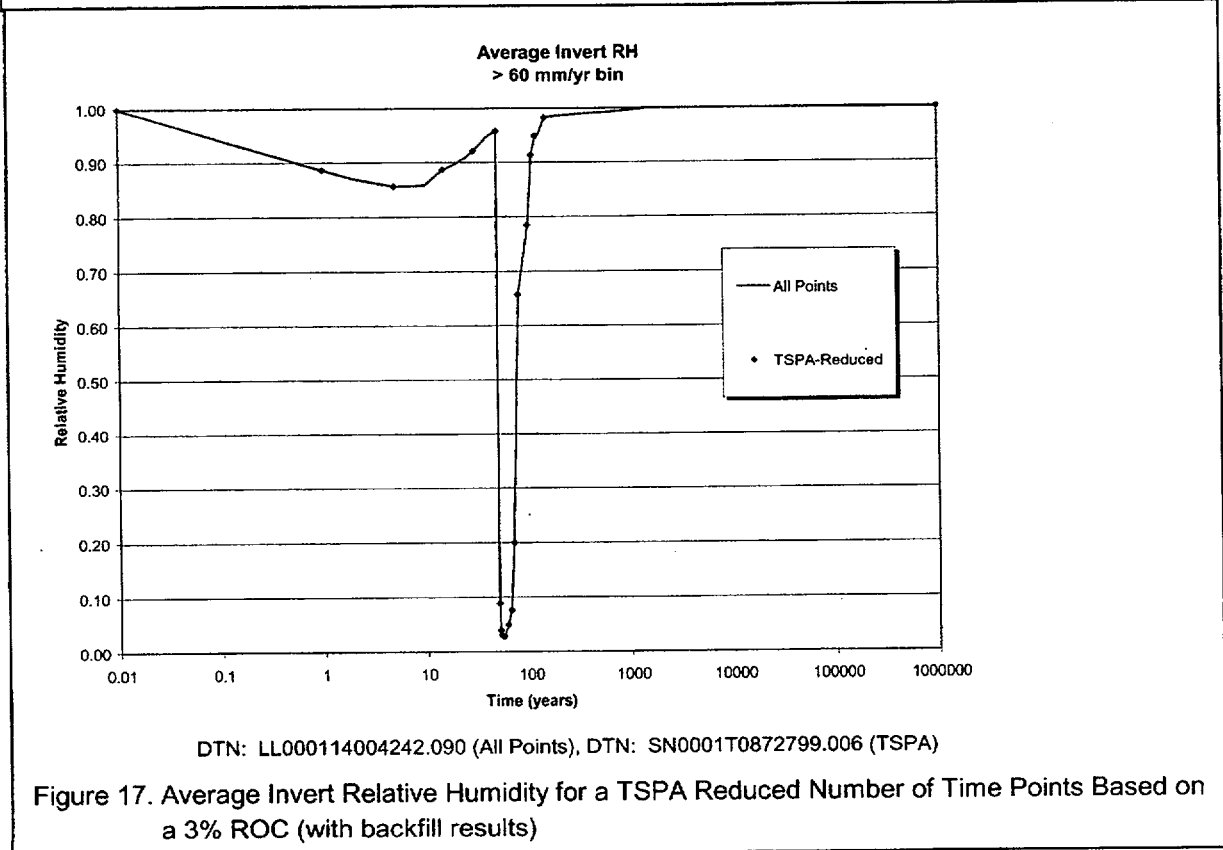
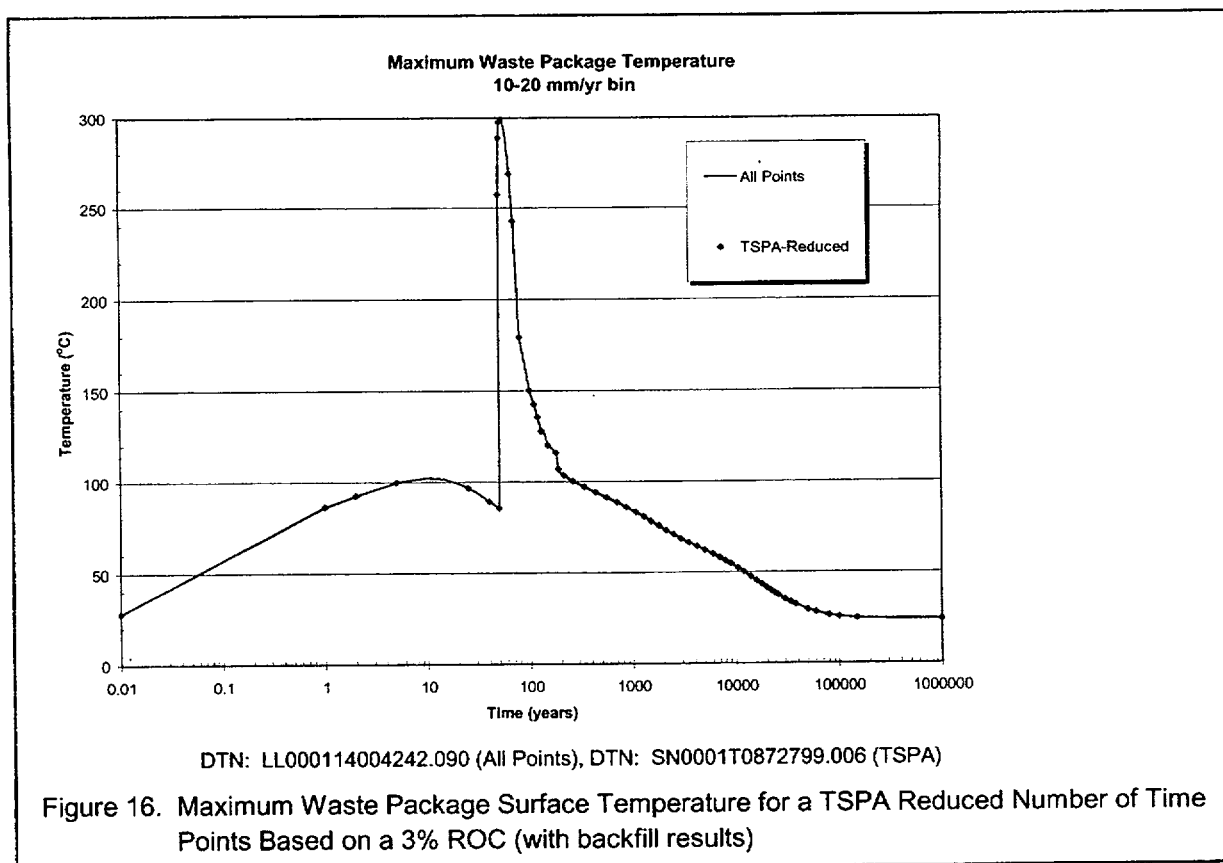
The raw data reduction described above is implemented in order to minimize runtime of the waste package corrosion model contained in the TSPA model. The seepage model also uses the percolation flux at the crown of the emplacement drift at each of the individual raw data locations (as contained within an infiltration bin). Since the variability in time point representation (from location-to-location within an infiltration bin) will not allow for a consistent data input into the seepage model, an additional raw file is needed for the TSPA model that contains all of the percolation flux data at both 3 and 5 m above the crown of the drift.

Similar time print restrictions are placed on the averaged (or max and min) results specified in Table 4. In the case of the averaged data, time print control for that parameter is based on Equation 3 where  $X$  is the parameter itself (not necessarily waste package temperature or percolation flux at 5 m, although these happen to be required as well). Using a 3% rate of change (recall actual abstraction uses 5% for the low infiltration case, 3% for the mean and high infiltration rate cases), the averaged results are the following. In the cases where zero is the result maintained over a specific time period (e.g., invert liquid saturation that remains dry for a number of years), the duration of the zero result is retained in the file used by the TSPA model. Some examples follow in Figures 13 through 17 of various infiltration bins for the mean infiltration rate case.









There are very few limitations/restrictions on this software routine (TH-msmabs\_ver\_1) or its validity of use. The routine is completely flexible through one simple change in the routine coding. The parameter statement in the routine can easily be changed as needed as the number of location dependent raw files (process-level inputs, in this case 623 for the backfill design case—see next section), time points in the raw files (442 time points for low, 352 mean, and 457 high infiltration flux cases), or infiltration bins (=5), change. The routine is verified (in Attachment I) for the ranges of validity given in parenthesis above. If the data format in the resulting process-level model data files change (e.g., new variables are added as columns to the process-level model outputs—which are the abstraction routine inputs), format statements in the routine would have to be changed to reflect the new/changed variables so that an accurate read can be made. However, this only requires minor modifications to the read/write statements of the routine. Note that the primary abstraction routine requires a driver input file that provides the routine input and output filenames that the TH abstraction data are read in from and written out to. The number of files listed in the input file and the order in which they are expected by the primary abstraction routine are given in the write statements that appear during the runtime of this software routine. A total of 76 filenames (some contain the filenames to be read in, others used for output to be written to) are required in the input file used to initialize the routine developed for the TH abstraction for the backfilled repository design. Additionally, the primary abstraction routine requires a single file that contains the filenames of all location dependent results from the multiscale TH model (e.g., 623 for the backfill repository design). Finally, the working directory in which these two files reside (and the executable for the routine) must contain the 623 files of data to be abstracted from.

As stated above, the primary TH abstraction routine (TH-msmabs\_ver\_2) for the without backfill TH abstraction did not require the same reduction of data points in time as described above for the backfilled repository design abstractions. As before, this routine is also completely flexible since it stems from the routine just described. The parameter statement in the routine can easily be changed as needed as the number of location dependent raw files (process-level inputs, in this case 610 for the without backfill case—see next section), time points in the raw files (99 time points for low, mean, and high), or infiltration bins (=5), change. The routine is verified (in Attachment IV) for the ranges of validity given in parenthesis above. If the format of the resulting process-level model data files change (e.g., new variables are added as columns to the process-level model outputs—which are the abstraction routine inputs), format statements in the routine would have to be changed to reflect the new/changed variables so that an accurate read can be made. This only requires minor modifications to the read/write statements of the routine. Note that as in the previous case, the primary abstraction routine requires a driver input file that provides the routine input and output filenames that TH abstraction data are read in from and written out to. The number of files needed and the order in which they are expected by the primary abstraction routine is given in the write statements that appear during the runtime of this routine. A total of 86 filenames (some contain the filenames to be read in, others used for output to be written to) are required in the input file used to initialize the routine developed for the TH abstraction for no backfill repository design. Additionally, the primary abstraction routine requires a single file that contains the filenames of all location dependent results from the multiscale TH model (e.g., 610 for the no backfill repository design). Finally, the working directory in which these two files reside (and the executable for the routine) must contain the 610 files of data to be abstracted from.

The backfill TH abstraction contains 623 different repository locations while the no backfill TH abstraction contains 610 different repository locations (CRWMS M&O 2000d, Sections 6., 6.11, 6.12). The difference in abstracted locations is due to a reallocation of modeled grid blocks out of the repository footprint for the no backfill case.

The TH abstraction results for the backfill repository design reside in the technical data management system (TDMS) under the data tracking number, DTN: SN0001T0872799.006 and DTN: SN0002T0872799.008. These TH data submittals to the TDMS are unqualified since their source inputs are unqualified. The TH abstraction results for the no backfill repository design reside in the TDMS under the data tracking number, DTN: SN0007T0872799.014. These TH data submittals to the TDMS are unqualified since their source inputs are unqualified.

## **6.2 INFILTRATION RATE BINNING**

For waste-package-degradation calculations within a TSPA simulation, the full range of environmental conditions is used. That is, each waste package for which degradation is modeled has its own histories of temperature, relative humidity, etc., drawn from the population of histories provided (e.g., 610 locations) by the multiscale thermal-hydrologic model. However, the calculation of radionuclide releases within a TSPA simulation is simplified by lumping waste packages together into groups. In the release calculations, all waste packages in a group have common environmental conditions—that is, the same histories of temperature, relative humidity, etc. (Note that the waste packages in a group do not all fail at the same time, though, because of the additional variability in the waste-package-degradation calculation.)

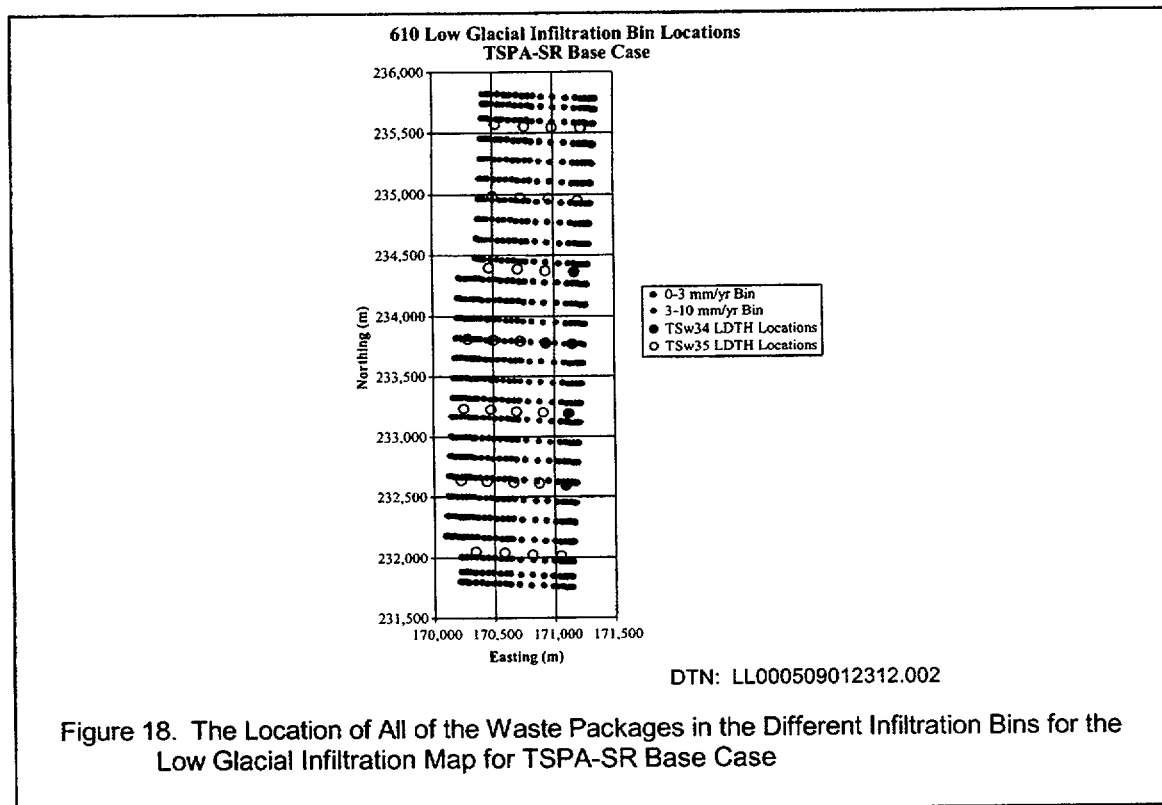
For the Viability Assessment, waste-package groups were based on physical location (six repository subregions), waste type (commercial spent nuclear fuel, vitrified high-level waste, or DOE spent nuclear fuel), and seepage (always exposed to seepage, exposed to seepage during the wettest two climates, exposed to seepage only during the wettest climate, or never exposed to seepage) (CRWMS M&O 1998b, Section 11.2.1.3). For the Site Recommendation, the waste-package groups are based on infiltration rather than physical location, because radionuclide dissolution and release depend more directly on infiltration than on repository location.

The five infiltration “bins” used are as follows: 0–3 mm/yr, 3–10 mm/yr, 10–20 mm/yr, 20–60 mm/yr, and 60+ mm/yr. They were chosen based on the distributions of glacial-transition infiltration for the three infiltration cases and on important flux levels in the seepage abstraction. The glacial-transition infiltration is used because the glacial-transition climate is in effect most of the time during a TSPA simulation (after 2000 years), and it is in effect during later times when radionuclide releases are most likely. The considerations in choosing the bins were as follows.

Three sets of seepage curves were defined for the seepage abstraction, corresponding to a lower-bound case, a most-likely case, and an upper-bound case for seepage (CRWMS M&O 2000b, Section 6.4 and Table 11). Each of those cases has a percolation-flux threshold, below which there is no seepage: 3.4 mm/yr for the upper bound case, 9.9 mm/yr for the most likely case, and 97.9 mm/yr for the lower bound case (DTN: SN9912T0511599.002). The first two bin boundaries (3 mm/yr and 10 mm/yr) were rounded from the seepage thresholds for the upper-bound and most-

likely cases. The seepage threshold for the lower-bound case is so high that few waste-package locations have infiltrations above it, so it was not used in defining the bins. Instead, the other bin boundaries were chosen primarily in order to differentiate among the three infiltration cases (complete differentiation is not possible since the infiltration distributions for the three cases have considerable overlap). With the bins as defined above, waste packages in low-infiltration realizations are all in the first two bins (i.e., between 0 and 10 mm/yr), waste packages in mean-infiltration realizations are mostly in the third and fourth bins but with some in the other bins as well, and waste packages in high-infiltration realizations are mostly in the fourth and fifth bins but with some in the second and third bins (refer to Tables 5 and 6).

The infiltration rate bins for the base case defined by TSPA are distributed over the repository footprint as shown (for the low, mean, and high infiltration flux cases) in Figures 18-20. Each infiltration flux case (e.g., the mean infiltration) contains 610 location dependent data results from the process-level model (refer to CRWMS M&O 2000d, Sections 6.10 and 6.11). The plotted result below is representative of the infiltration rate during the glacial transition climate state. The spatial location (or repository coverage) of each infiltration bin is given in Figures 18 through 20 for each infiltration flux case considered in the abstraction. The figures also indicate the location of the 31 line-averaged, drift-scale, thermal hydrology (LDTH) models (CRWMS M&O 2000a and 2000d, Section 6.3.1).



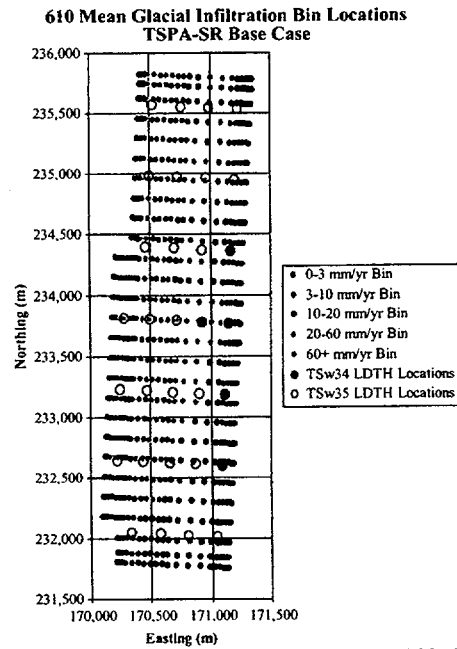


Figure 19. The Location of All of the Waste Packages in the Different Infiltration Bins for the Mean Glacial Infiltration Map for TSPA-SR Base Case

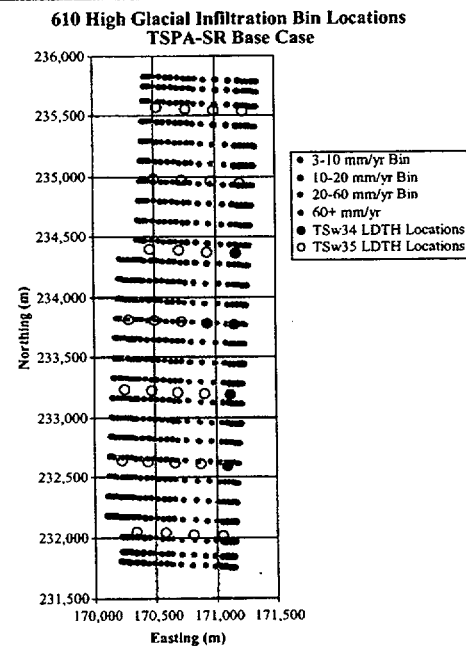


Figure 20. The Location of All of the Waste Packages in the Different Infiltration Bins for the High Glacial Infiltration Map for TSPA-SR Base Case

The number of waste package locations that fall into particular infiltration rate bins for all three infiltration flux cases for the TSPA-SR base case are presented in Table 5 (information extracted from waste package files in DTN: LL000509012312.002, LL000509112312.003, and LL000509212312.004). Since the location dependent data (610 different process-level model results) from the process-level model are representative of different footprint area fractions, the repository represented (by a particular bin) is not computed as the fraction of the number of entries (e.g., repository area fraction is not equal to 170/610 for the 10-20 mm/yr bin in the mean infiltration rate case). The results in Table 5 are based on the sum of each of the individual area fractions of the data that fall into a particular infiltration bin.

Table 5. Distribution of Process-Level Model Results within Infiltration Bins for the TSPA-SR Base Case

<b>Low Infiltration Case</b>	<b>Number of Process-Level Model Entries in the Bin</b>	<b>Repository Area Fraction (%)</b>
0-3 mm/yr	361	59.9
3-10 mm/yr	249	40.1
10-20 mm/yr	0	0
20-60 mm/yr	0	0
60+ mm/yr	0	0
<b>Mean Infiltration Case</b>	<b>Number of Process-Level Model Entries in the Bin</b>	<b>Repository Area Fraction (%)</b>
0-3 mm/yr	4	0.3
3-10 mm/yr	102	13.9
10-20 mm/yr	170	32.1
20-60 mm/yr	331	53.4
60+ mm/yr	3	0.3
<b>High Infiltration Case</b>	<b>Number of Process-Level Model Entries in the Bin</b>	<b>Repository Area Fraction (%)</b>
0-3 mm/yr	0	0
3-10 mm/yr	14	1.2
10-20 mm/yr	95	13.3
20-60 mm/yr	314	55.3
60+ mm/yr	187	30.2

DTN: LL000509012312.002, LL000509112312.003, and LL000509212312.004

The waste package thermal environment as described by the resulting location dependent process model data is strongly dependent upon the results from the mountain scale thermal-conduction submodel (CRWMS M&O 2000a and 2000d, Section 6.2). Consequently, the variability of temperature and relative humidity within each bin will be a strong function of the spatial distribution of the waste packages within the repository. The waste packages at the edge of the repository will cool off quicker than those near the center of the repository due to higher lateral heat losses. As a result, the number of waste packages located near the center and near the edge of the repository will strongly affect the variability of the temperature and relative humidity time-histories in each bin. The

31 LDTH models have been placed on the plots. Five of the LDTH models are located in the repository horizon geology called middle non-lithophysal (TSw34 using UZ flow model nomenclature) with the other 26 located in the lower-lithophysal repository host unit (TSw35 using UZ flow model nomenclature).

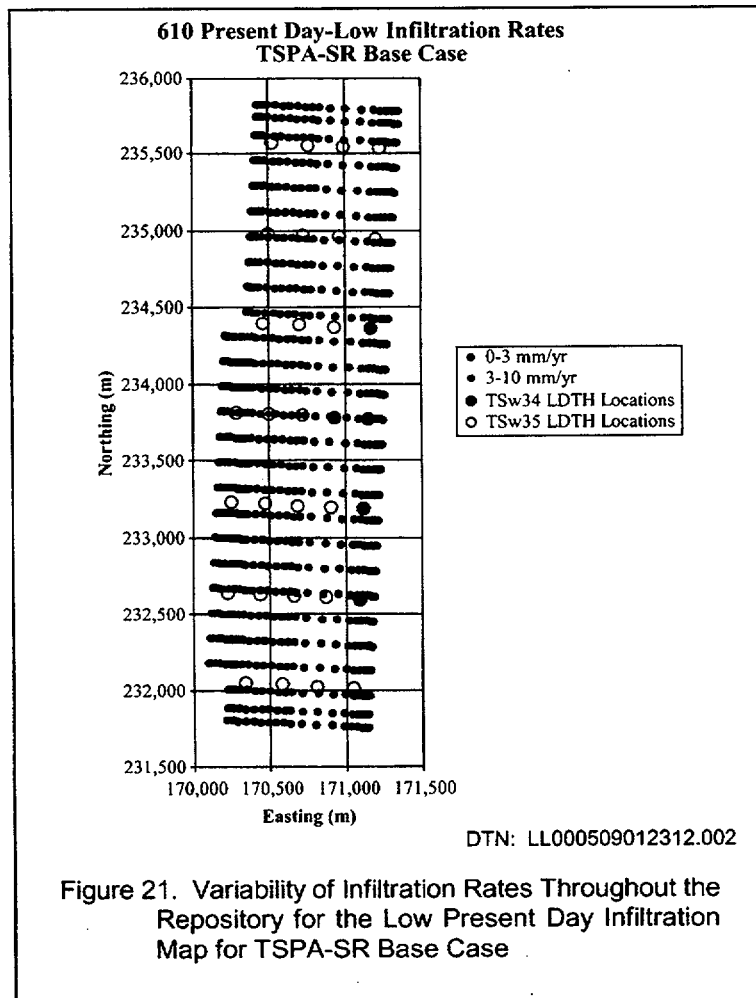
For the low infiltration flux case, only the driest two infiltration bins are populated. Waste packages are located in the interior and near the edges of the repository in both infiltration bins. For the mean infiltration map, all five bins are populated. Over half of the waste packages are in the 20-60 mm/year bin and only three waste packages fell in the 60+ mm/year bin. The four waste packages in the lowest infiltration bin and the three waste packages in the highest infiltration rate bin are all located at edge locations while the other three infiltration bins contain waste packages near the center of the repository as well as at the edge of the repository.

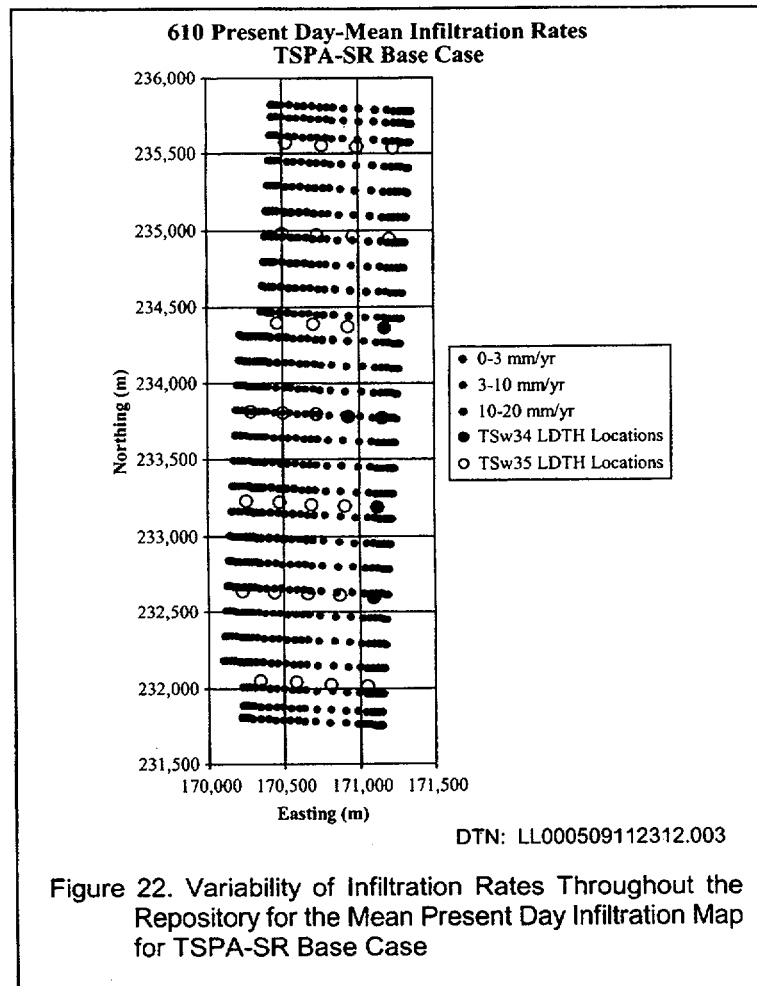
For the high infiltration flux case, only the four highest infiltration bins are populated with waste packages. The 3-10 mm/year infiltration flux bin contains 14 waste packages, all of which are on the eastern edge of the repository. The other three infiltration rate bins contain waste packages at the center and at the edge of the repository footprint.

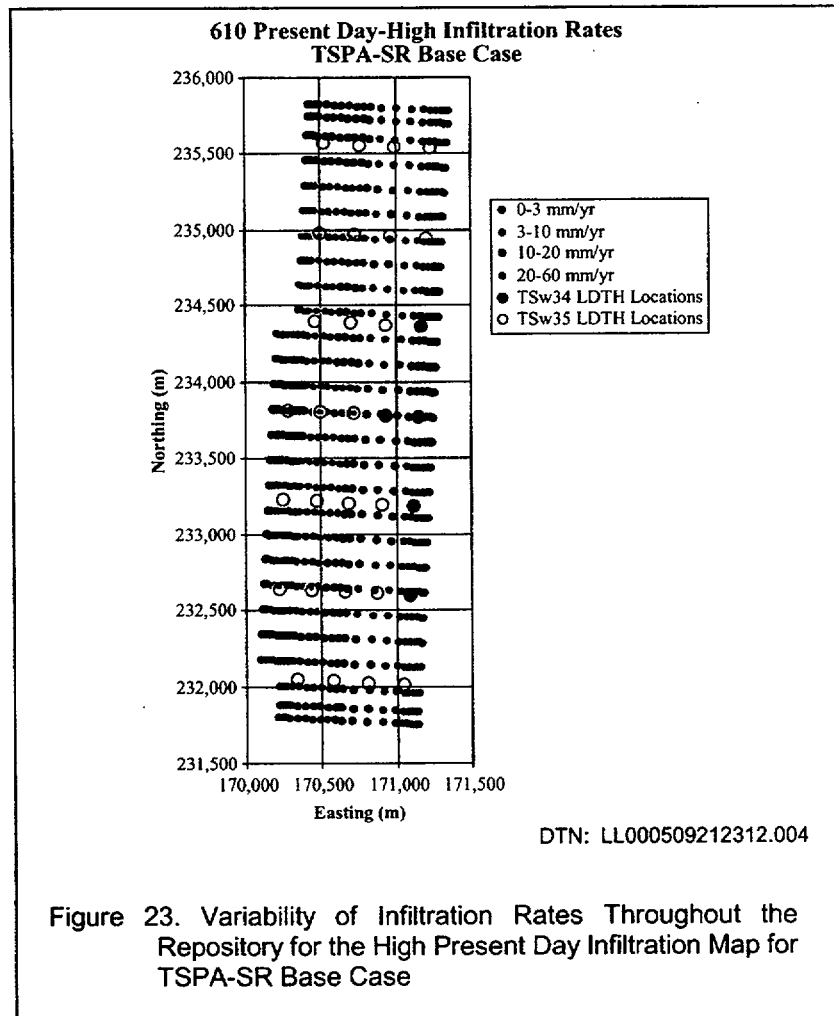
Some of the TSPA required quantities from the TH abstraction (as given in Table 4) are average values based on the location dependent results that fall within a given infiltration bin (accounting for the appropriate area fraction "weight" of the location dependent data from the process-level model). The figures below provide a visual representation of the spatial locations of an average value for the low, mean, and high infiltration flux cases. The TSPA raw files, a total of 610 location dependent results as specified in Table 3, are used in the waste package corrosion model and are located within the infiltration bins as shown below for each of the three cases. So, as an example, the 60+ mm/yr bin for the mean infiltration rate case contains TSPA averaged and raw data based on the results of three process-level model locations with the average curve as shown in Figure 33.

The infiltration rate distribution for the base case for the present-day climate low, mean, and high infiltration flux cases are shown in Figures 21-23. Comparing the figures reveals that the overall present day infiltration rates are much lower than those for the glacial transition climate previously shown.









The infiltration rate bins for the backfill design alternative as defined by TSPA are distributed over the repository footprint are shown (for the low, mean, and high infiltration flux cases) in Figures 24-26. The representation of the repository is changed slightly between the backfill design alternative and the TSPA-SR base case so both the number and bin distribution of waste package locations are slightly different. Each infiltration rate case contains 623 location dependent data results (instead of 610) from the process-level model (refer to CRWMS M&O 2000a, Sections 6.10 and 6.11). The spatial location (or repository coverage) of each infiltration bin is given in Figures 24 through 26 for each infiltration rate case considered in the abstraction. The figures also indicate the location of the 31 LDTH models (CRWMS M&O 2000a, Section 6.3.1).

**623 Low Glacial Infiltration Bin Locations  
TSPA-SR Backfill Design Alternative**

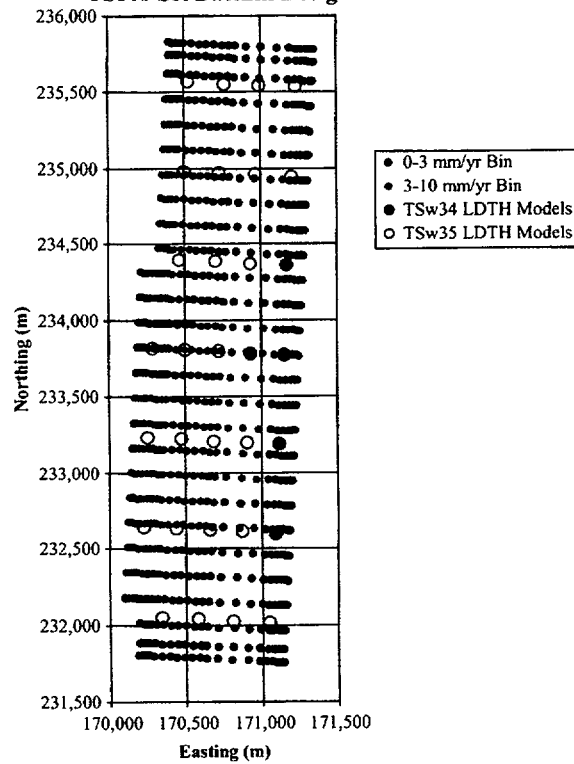


Figure 24. The Location of All of the Waste Packages in the Different Infiltration Bins for the Low Glacial Infiltration Map Backfill Design Alternative

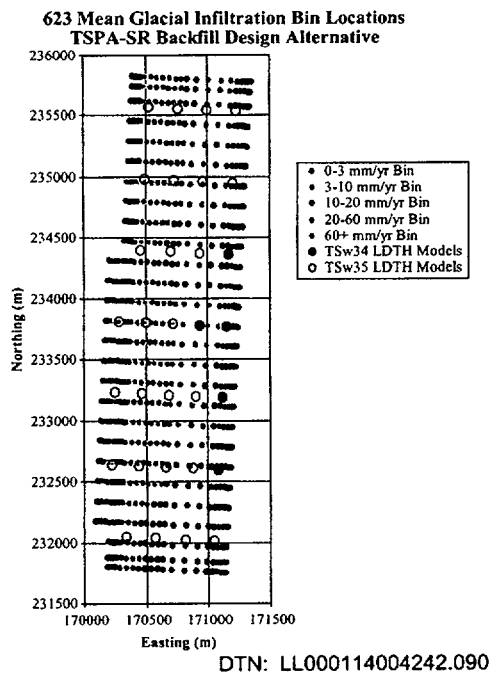


Figure 25. The Location of All of the Waste Packages in the Different Infiltration Bins for the Mean Glacial Infiltration Map Backfill Design Alternative

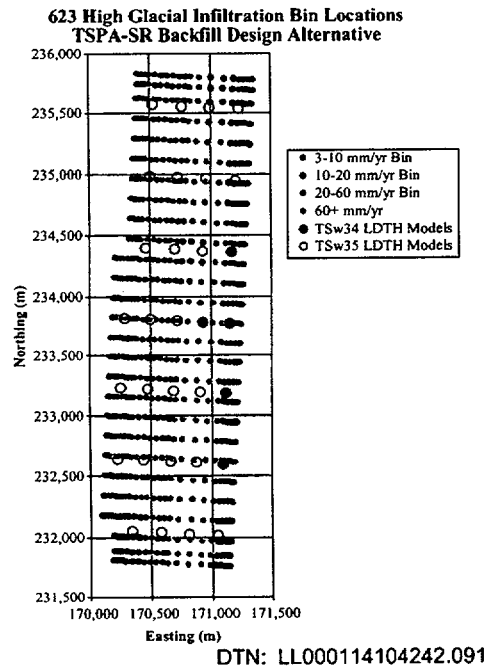


Figure 26. The Location of All of the Waste Packages in the Different Infiltration Bins for the High Glacial Infiltration Map Backfill Design Alternative

The number of waste package locations that fall into particular infiltration rate bins for all three infiltration flux cases for the backfill design alternative are also presented in Table 6 (information extracted from waste package files in DTN: LL000114004242.090, LL000114104242.091, and LL000113904242.089).

Table 6. Distribution of Process-Level Model Results within Infiltration Bins for the TSPA-SR Backfill Design Alternative

<b>Low Infiltration Case</b>	<b>Number of Process-Level Model Entries in the Bin</b>	<b>Repository Area Fraction (%)</b>
0-3 mm/yr	368	59.7
3-10 mm/yr	255	40.3
10-20 mm/yr	0	0
20-60 mm/yr	0	0
60+ mm/yr	0	0
<b>Mean Infiltration Case</b>	<b>Number of Process-Level Model Entries in the Bin</b>	<b>Repository Area Fraction (%)</b>
0-3 mm/yr	21	1.6
3-10 mm/yr	91	13.2
10-20 mm/yr	174	32.1
20-60 mm/yr	334	52.9
60+ mm/yr	3	0.3
<b>High Infiltration Case</b>	<b>Number of Process-Level Model Entries in the Bin</b>	<b>Repository Area Fraction (%)</b>
0-3 mm/yr	0	0
3-10 mm/yr	14	1.2
10-20 mm/yr	98	13.4
20-60 mm/yr	318	54.8
60+ mm/yr	193	30.6

DTN: LL000114004242.090, LL000114104242.091, and LL000113904242.089

### 6.3 TH ABSTRACTION RESULTS FOR THE NO BACKFILL (BASE CASE) REPOSITORY DESIGN

Waste packages are divided into two types: commercial spent nuclear fuel (CSNF) and co-disposed waste (CDSP). Co-disposed waste consists of a combination of vitrified high-level waste (HLW) and DOE spent nuclear fuel in a waste package. In addition to having different radionuclide inventories, the waste type affects the local temperature, relative humidity, seepage, and chemistry because CDSP packages tend to be somewhat cooler than CSNF packages.

### 6.3.1 CSNF Temperature Profiles

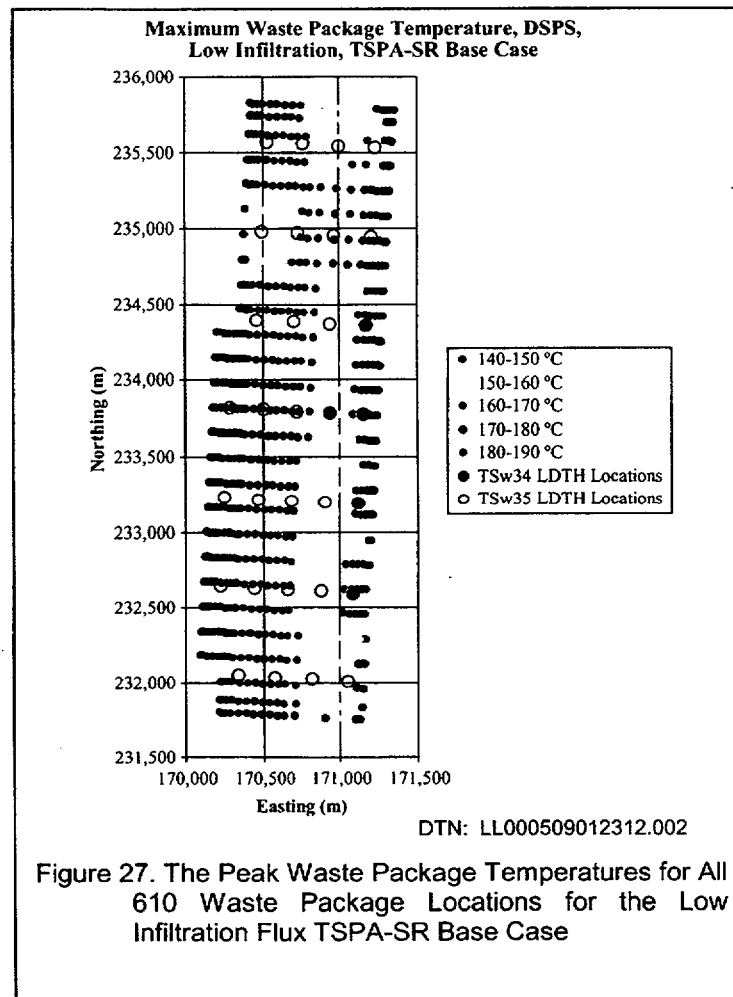
There is considerable variability in the peak waste package temperatures throughout the repository for different glacial infiltration flux cases. The peak waste package temperature is important to TSPA since high temperatures can lead to creep rupture or stress corrosion cracking of the fuel cladding. The highest, the mean, and the lowest peak waste package temperatures for all of the bins and infiltration flux cases for both HLW and CSNF are presented in Table 7. The peak waste package temperatures all occurred during the first 20 years after closure (50-70 year simulation times). The peak waste package temperatures occurred near 55 years at the edges of the repository and near 70 years at the center of the repository. The highest peak waste package temperature of 186°C was a CSNF waste package in the 3-10 mm/year bin of the low infiltration flux case. The lowest maximum waste package temperature of 127°C was for a HLW waste package in the 20-60 mm/year bin in the high infiltration flux case. The bin averaged CSNF waste package peak temperatures were between 9 and 14°C higher than the corresponding HLW bin averaged waste package peak temperatures. This table illustrates the variability in the peak temperature contained inside individual bins as well as the variability in thermal response throughout the repository.

Table 7. The Minimum, Mean, and Maximum of the Peak CSNF and HLW Waste Package Temperatures(°C) for All Bins for the Three Infiltration Flux Cases for the TSPA-SR Base Case

Bin (mm/yr)	Infiltration Flux Map	HLW Min (°C)	HLW Mean (°C)	HLW Max (°C)	CSNF Min (°C)	CSNF Mean (°C)	CSNF Max (°C)
0-3	High	-	-	-	-	-	-
	Mean	159	159	160	173	173	173
	Low	129	151	170	140	162	184
3-10	High	131	149	156	141	162	169
	Mean	136	149	161	145	160	174
	Low	133	153	172	143	163	186
10-20	High	130	146	156	140	157	170
	Mean	131	144	161	141	154	175
	Low	-	-	-	-	-	-
20-60	High	127	141	156	138	151	170
	Mean	132	147	160	142	157	173
	Low	-	-	-	-	-	-
60+	High	137	144	154	146	154	166
	Mean	155	156	156	169	169	170
	Low	-	-	-	-	-	-
Overall	High	127	143	156	138	153	170
	Mean	131	146	161	141	157	175
	Low	129	152	172	140	162	186
Overall	Overall	127	147	172	138	157	186

DTN: SN0007T0872799.014

Figures 27 through 29 show spatial distribution of the peak waste package temperatures for the low, mean, and high infiltration flux cases for the TSPA-SR base case. For the mean infiltration flux case, the peak temperatures tended to be slightly higher near the edges of the repository (but they fall off far more rapidly compared to other locations) and slightly lower in the regions around the region of the repository contained in the TSw34. For the low infiltration flux case, there does not seem to be any correlation between the peak temperature and either infiltration, center/edge location, or repository host unit. For the high infiltration flux case, the peak waste package temperatures were lowest in the TSw34 host unit and highest in the TSw35 edge regions. (Note: DSPS in all figures refers to the drift-scale hydrologic property set used in the LDTH submodels.)





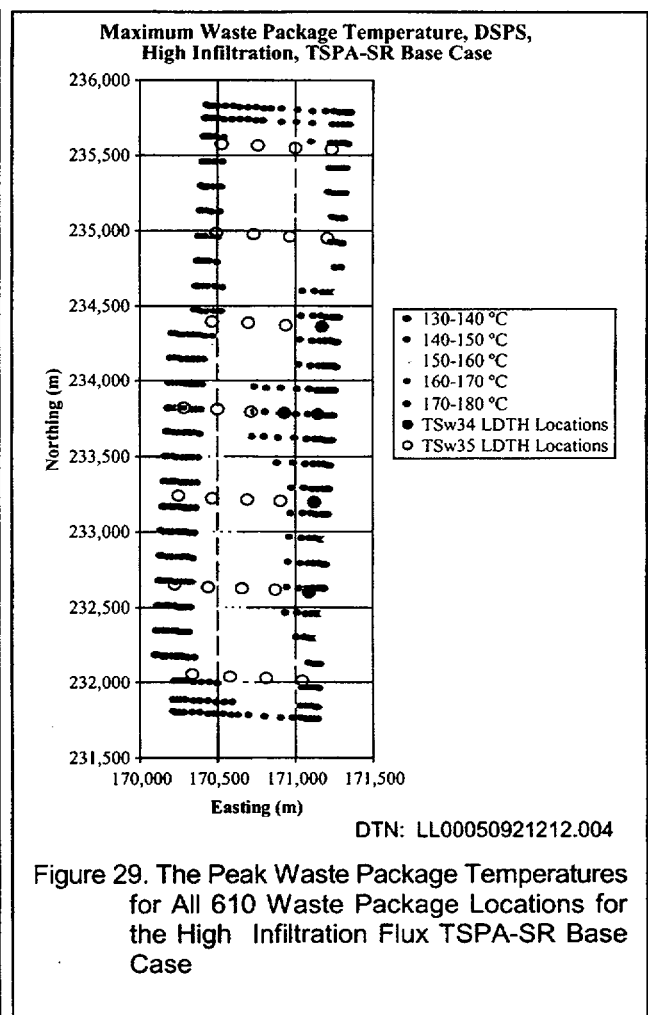
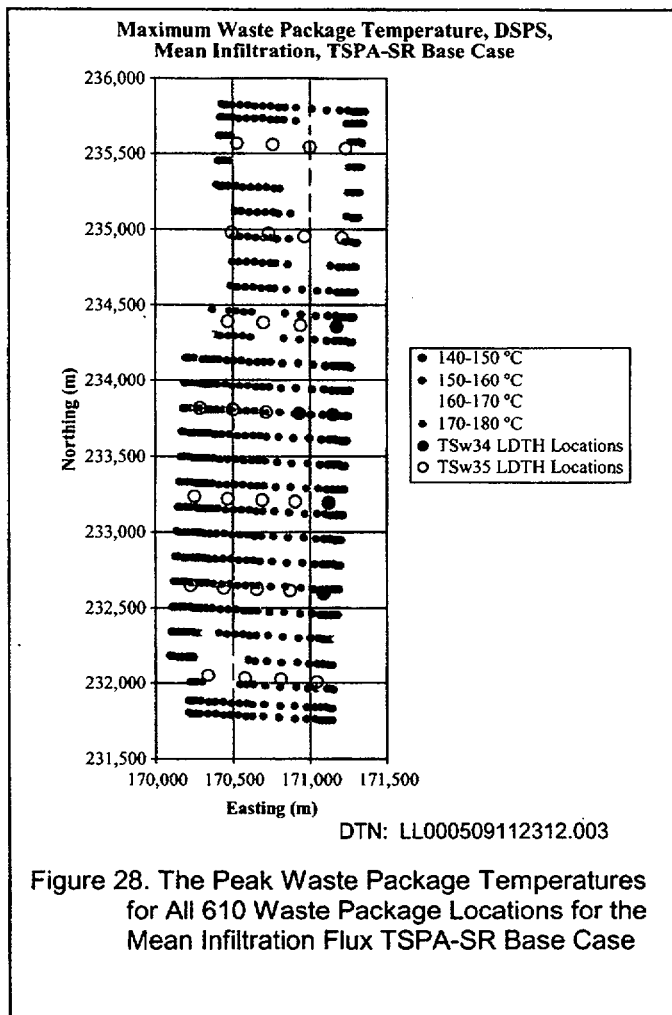


Table 8 contains the difference between the highest and lowest peak waste package temperature for each of the bins. The variability within each bin was as high as 40°C (HLW) and 44°C (CSNF) for the 0-3 mm/year in the low infiltration flux case. The small variability (~1°C) in the 0-3 and 60+ mm/year mean infiltration flux bins is directly attributable to there being only three waste packages in those two bins. The waste package locations in these bins were also adjacent to each other and had nearly identical local infiltration fluxes.

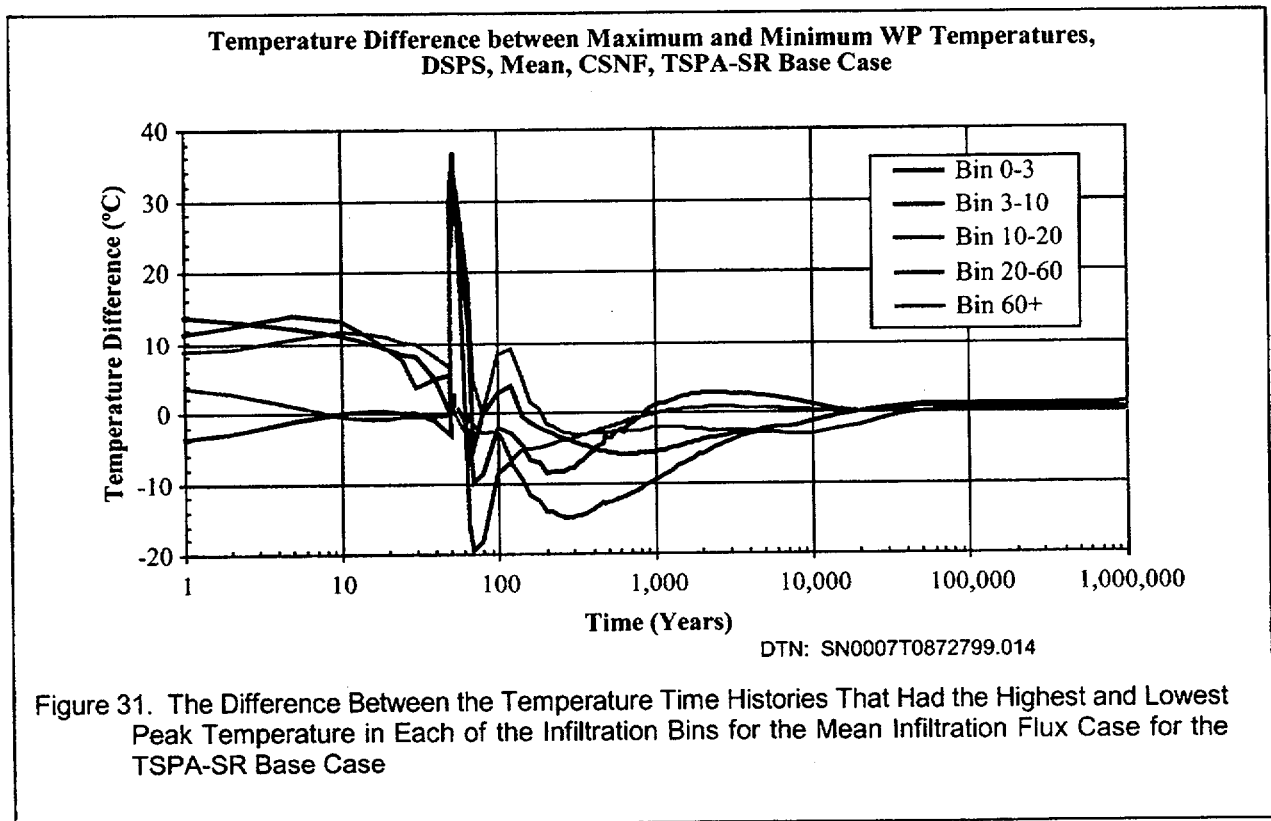
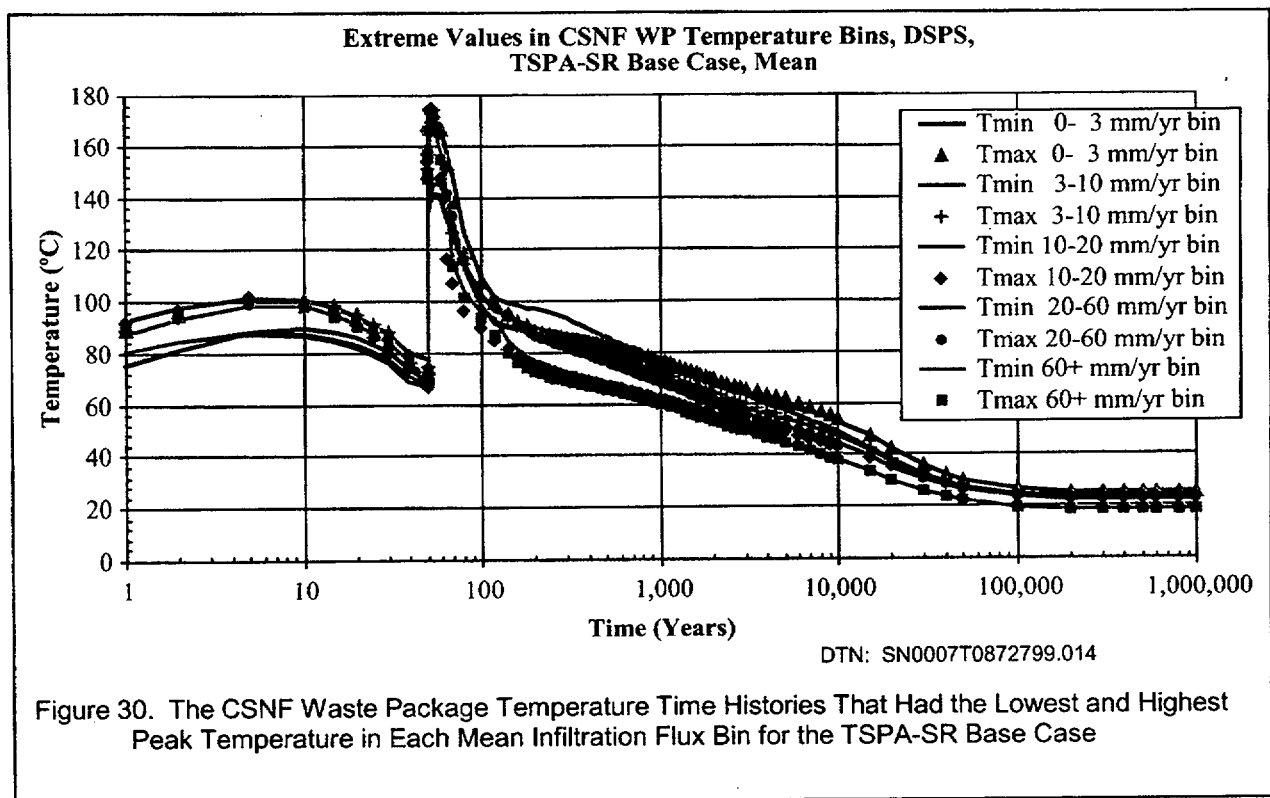
The variability within each infiltration rate flux case were between 29 and 43°C for the HLW waste packages and from 33 to 47°C for the CSNF waste packages. Overall, between waste package types and infiltration flux case, the difference between the highest and lowest peak waste package temperature was 59°C.

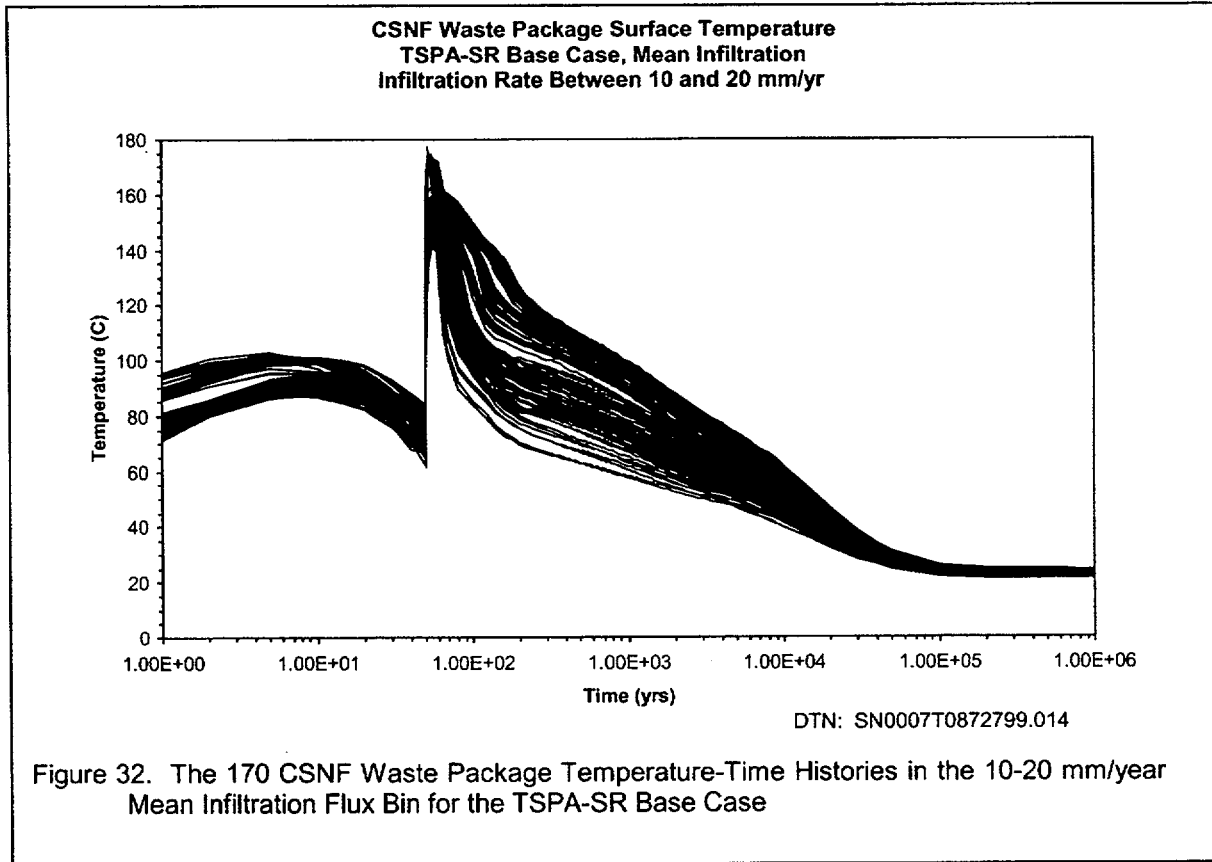
Table 8. The Difference Between the Highest and the Lowest Maximum Temperature (°C) in Each Bin for Each Infiltration Flux as well as the Overall Temperature Difference for Each Infiltration Flux TSPA-SR Base Case

Bin mm/yr	Infiltration Rate	HLW (°C)	CSNF (°C)	CSNF+HLW (°C)
0-3	High	-	-	-
	Mean	1	1	14
	Low	40	44	54
3-10	High	25	29	39
	Mean	25	29	38
	Low	39	43	53
10-20	High	26	29	40
	Mean	30	34	44
	Low	-	-	-
20-60	High	29	33	43
	Mean	28	31	41
	Low	-	-	-
60+	High	16	20	29
	Mean	1	0	14
	Low	-	-	-
Overall	High	29	33	43
	Mean	30	34	44
	Low	43	47	57
Overall	Overall	45	49	59

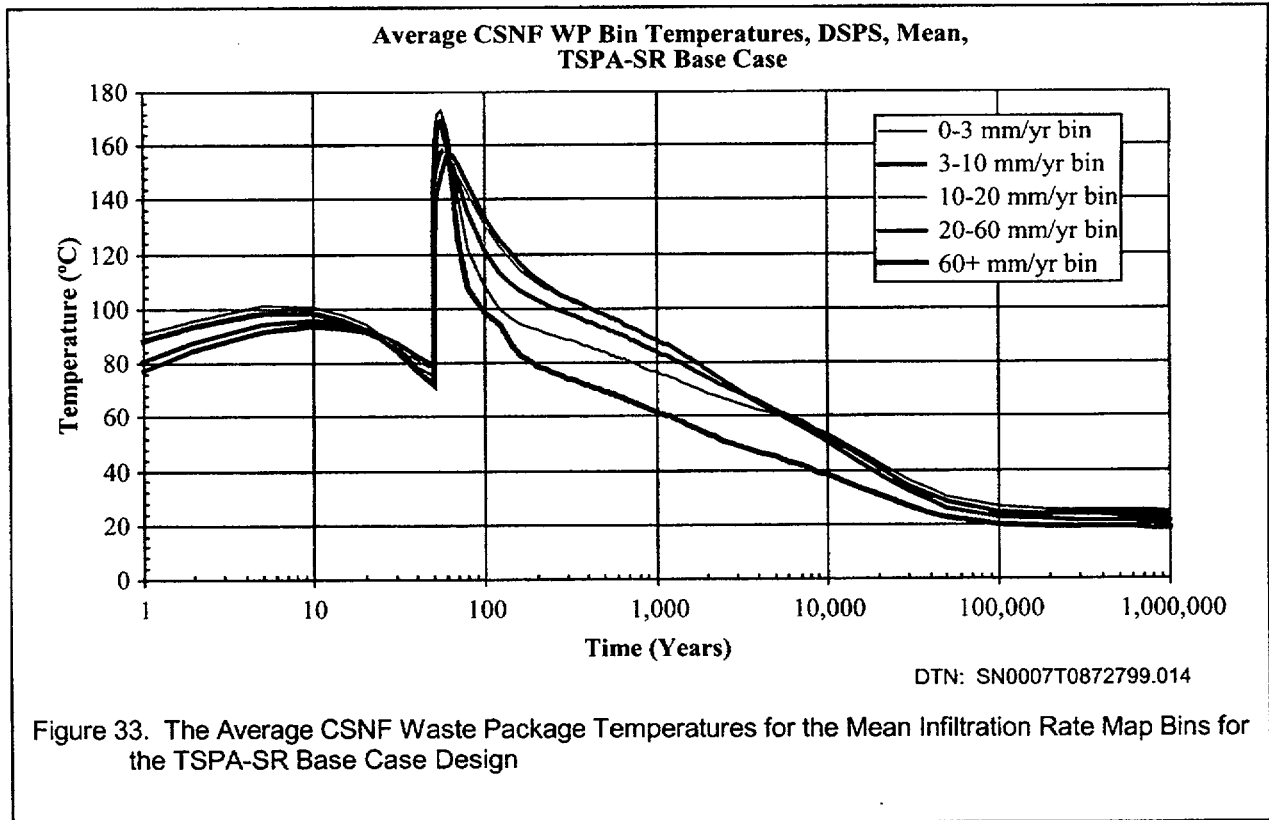
DTN: SN0009T0872799.014

Figure 30 shows the CSNF waste package temperature time history for the highest and lowest peak temperature curves in each of the five infiltration bins for the mean infiltration flux TSPA-SR base case. Figure 31 shows the difference between the highest and lowest peak temperature time-history curves for each of the infiltration bins for the no backfill, mean infiltration flux case. The largest difference between curves was 38°C just after closure for the 10-20 mm/year infiltration bin. The difference in temperature drops quickly after closure resulting in similar temperature-time histories for the minimum and maximum curves. After 150 years, the minimum and maximum curves are all within 15°C of each other. While capturing the variability in peak temperatures in each bin, Figure 31 masks the variability that exists within each of the infiltration bins after the peak temperature has been attained. Figure 32 shows all 170 of the CSNF waste package temperature-time histories for the locations in the 10-20 mm/year mean infiltration flux bin. At 100 years of simulation time, there is over 60°C difference between the hottest and coldest CSNF waste packages. The difference drops with time but the variability is still over 40°C after 1000 years and 20°C after 10,000 years.





The five infiltration bin averaged waste package temperature time-histories for the mean infiltration flux TSPA-SR base case are presented in Figure 33. The average maximum temperature for the bins were reached between 55 and 65 years and ranged from a low of 154°C for the 10-20 mm/year bin to a high of 173°C for the 0-3 mm/year infiltration rate bin. The 0-3 and 60+ mm/year infiltration rate waste package bins cooled off the quickest as a result of the waste packages all being at the edges of the repository. All of the bin-averaged waste package temperatures dropped below the local boiling temperature after 550 years. The average temperatures returned to ambient conditions within 100,000 years.



### 6.3.2 CSNF and HLW Waste Package Bin Temperature Comparison

The average CSNF and HLW waste package bin temperatures for the mean infiltration flux are presented in Figure 34. There is a steep rise in temperatures at the time of repository closure (50 years) with peak maximum bin averaged temperatures between 150 and 175°C. At 100 years after waste emplacement, there is much variability in the bin averaged temperatures from a low of 89°C (60+ mm/year HLW bin) to a high of 134°C (20-60 mm/year CSNF bin). After 1000 years of waste emplacement, the bin averaged temperatures ranged from a low of 58°C (60+ mm/year HLW bin) to a high of 88°C (20-60 mm/year CSNF bin).

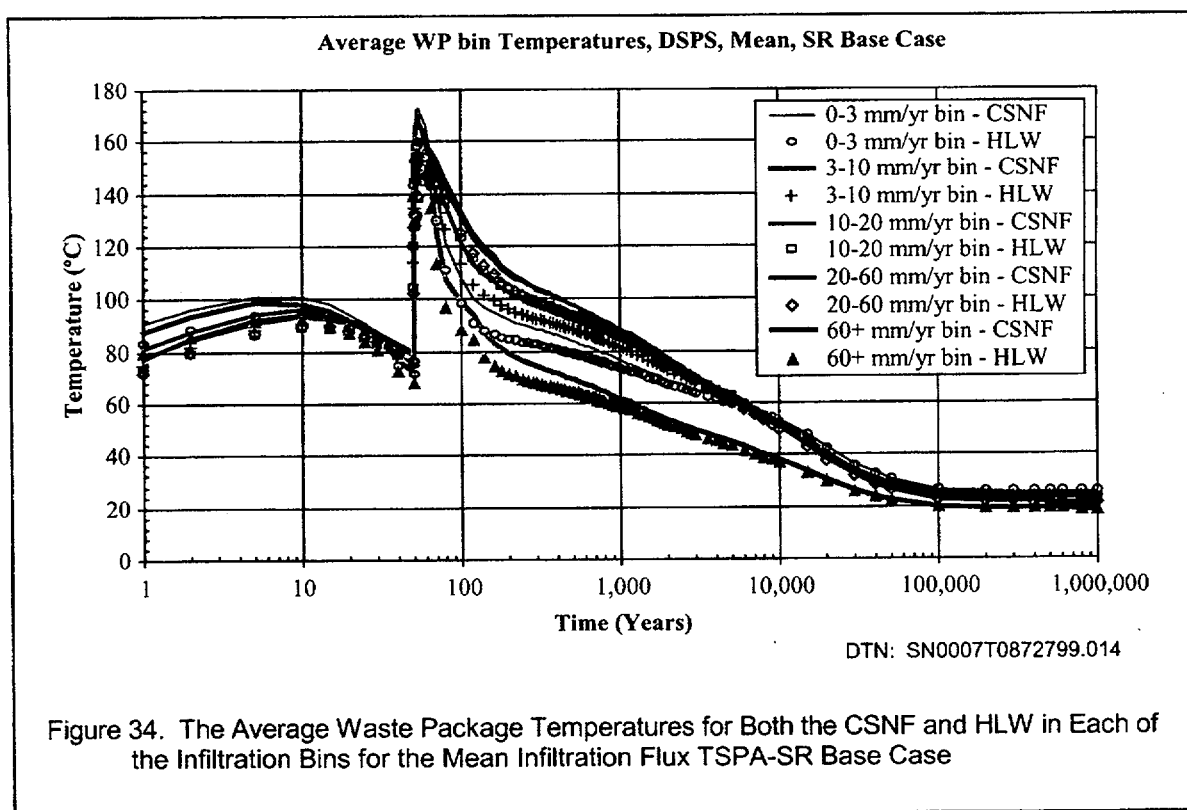
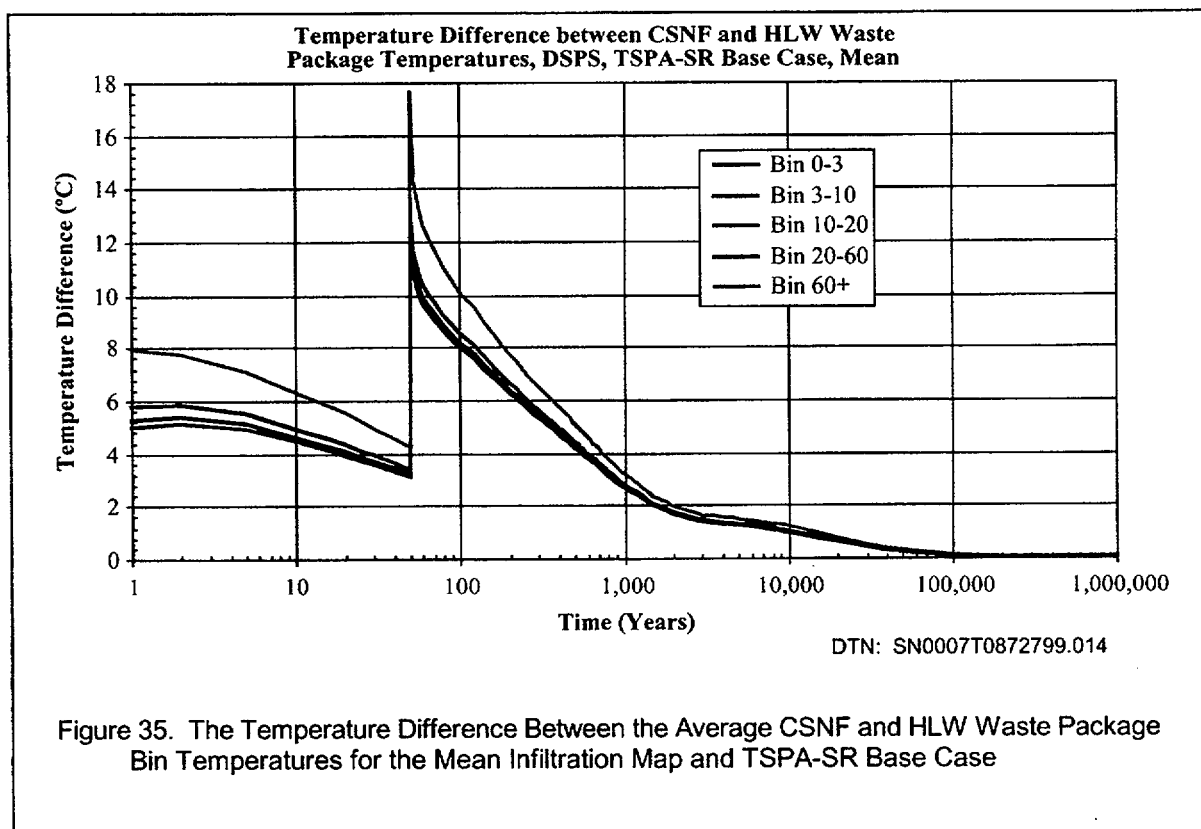


Figure 35 contains the difference between the bin averaged CSNF and HLW waste package temperatures. The maximum difference between the CSNF and HLW packages was 17.8°C for the 0-3 and the 60+ mm/year bins just after 50 years. The maximum difference between bin averaged CSNF and HLW waste package temperatures for the other three bins ranged from 12 to 14°C. After 100 years, the average CSNF waste package bin temperatures were 8 and 10°C higher than bin averaged HLW temperatures. This difference decreased to 4-5°C after 500 years, 2°C after 2000 years and to 1°C after 15,000 years.



### 6.3.3 CSNF and HLW Waste Package Bin Relative Humidity Comparison

Figure 36 contains the relative humidity of the bin averaged CSNF and HLW waste packages for the mean infiltration flux map for the TSPA-SR base case. The relative humidities reach a minimum of between 14% and 23% right after closure between 60 and 70 years after waste emplacement. The HLW 60+ mm/year bin relative humidities return to above 90% after only 230 years. The last bins to reach 90% relative humidity were the 0-3 and the 60+ mm/year CSNF bins after 7000 years.

Since the temperatures of the CSNF waste packages are always higher than those of the HLW waste packages, the relative humidity of the HLW waste packages is always higher than that for the corresponding CSNF waste package (see Figure 37). The difference between the HLW and the CSNF relative humidities is between 5 and 12 % at the time of closure when the absolute value of the relative humidities are at a minimum. The difference then increases reaching a maximum for different bins of 11% to 22% between 200 and 340 years. By 1300 years, the difference between all sets of curves dropped below 10%. At 10,000 years, the bin averaged RH differences varied between a high of 5.5% for the 60+ mm/year bin to a low of 3.8% for the 10-20 mm/year bin. After 100,000 years of simulation time, the differences had dropped below 0.68% in all five bins.

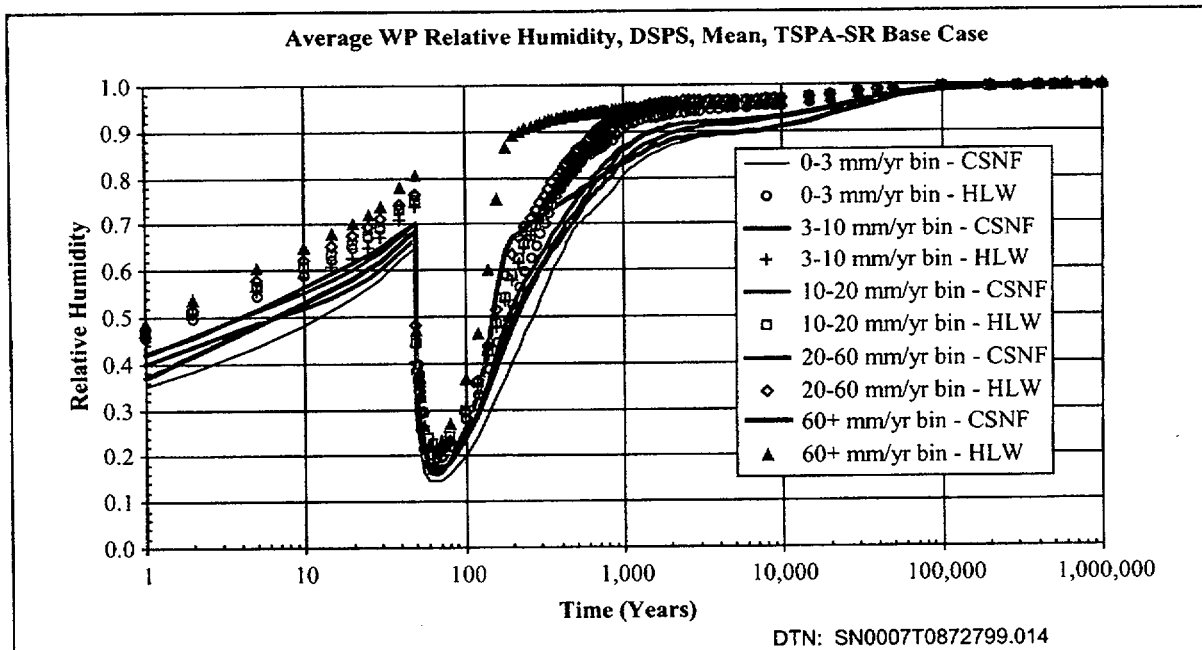


Figure 36. The Average Waste Package Relative Humidity for Both the CSNF and HLW in Each of the Infiltration Bins for the Mean Infiltration Flux Map and TSPA-SR Base Case

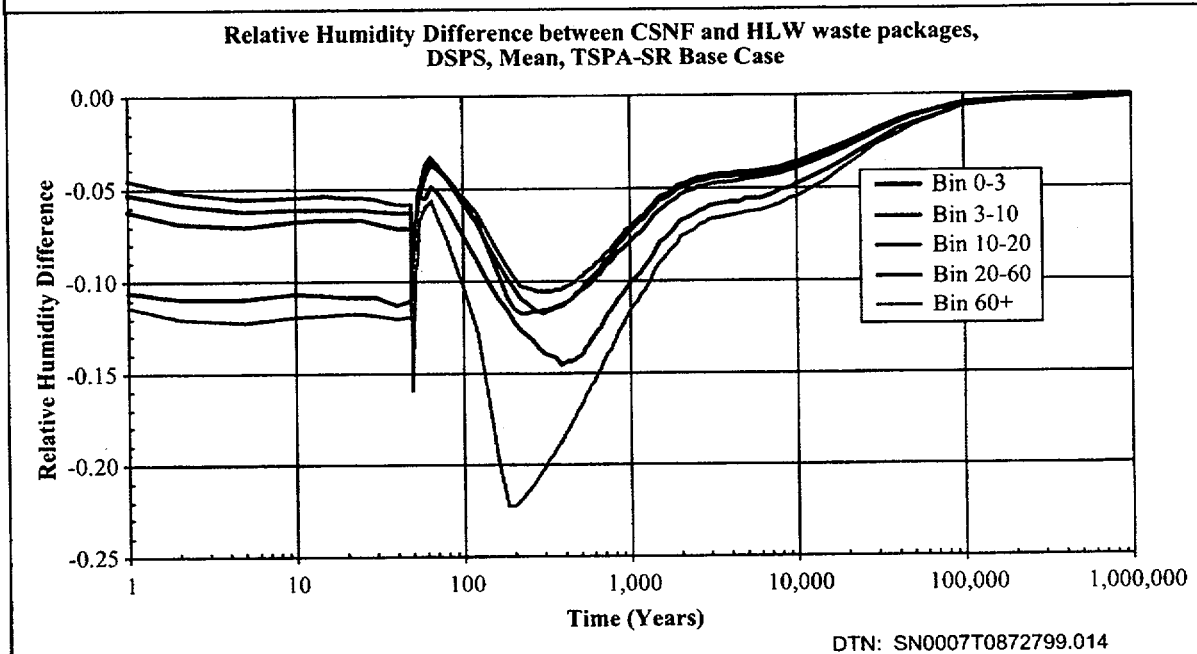
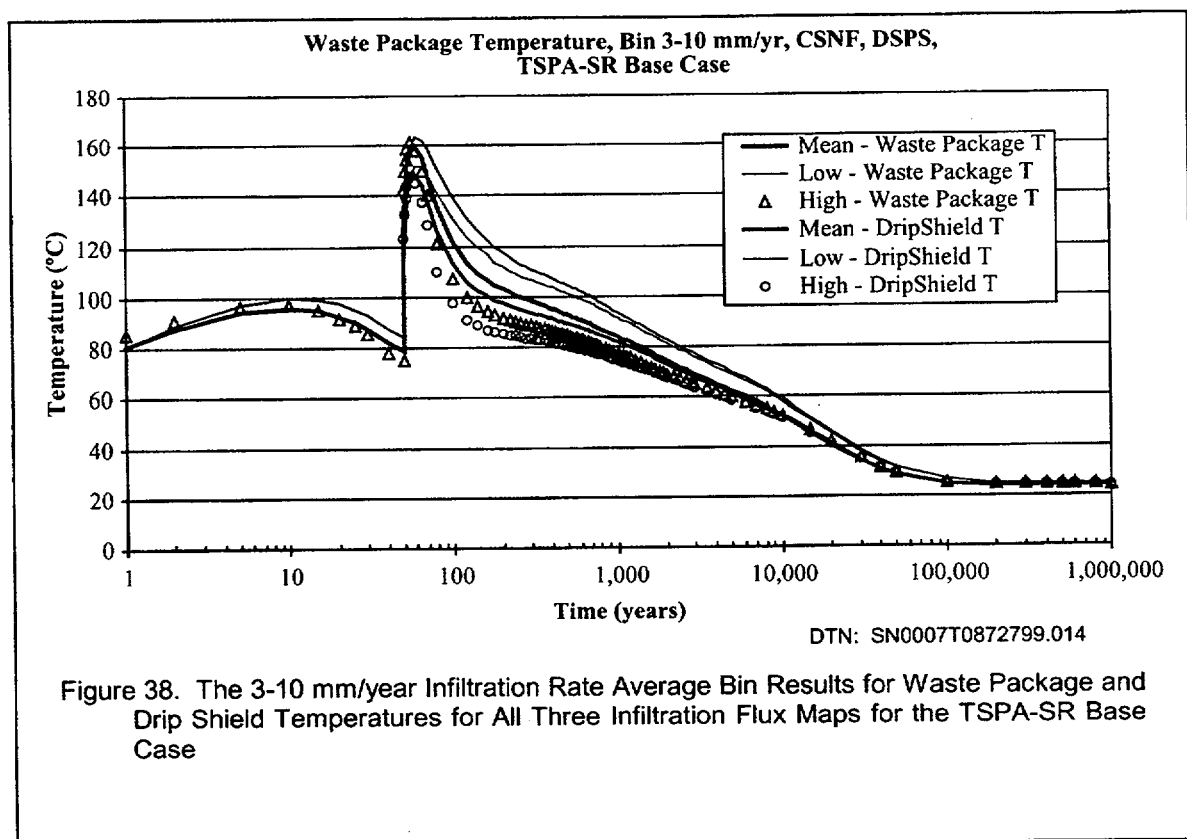


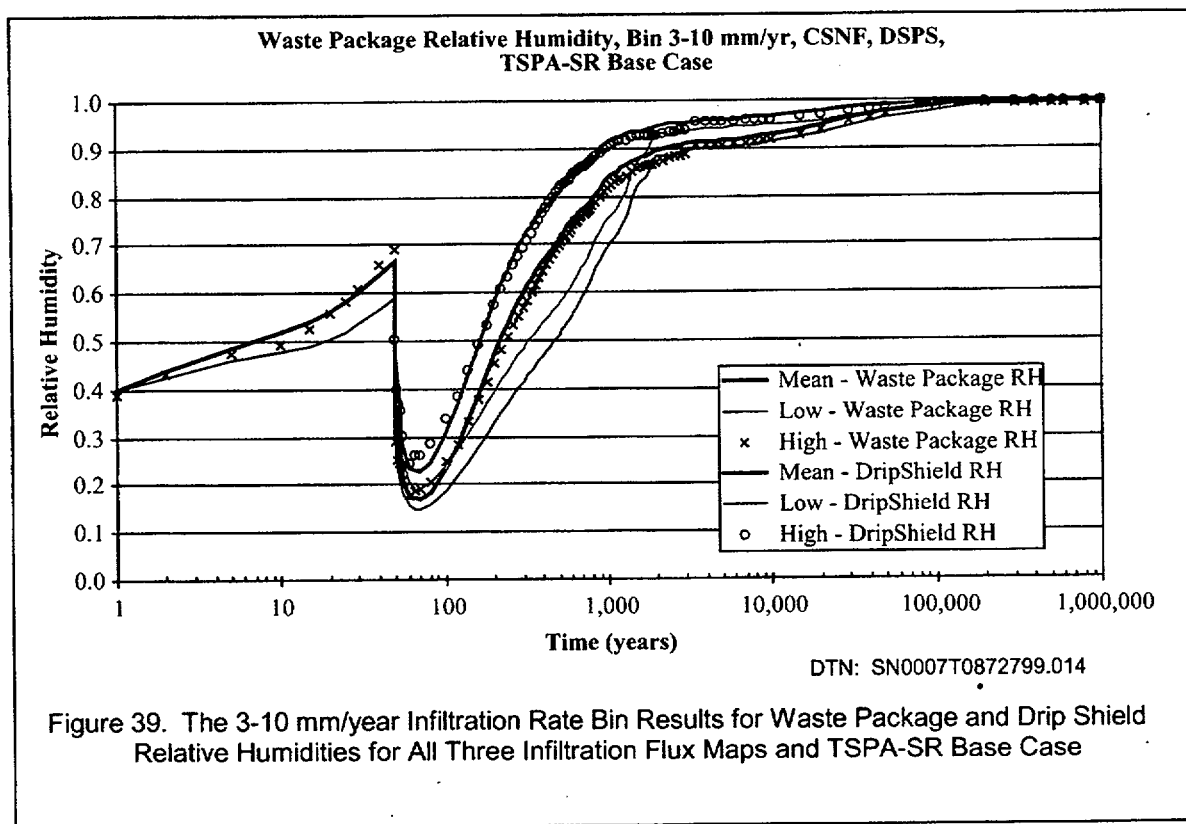
Figure 37. The Difference in Relative Humidity Between the Average CSNF and HLW Waste Package Bin Temperatures for the Mean Infiltration Maps and TSPA-SR Base Case



### 6.3.4 Comparison of Waste Package 3-10 mm/year Bin Averaged Temperatures and Relative Humidity for All Infiltration Flux Cases for the TSPA-SR Base Case

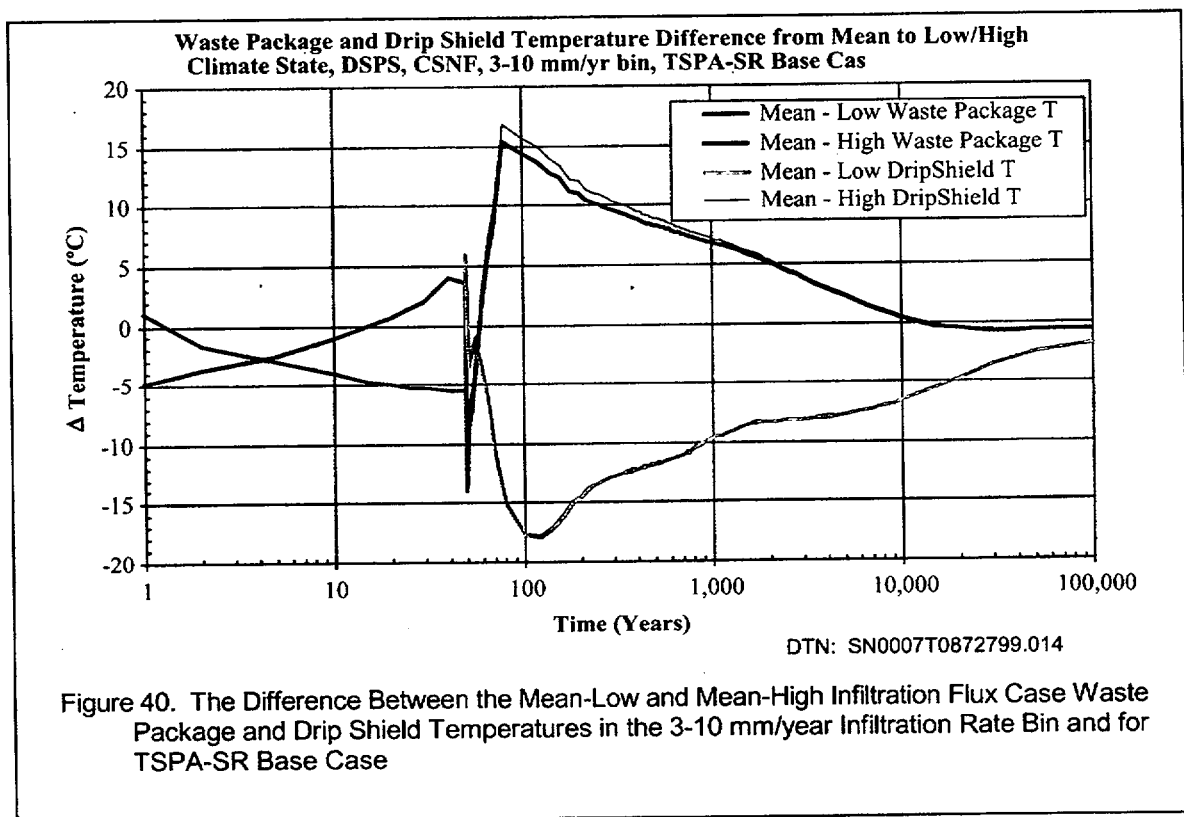
The average CSNF waste package temperature and relative humidity time-histories for the 3-10 mm/year infiltration flux bin for the TSPA-SR base case for all three infiltration cases are presented in Figure 38 and Figure 39. The 3-10 mm/year bin is presented here since it is the only infiltration flux interval that contained waste packages for each of the three infiltration flux cases. There are 14 waste package locations for the high infiltration flux case, 102 waste package locations for the mean infiltration flux case, and 249 waste package locations for the low infiltration flux case.





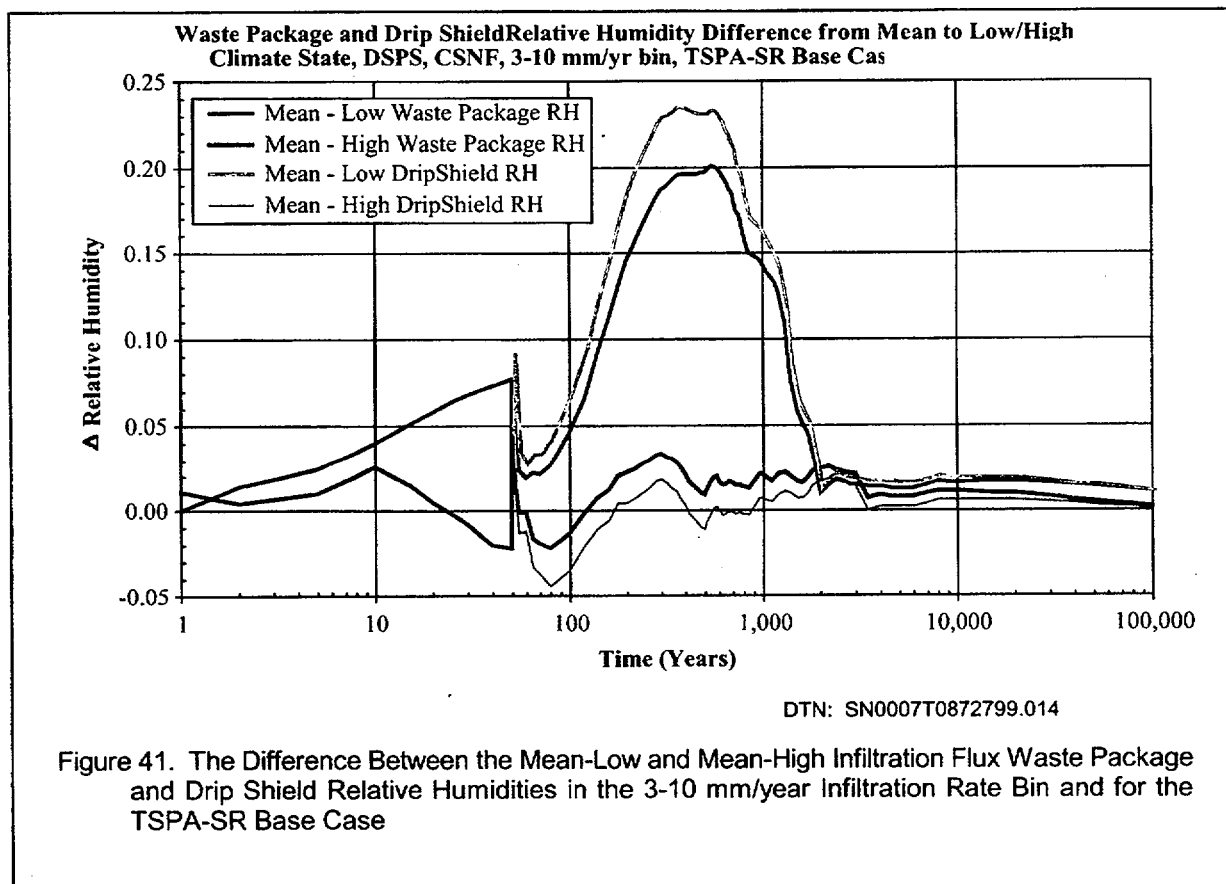
In Figure 38, the bin averaged waste package temperatures were higher for the drier infiltration flux cases. This result is caused by the spatial distribution of the waste packages in the three bins with the waste packages from the high infiltration flux case all concentrated next to the edge of the repository, the waste packages from the mean infiltration flux case having some in the center of the repository and others near the edge of the repository, and the waste packages from the low infiltration flux case having a large fraction of waste packages near the center and edge of the repository. The waste package and drip shield relative humidity time histories for the 3-10 mm/year infiltration bins for all three infiltration maps are presented in Figure 39. The waste package relative humidities bin averages all have minima between 14.9% to 17.5% at 60 to 70 years of simulation time. The drip shield relative humidities bin averages all have minima between 19.4% to 24.5% at 60 to 70 years of simulation time. The bin averaged relative humidity curves are almost always higher for the higher infiltration maps.

The difference between the bin averaged waste package and drip shield temperatures from the high and low to the mean infiltration maps are shown in Figure 40. The respective curves are very similar to each other. The temperature difference between the waste package and drip shield for the mean and low cases were usually within 0.1°C of each other while the difference between the high and mean cases were always smaller than 2°C. The maximum difference between the 3-10 mm/year bin averaged waste package temperatures from the mean and low and the mean and high infiltration maps was 18°C at 120 years and 15°C at 80 years, respectively. The difference between the high and low infiltration map bin averaged waste package temperatures drops to 16.3°C after 1000 years and to 10°C after 5000 years. These plots illustrate that there is considerable variability in the temperature time-histories within the same bin (3-10 mm/yr contains entries for each infiltration flux case) for different infiltration maps. The variability in temperature is a direct result of infiltration rate uncertainty (e.g., three infiltration flux cases).



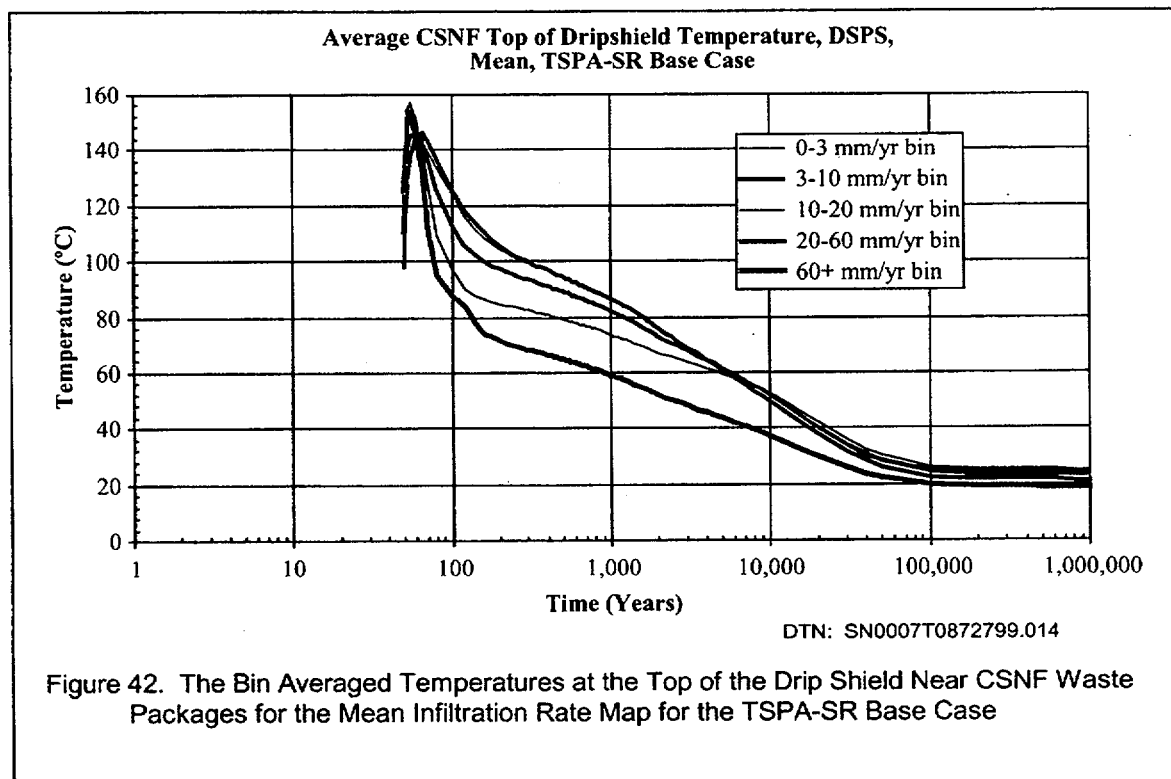
The difference in waste package and drip shield relative humidity between the 0-3 mm/year bins is presented in Figure 41. The difference between the mean and the low bin averaged relative humidity curve was usually greater than the difference between the mean and the high bin averaged relative humidity curve. At repository closure (e.g., 50 years), the difference between the curves were within 10% of each other. The greatest bin averaged waste package relative humidity difference between the mean and the low curves was 20% at 560 years and the largest difference between the mean and

high curves was 3.7% immediately after closure (51 years). The largest difference between the bin averaged waste package low and high curves was 19% at 500 years. The difference between the RH curves drops below 5% by 1700 years. The greatest bin averaged drip shield relative humidity difference between the mean and the low curves was 23% at 380 years and the largest difference between the mean and high curves was 5% immediately after closure (51 years). The largest difference between the bin averaged dip shield RH low and high curves was 24% at 500 years. The difference between the curves drops below 5% by 1800 years. These results show the variability between the same relative humidity infiltration bin (3-10 mm/yr contains entries for each infiltration flux case) for different infiltration rate maps. The variability in relative humidity is a direct result of infiltration rate uncertainty (e.g., three infiltration flux cases).



### 6.3.5 Temperature at the Top of the Drip Shield

The bin averaged temperature at the top of the CSNF drip shield for the mean infiltration flux case is presented in Figure 42. The temperature time-histories are similar to those for the CSNF waste packages only a few degrees cooler. The peak temperatures for the bins were between 143 and 157°C and were reached between 55 and 65 years after waste emplacement.



### 6.3.6 Invert Thermodynamic Variables

The bin averaged CSNF invert temperatures for the mean infiltration flux case are presented in Figure 43. The invert temperature time-histories are cooler but contain the same trends as the waste package temperature curves. The peak temperatures for the five bins were between 144 and 159°C, which is approximately 11°C lower than those of the waste packages. The time that it takes for the invert to cool to 96°C range from 100 years for the 60+ mm/year infiltration bin to 460 years for the 10-20 and the 20-60 mm/year infiltration bins. It is noted from Figures 42 and 43 that the bin average drip shield temperatures are very similar to the bin averaged invert temperatures. Since this is the case, it is unlikely that water evaporated from the invert will re-condense on the underside at the top drip shield. The bin averaged CSNF invert relative humidity curves (Figure 44) also show the same trends as the waste package relative humidity curves. The bins all reach a minimum

ranging from 21% and 25% between 60 and 70 years and all increase to 90% relative humidity between 240 and 1050 years. Since the invert temperatures are lower than the waste package temperatures, it is expected that the relative humidity for the invert would recover to ambient values faster than the waste package values.

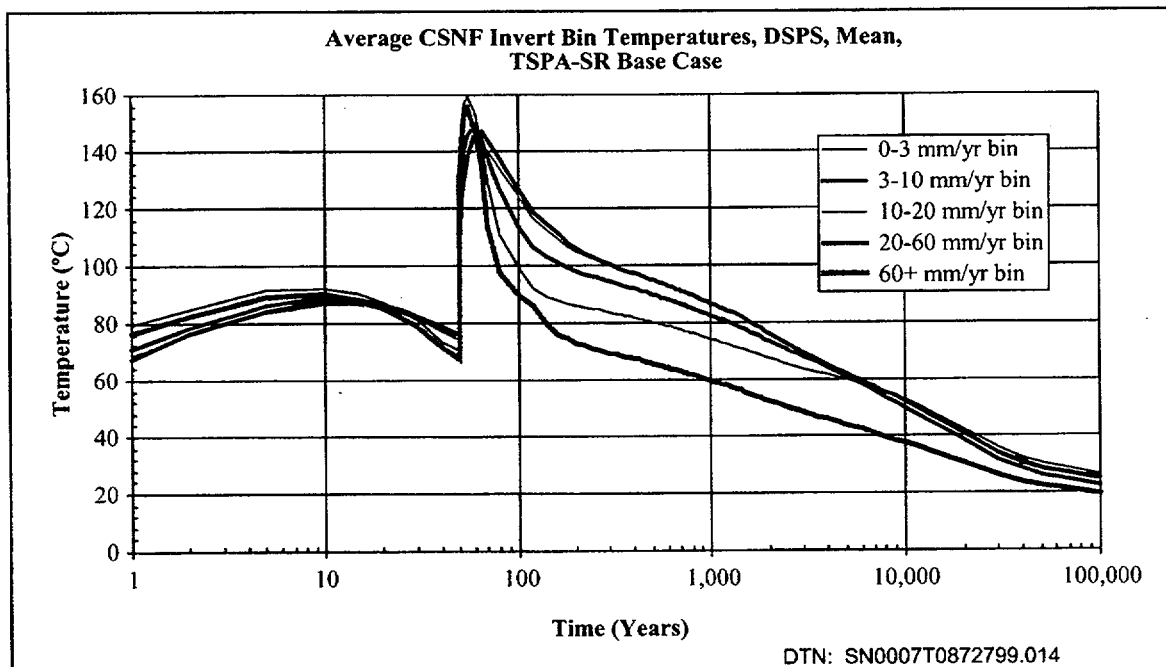


Figure 43. The Bin Averaged Invert Temperatures Near CSNF Waste Packages for the Mean Infiltration Rate Map for the TSPA-SR Base Case

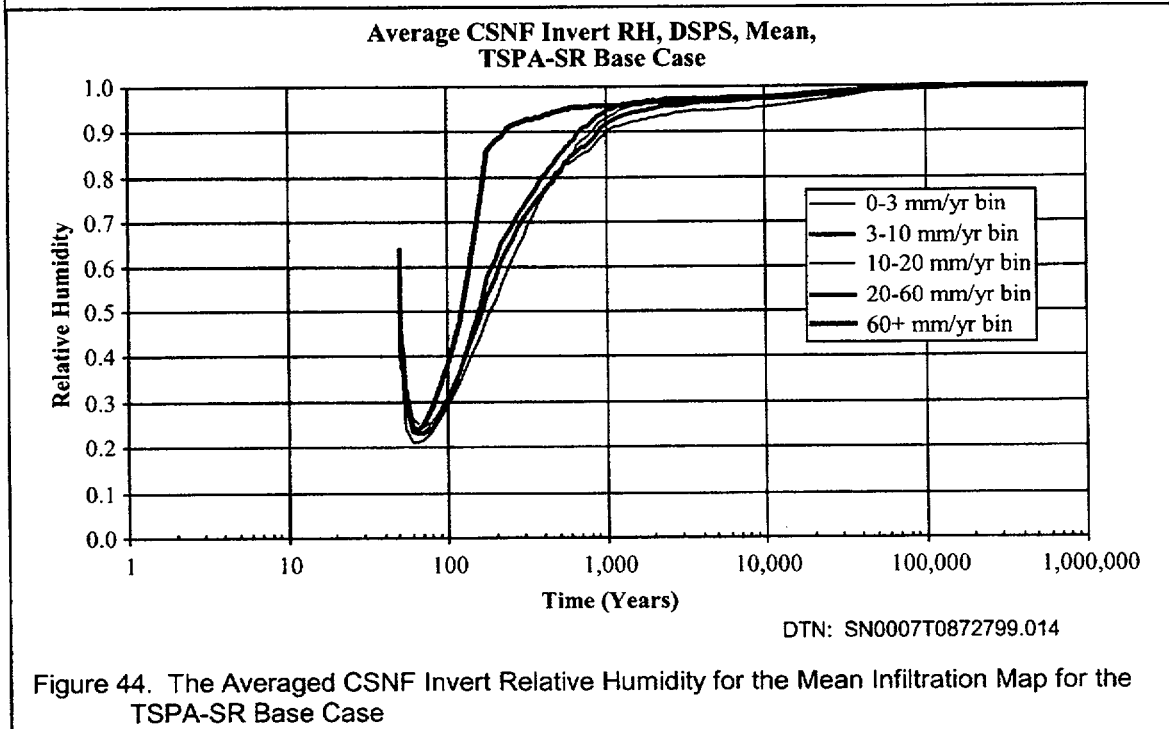
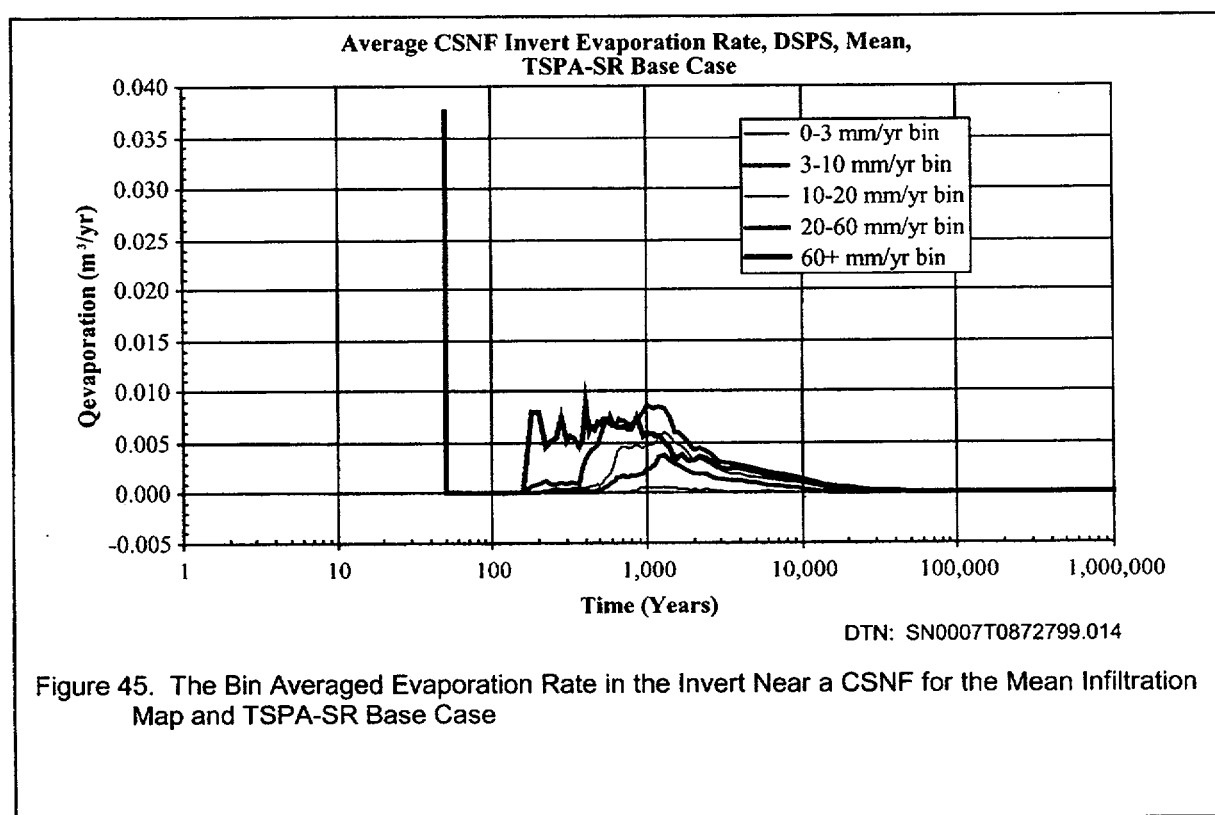
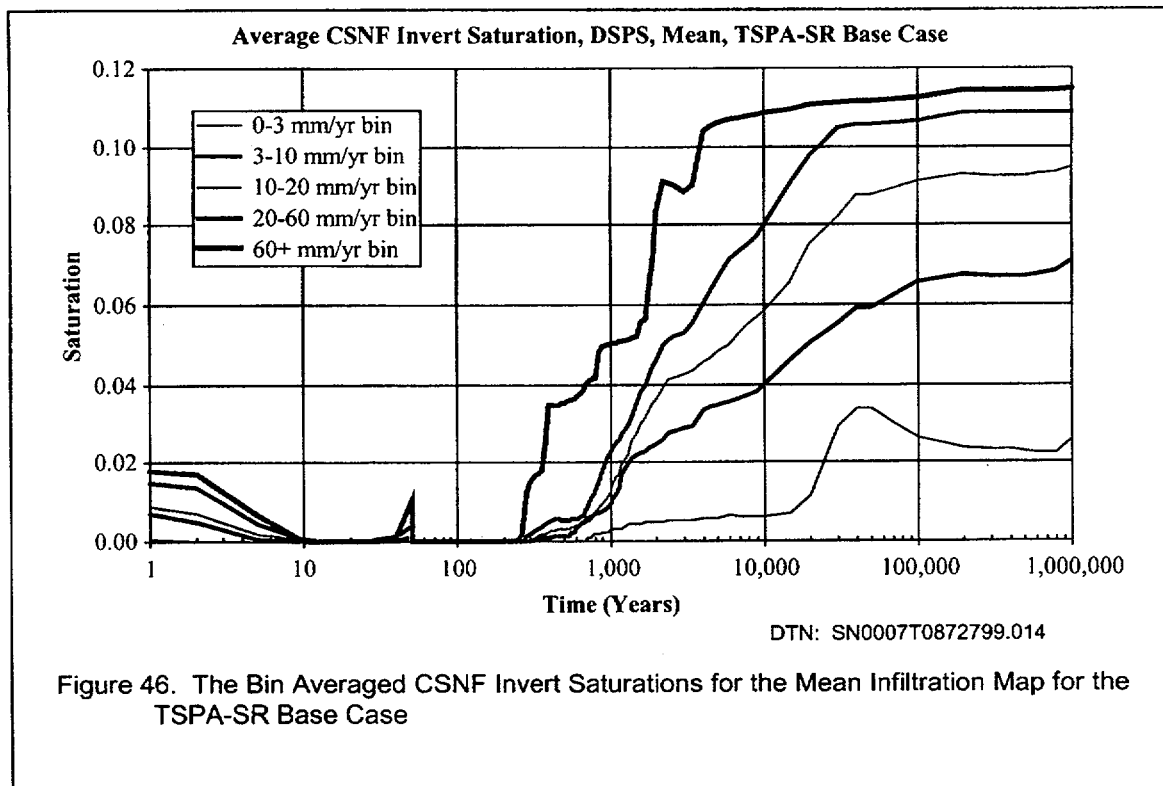


Figure 44. The Averaged CSNF Invert Relative Humidity for the Mean Infiltration Map for the TSPA-SR Base Case

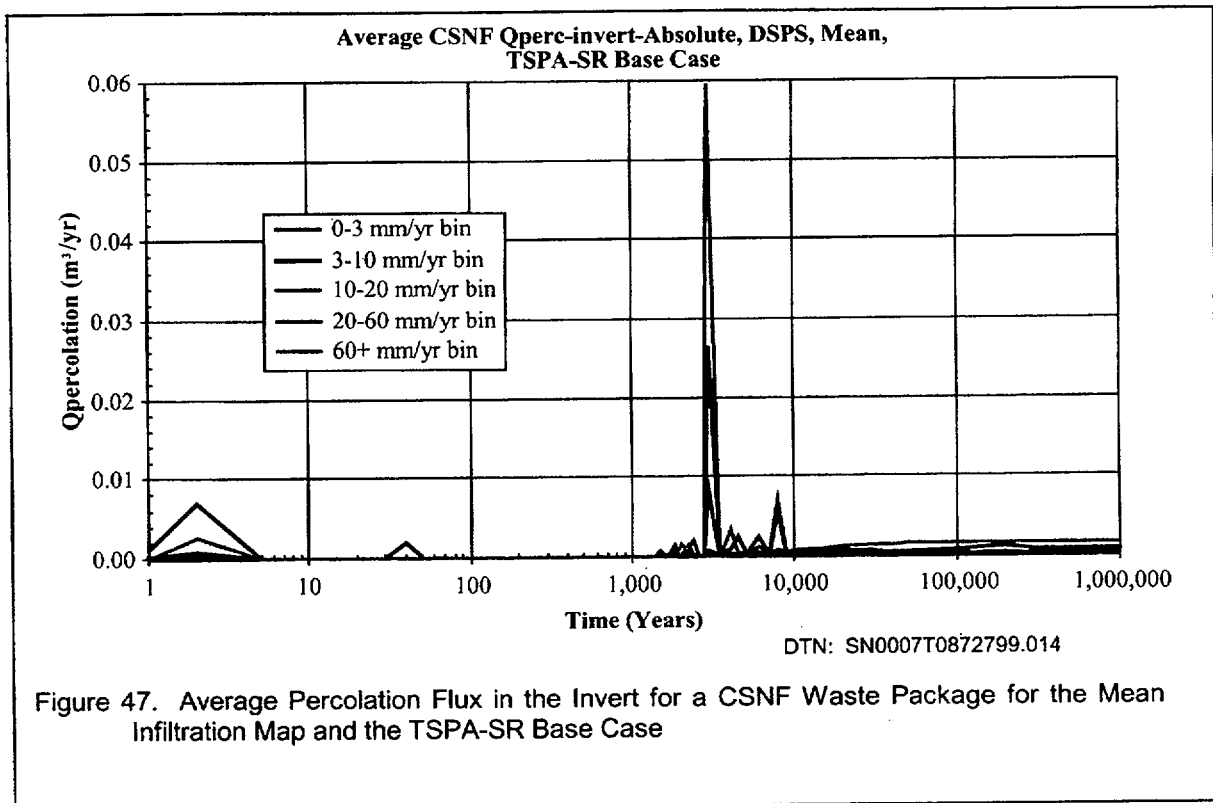
The CSNF bin averaged invert evaporation rate and invert liquid saturations for the mean infiltration case are presented in Figures 45 and 46. The invert evaporation rate immediately jumps when water is introduced into the invert (Figure 45). The evaporation rate for the 60+ mm/year infiltration rate bin peaks at 0.009 m<sup>3</sup>/year/m-drift (24 ml/day/m-drift) at 400 years. The invert saturation drops during the first 15 years of heating as a result of evaporation in the invert (Figure 46). The invert saturation time-histories recover (slightly resaturate) just before 50 years but all drop to zero immediately following closure. The invert liquid saturation in all of the bins starts to rise at 260 years although the 60+ mm/year bin liquid saturation rose to 3% at 400 years while the other four bins are all still below 1.5% at that time. The final invert saturations for the bins are different. This is a result of the higher percolation fluxes requiring higher saturations to allow the water to flow through the system. It takes the 60+ mm/year bin only 1700 years to reach 50% of the final saturation, while it takes between 3,500 and 30,000 years for the other four bins to reach 50% of their final saturations. After 10,000 years, the evaporation rates have all dropped to below 0.00146 m<sup>3</sup>/year/m-drift (4 ml/day/m-drift).





The bin averaged CSNF percolation flux in the invert used by the TSPA model is presented in Figure 47.





### 6.3.7 Drift Wall Temperatures

The bin averaged drift wall temperatures adjacent to the CSNF and HLW waste packages for the mean infiltration flux case are presented in Figure 48. The difference between the bin averaged CSNF and HLW temperatures are presented in Figure 49. These figures show that there is only a small difference in drift wall temperatures due to the variability in heat output from HLW and CSNF waste packages in the drift. The peak temperature differences were less than 4°C after repository closure and these dropped to under 2.5°C at 100 years and less than 1°C after 700 years.

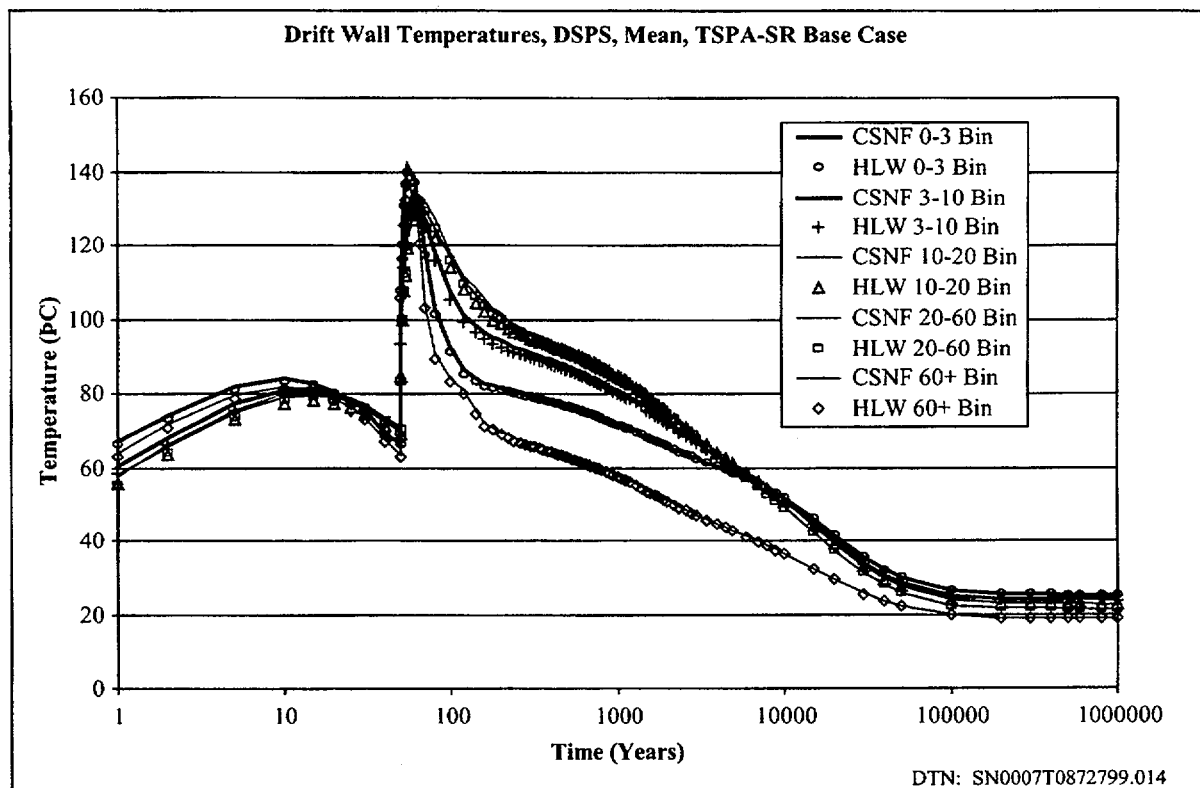


Figure 48. Bin Averaged Drift Wall Temperatures Adjacent to the CSNF and HLW Waste Packages for the Mean Infiltration and TSPA-SR Base Case

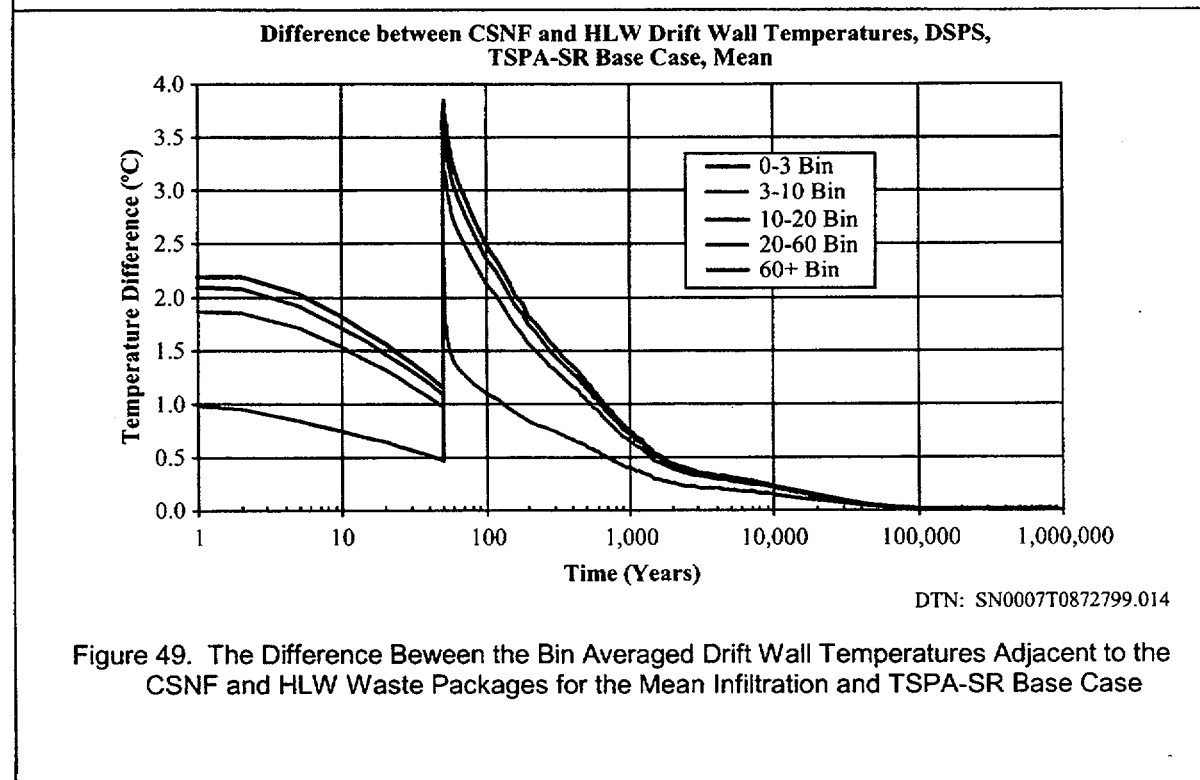
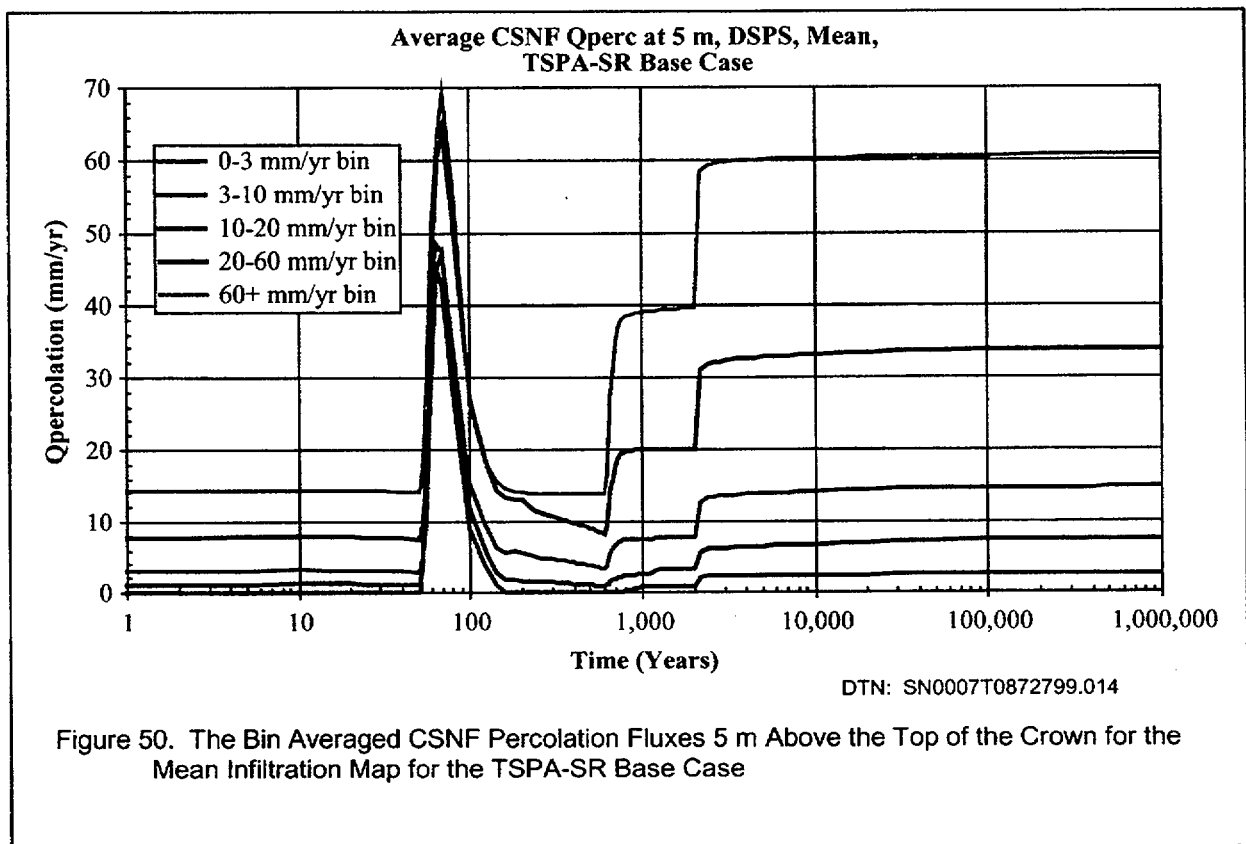


Figure 49. The Difference Between the Bin Averaged Drift Wall Temperatures Adjacent to the CSNF and HLW Waste Packages for the Mean Infiltration and TSPA-SR Base Case

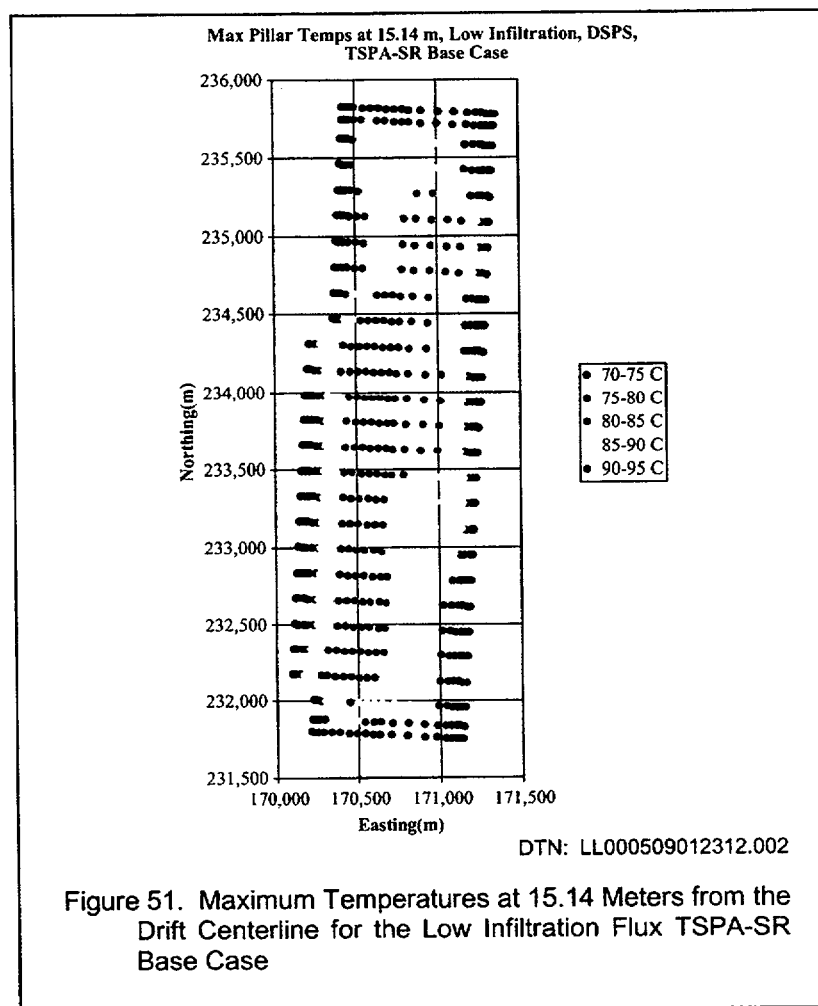
### 6.3.8 CSNF Percolation Flux 5 Meters Above Drift

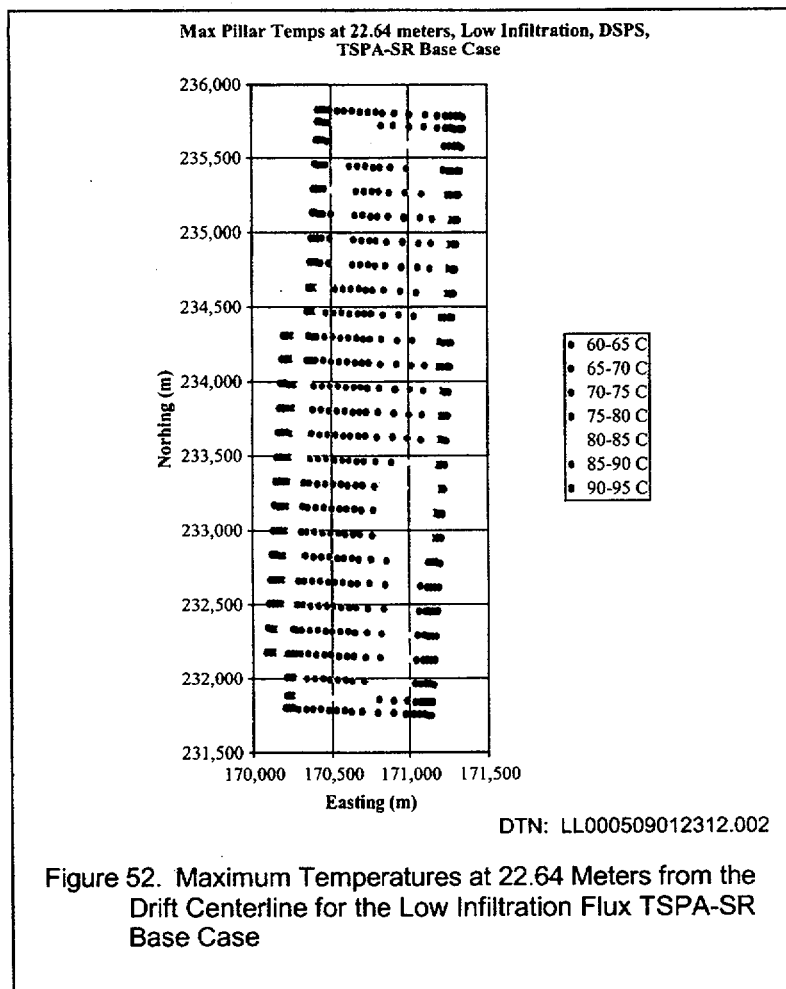
The bin averaged CSNF percolation flux 5 m above the drift is presented in Figure 50. This variable is used to illustrate the average variability from bin to bin for the mean infiltration flux case. The TSPA seepage model uses as its input the individual curves that determined the bin averaged values shown in the figure below. The percolation flux has a peak just after closure and two jumps corresponding to the monsoonal climate change at 600 years and the glacial transition climate at 2000 years. The peaks between 65 and 70 years are due to thermal reflux and are higher than the steady state value after the second climate change for every bin. The main thermal perturbation has mostly dissipated by 200 years although the percolation flux does change slowly in several of the bins until the first climate change at 600 years.



### 6.3.9 Pillar Temperatures in Repository

The pillar temperatures indicate how quickly the heat from the waste packages is able to diffuse into the rock. If the temperature of the host rock goes above the local boiling temperature of 96°C, then water, either condensate or infiltrating, may not be able to drain through the superheated pillar as easy as it would in a subcooled pillar. Figures 51 and 52 show the maximum pillar temperature at the 610 waste package locations at two different pillar locations (15.14 and 22.64 meters from the center of the drift) for the low infiltration map. The low infiltration case map is shown here since the pillar temperatures are the highest for this case. The half-distance between drift centerlines is 40.5 meters so the two different pillar locations lie on each side of the quarter-pillar location.





At the 15.14 meter pillar location, the maximum pillar temperatures reach the highest values of 94°C at the center of the repository and the lowest value of 71°C at the edge of the repository. The temperatures reach maximum values at the edge of the repository within 200 years while closer to the center of the repository, the maximum temperatures are reached as late as 720 years. At the 22.64 meter location, the maximum pillar temperatures range from 62 to 91°C. The maximum temperatures are lower for the 22.64 meter location because of a larger volume of rock being heated. The time to maximum temperatures are somewhat higher as a result of the longer distance that the waste package heat needs to diffuse. It took more than 200 years to reach maximum temperature years at edge locations and up to 800 years for center locations at 22.64 meters into the pillar. Clearly, at least half of the pillar does not reach the local boiling temperature for all locations within the repository for the TSPA-SR base case.

### 6.3.10 Drip Shield Evaporation Rate

The TH abstraction (without backfill) of the drip shield evaporation rate and water volume flow rate can not be obtained directly from the results of the process-level multiscale TH model. The primary reason is due to the lack of fracture property heterogeneity and coarse gridding in the process model that result in an incomplete description of the processes that would potentially occur at the top of the drip shield in the absence of a (porous) backfill material. Consequently, an alternative approach is developed to abstract the potential evaporation rate of the incoming water at the top of the drip shield after emplacement. Testing and verification of the routine used in this approach is given in detail in Attachment V.

The evaporation rate at the top of the drip shield is bounded by the amount of heat available to vaporize water on the upper portion of the drip shield. This heat flow rate into the upper portion of the drip shield is used to determine the maximum volumetric flow rate of incoming seepage water that can be completely vaporized at this location. The result of this abstraction is used to approximate the amount of mineral precipitation that can potentially occur on the upper surface of the drip shield. The precipitation represents the maximum potential deposition (of chemical constituents) on the drip shield due to vaporization of incoming seepage water. The evaporation rate is computed as the following.

An energy balance is performed on the upper surface of the drip shield. The energy balance relates the heat input at this location to the maximum amount of incoming water that can be completely vaporized by the heat flow. The energy balance is the following:

$$q_{ds} = \rho_l Q_{evap} h_{fg} \quad (\text{Eq. 4})$$

where  $q_{ds}$  is the heat input to the drip shield [W],  $\rho_l$  is the density of the incoming water [ $\text{kg}/\text{m}^3$ ],  $Q_{evap}$  is the maximum rate that water can be vaporized by the heat at this location [ $\text{m}^3/\text{s}$ ], and  $h_{fg}$  is the latent heat of vaporization [J/kg]. The seepage rate into the drift is considered to be non-episodic and applied uniformly over the top of the drip shield. Since, the heat input term ( $q_{ds}$ ) in the equation decreases with time, equation 4 can be applied as a series of semi-steady state solutions evaluated at each time in which the heat flow ( $q_{ds}$ ) is evaluated. The energy balance equation also assumes that the incoming water reaches the top of the drip shield is at the vaporization temperature of the drip shield. This assumption neglects sensible heating of liquid water (typically small compared to latent) and is consistent with the desire to determine the maximum amount of precipitate that may form on the surface of the drip shield.

Equation 4 can be evaluated using temperature dependent or constant (evaluated at an appropriate average temperature) fluid properties. In order to reduce the complexity of this abstraction, constant fluid properties are selected at an average incoming fluid temperature of 60°C. In order to ensure that this assumption is reasonable, a single case is considered in which the fluid properties are based on a repository-wide average drip shield temperature for the expected value case (e.g., mean infiltration flux case). The drip shield temperature result is taken directly from the TSPA abstraction of the

multiscale TH model without backfill. Since the drip shield temperature varies with time after waste emplacement the fluid properties will also vary with time.

Equation 4 heat input (at the drip shield,  $q_{ds}$ ) can be rewritten in terms of the waste package heat output. The representative heat flow (by thermal radiation) from the top waste package to the underside of the top portion of the drip shield is approximately half of the total waste package heat output. This is a reasonable approximation since thermal radiation is the dominant mode of heat transfer in an unbackfilled emplacement drift. Implementing the assumptions above, equation 4 takes the following form:

$$Q_{evap} = \frac{\left(\frac{1}{2}\right)q_{wp}}{\rho_l h_{fg}} \quad (\text{Eq. 5})$$

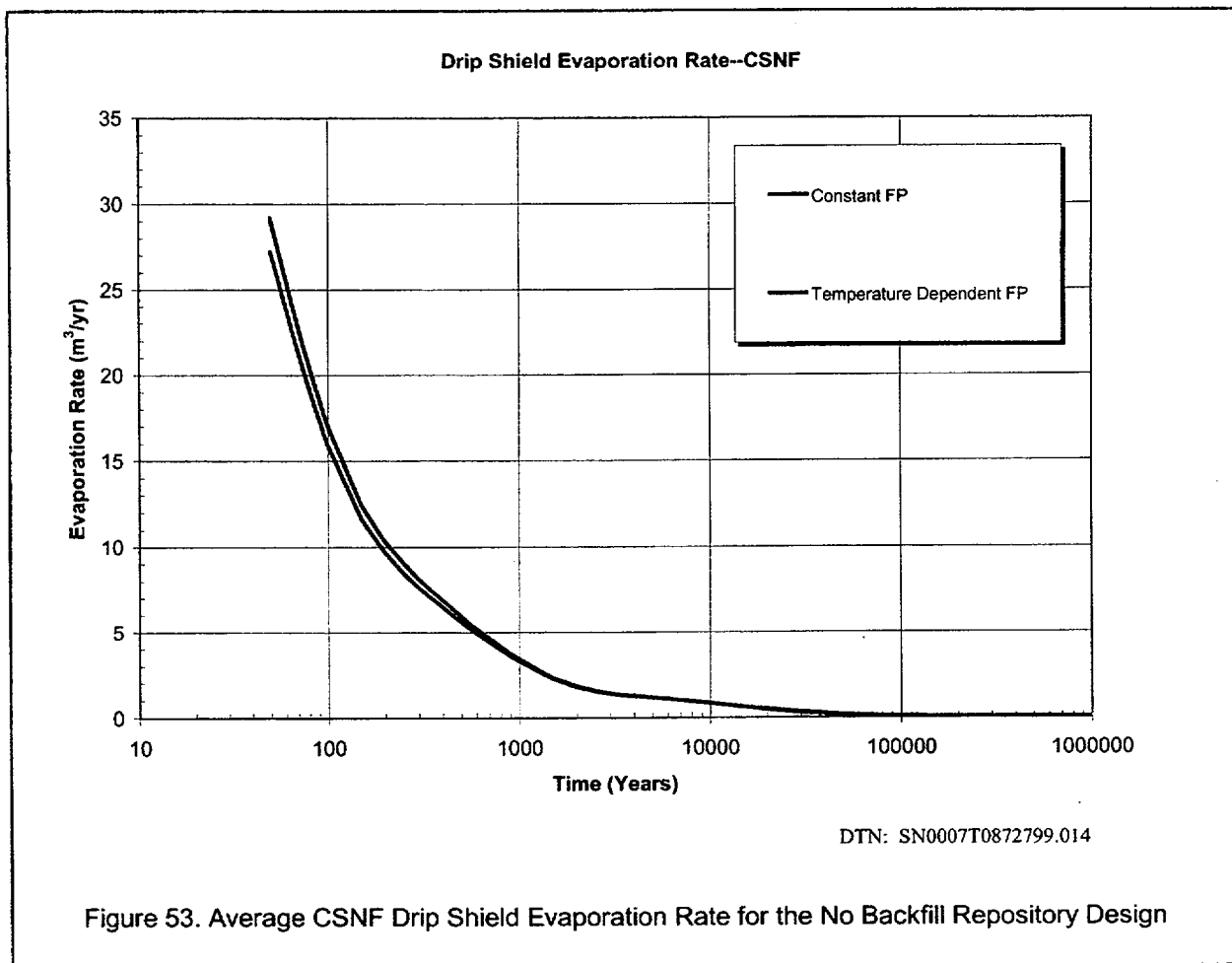
The waste package heat generation rate,  $q_{wp}$ , is evaluated for an average commercial waste package (CSNF) heat output and an average non-commercial waste package heat output. The non-commercial waste package heat output is based on the high-level waste (HLW) only. Implementation of an average waste package heat generation rate implies that the waste packages are close enough together such that the radiant heat exchange and the (axial) heat flux through the drip shield is uniform.

Equation 5 is divided by the seepage volume flow rate obtained from the TSPA seepage model to provide the ratio required by the TSPA in-drift geochemical model. The ratio used by TSPA is defined as the following:

$$R = \frac{Q_{evap}}{Q_{seep}} = \frac{\left(\frac{1}{2}\right)q_{wp}}{Q_{seep}} \quad (\text{Eq. 6})$$

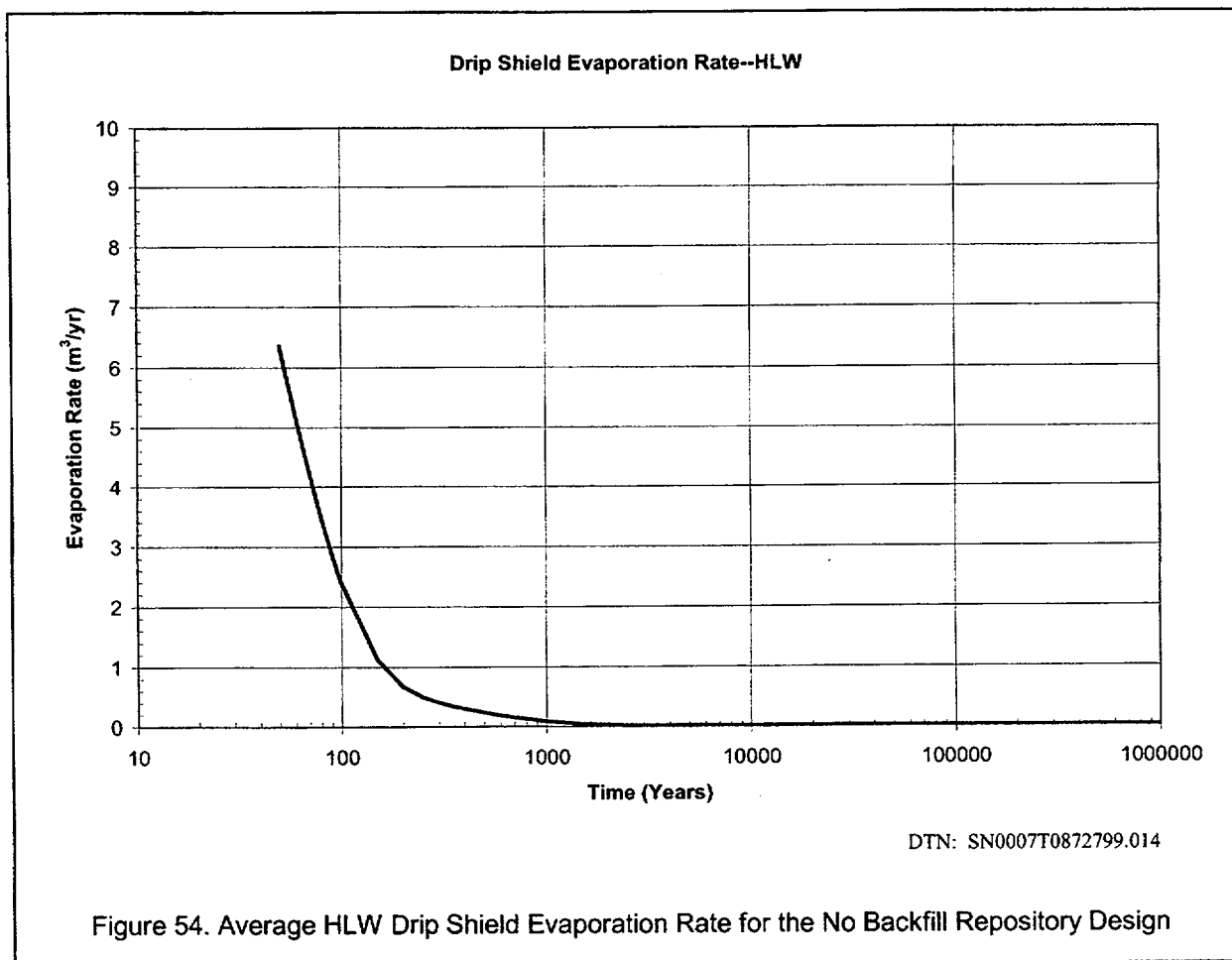
The incoming water contacting the top drip shield [in  $\text{m}^3/\text{yr}$ ] is denoted as  $Q_{seep}$  and is determined by the TSPA seepage model. Note that  $Q_{seep}$  is used as the liquid volume flow rate at the drip shield, not the results of the multiscale TH model (unlike the backfill case). Equation 6 can never physically be greater than 1 since more water cannot evaporate than can seep onto the drip shield. Consequently, the ratio should be set equal to one if  $Q_{evap}$  ever exceeds  $Q_{seep}$ . That is, all incoming seepage is evaporated at the surface of the drip shield. Recall that equation 6 is valid only for the no backfill repository design TH abstraction.

Equation 5 is plotted for an average CSNF and HLW waste package. The figures for the drip shield evaporation rates are the following. Figure 53 illustrates the abstracted drip shield evaporation rate [in  $\text{m}^3/\text{yr}$ ] for an average CSNF waste package. It contains solutions of equation 5 for both temperature dependent and constant fluid properties. The temperature dependent solution obtained from equation 5 utilizes an overall average drip shield temperature time-history curve abstracted from the mean infiltration flux case to evaluate the fluid properties. The fluid properties vary with time since the drip shield temperature varies with time.



The difference between evaporation rate curves is small at early times and is approximately zero for times after about 500 years on. Therefore, the approximation of the drip shield evaporation rate using constant fluid properties evaluated at an average temperature is a reasonable approximation for use in this abstraction. Figure 54 shows the drip shield evaporation rate for an average HLW waste package. It applies equation 5 for incoming fluid properties evaluated at a constant average temperature.





Due to differing heat generation rates, the drip shield evaporation rate is less for the HLW waste package than that of a CSNF waste package. The HLW drip shield evaporation rate as shown in Figure 54 may be less than what would occur in the repository since conduction heat transfer through the drip shield and radiant sharing (from surrounding waste packages) is not included in the heat input term (e.g., evaporation rate is proportional to the heat input). For a maximum evaporation rate at the non-commercial waste packages, the curve shown in Figure 53 can be applied to all of the waste packages (including the HLW). However, this would most certainly overpredict the amount of evaporation occurring at the drip shield located adjacent to an HLW waste package.

### 6.3.11 Average TH Abstraction Uncertainty

The TH model uncertainty included in the abstraction of TH data for the near-field environment component of TSPA is specified by the UZ flow and transport component of TSPA. Subsequently, the primary focus of TH process model uncertainty is on the uncertainties associated with the ground surface infiltration rate boundary condition, fracture hydrologic properties, and the initiation of future

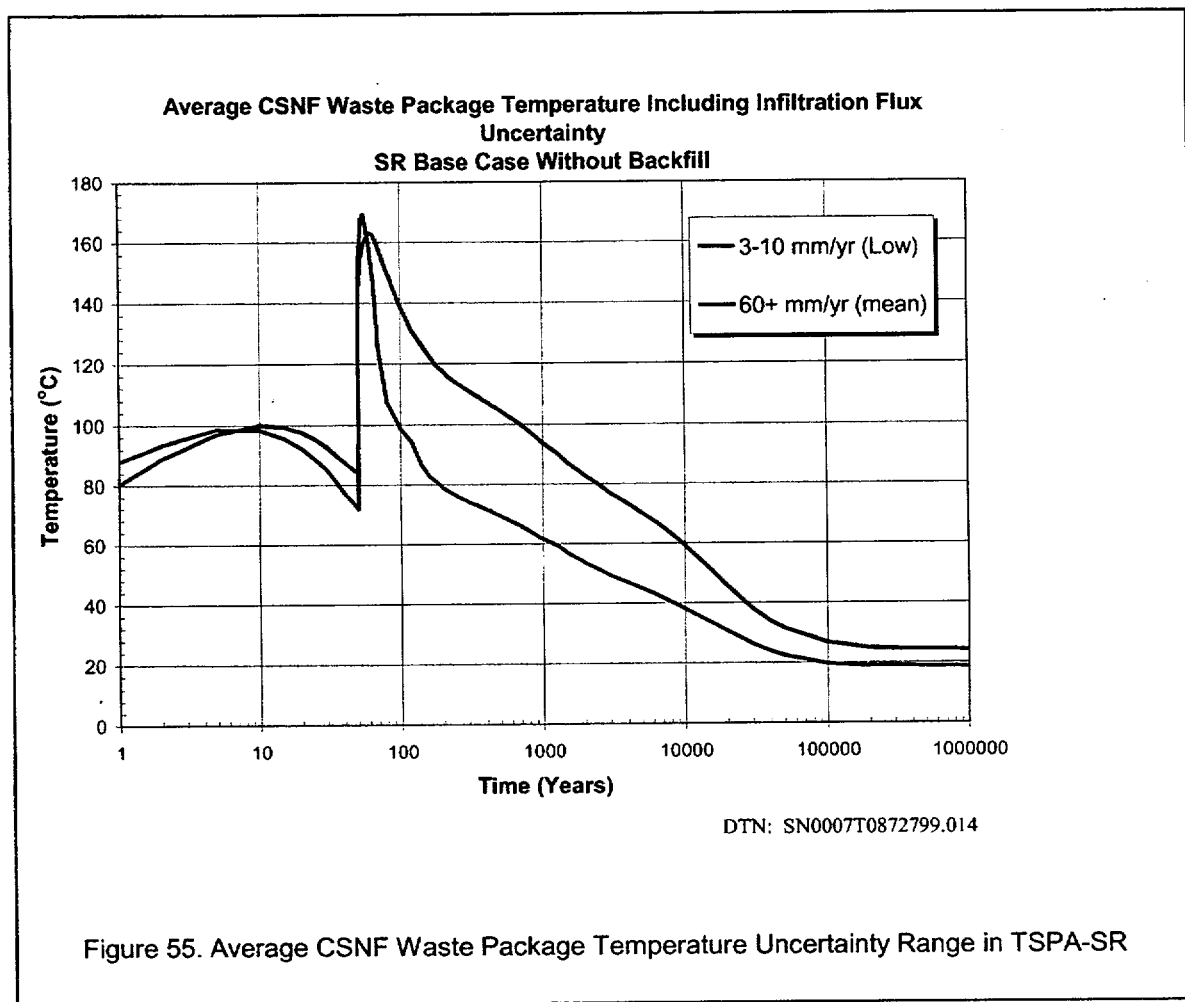
climate states. Uncertainty in thermal properties (e.g., wet and dry thermal conductivity of a repository host unit) is not considered in the TH process model. Additionally, design variability (e.g., with or without backfill) is considered on a case-by-case basis. So, as an example, the results of the TH abstraction documented in this section are for the no backfill repository design computed individually for all associated uncertainty. The previous description was for the backfill repository design. It is noted that since the multiscale TH model characterizes the influence of repository edge proximity, the process of edge heat loss plays an important role in the following discussions of the bounding thermal hydrologic time-histories applied in the TSPA abstractions.

The average uncertainty is shown for the waste package surface temperature and relative humidity (RH) and the near-field host rock percolation flux at 5 meters above the crown of the emplacement drift. Each is shown for the commercial waste (CSNF) and the high-level waste (HLW). Using the TSPA defined infiltration rate bins described in Section 5.1.1 of the AMR as a basis, the bin averaged TH uncertainty is illustrated in the following figures. The figures illustrate the potential ranges in temperature, RH, and fracture liquid flux associated with uncertainty in infiltration rate, hydrologic properties, and future climate states. Three cases (and their associated hydrologic properties) are considered: low infiltration flux, mean, and high. Each infiltration flux case applies the same future climate states (at 600 and 2000 years after waste emplacement). The emphasis of the following discussion is placed on the portion of the time-history curves after the occurrence of a maximum or minimum value. The infiltration bin averaged curves shown in the figures represent the bounding abstraction results. All other infiltration rate bin averaged results fall in-between the curves shown.

The average uncertainty in CSNF waste package temperature is illustrated in Figure 55. The bounding temperature time-histories are represented by the 3-10 mm/yr (low infiltration flux case) and 60+ mm/yr (mean infiltration flux case) infiltration rate bins. The largest temperature difference ( $T_{(3-10)} - T_{(60+)} = 40^{\circ}\text{C}$ ) between infiltration flux cases occurs from about 100-300 years after initial emplacement. At 10,000 years this difference has dropped to approximately  $20^{\circ}\text{C}$ . At 100,000 years the difference is less than  $10^{\circ}\text{C}$  (note that this difference is nearly equivalent to the ambient difference driven by the difference in steady state infiltration rates).

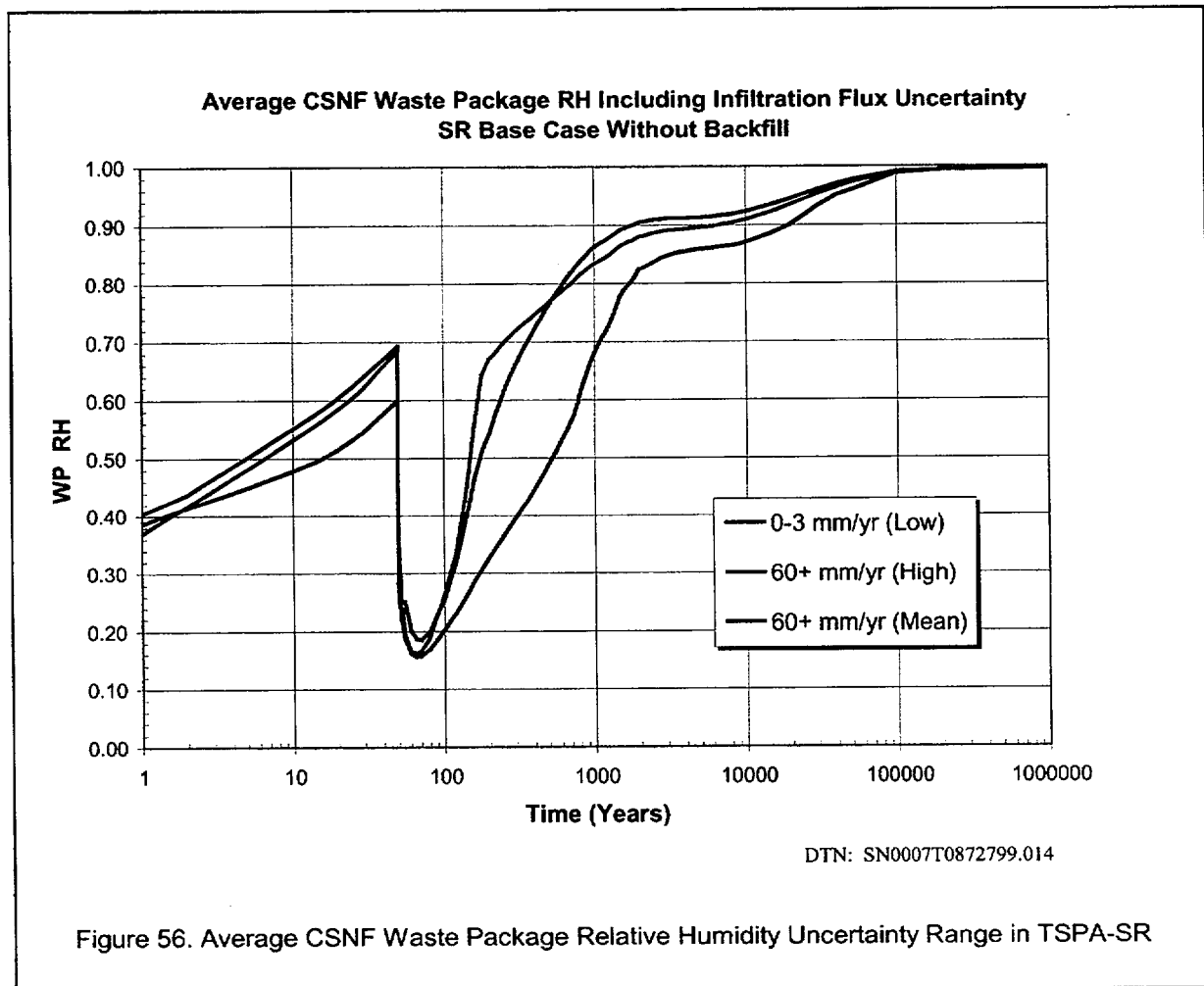
Although the 3-10 mm/yr bin (low infiltration flux case) has a higher average infiltration rate than the 0-3 mm/yr bin in this flux case, its location dependent results (from the process-level model) are primarily repository center located (but not entirely); the 0-3 mm/yr bin (low infiltration flux case) has a large number of repository edge location dependent results.

Subsequently, the 3-10 mm/yr average curve is slightly higher in temperature than the 0-3 mm/yr curve and hence is plotted in Figure 55 as the upper bound temperature for the overall abstraction including low, mean, and high infiltration flux results.

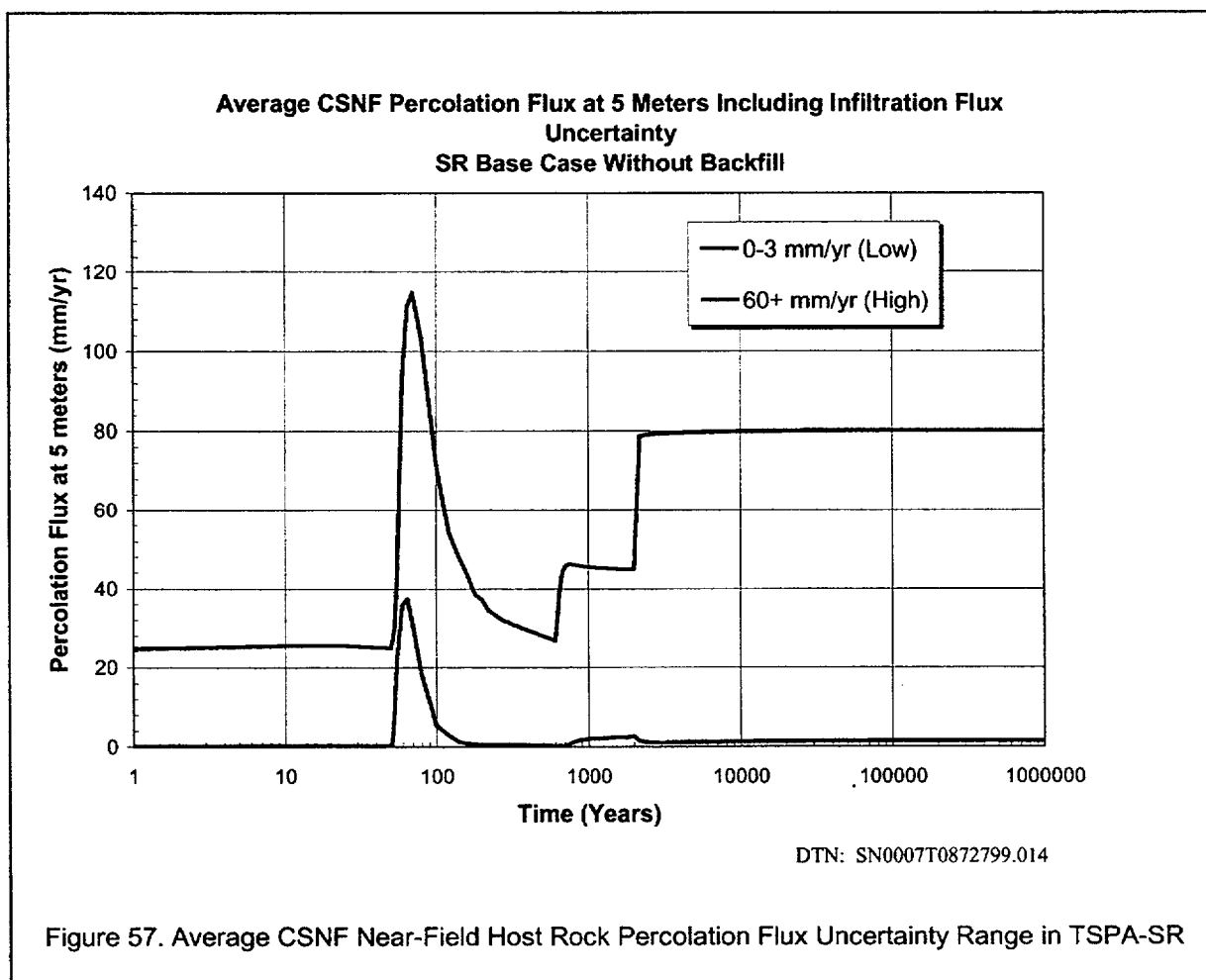


The average uncertainty in waste package relative humidity is shown in Figure 56 for the CSNF. The bounding relative humidity time-histories at early times are the 0-3 mm/yr (low infiltration flux case) and the 60+ mm/yr (mean infiltration flux case) infiltration rate bins. At late times, the bounding curves are the 0-3 mm/yr and the 60+ mm/yr (high infiltration flux case). The crossover point for the upper bound is at approximately 600 years after waste emplacement. The 60+ mm/yr bin for the mean infiltration flux case represents the upper bound in RH due to its specific edge location and high infiltration rate. The 60+ mm/yr bin for the high infiltration flux case represents the upper bound in RH at later times since it contains location dependent results indicative of both center and edge repository (which delays the time at which this becomes the upper bound) locations and it has a much higher average infiltration rate than does the 60+ mean infiltration flux bin.

The 0-3 mm/yr infiltration bin (low infiltration flux case) has a lower average RH than the 3-10 mm/yr (even though this bin has a slightly higher temperature, refer to Figure 55) because of the differences in the air mass fractions of these low infiltration flux bins. For similar total pressures, the 0-3 mm/yr bin has a higher average air mass fraction thus a lower RH.



The average uncertainty in the percolation flux 5 meters above the crown of the emplacement drift for the CSNF is shown in Figure 57. The bounding time-history fracture flow curve is representative of the 0-3 mm/yr (low infiltration flux case) bin for a lower bound and the 60+ mm/yr (high infiltration flux case) bin for an upper bound. Figure 57 illustrates the potential range in fracture flow above the CSNF including the same uncertainty incorporated into the UZ flow and transport model. From the figure it is noted that the bounding curves shown are those expected for the infiltration flux cases considered in the TSPA. The first peak (at about 70 years) is due to the heat driven enhanced fracture flow, the second peak at 600 years signifies the first future climate state (monsoonal), and the final peak at 2000 years signifies the onset of the final future climate state (glacial transition climate). From the figure it is noted that the thermally enhanced fracture flow at this location subsides before the onset of the first (monsoonal) future climate. The fracture flow at this location is always greater than or equal to the ambient flow for this location (5 meters above the crown of the drift). Recall that the percolation flux at this location serves as an input to the TSPA seepage model in order to determine the seepage volume flow rate into the emplacement drifts.



Analogous figures are shown for the HLW. The trends are virtually identical when compared to Figures 55-57 for the CSNF. The primary differences arise in the max and min values for temperature or RH in the figures previously shown. Figure 58 indicates an average waste package temperature time-history for the HLW that contains the same infiltration bin bounding curves and nearly the same trends as shown in Figure 55 for the CSNF.

Both the upper and lower temperature bounds for the HLW are less than the CSNF for the first 10,000 years after waste emplacement. The average peak temperatures are both somewhat below 160°C whereas the CSNF both exceed 160°C. The difference between the fuel types declines almost immediately as time progresses from the maximum temperature (note that the HLW drops through the boiling point about 50 years before the CSNF). After 10,000 years, the temperature difference between the upper and lower bounds of the different fuel types is negligible.

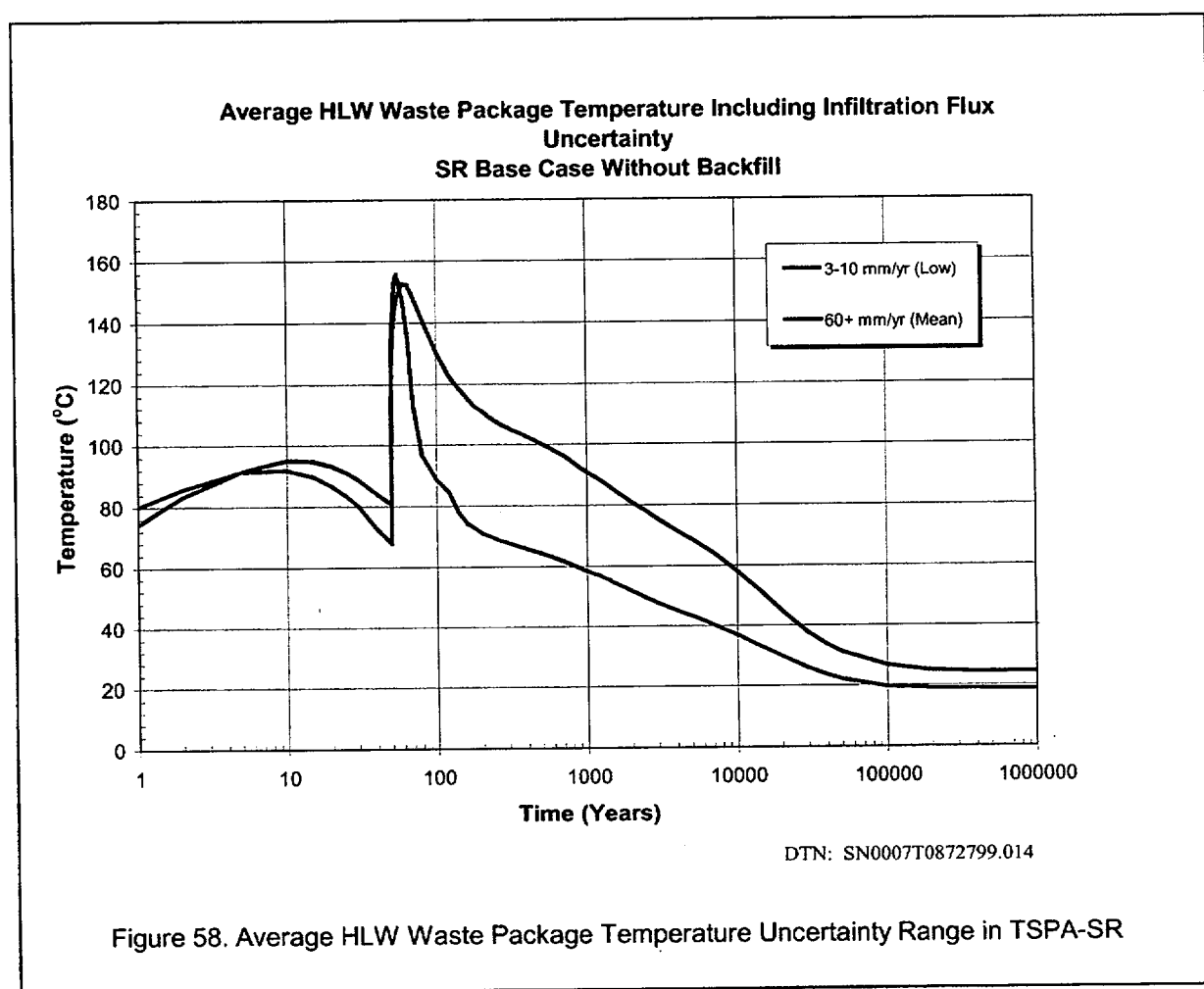
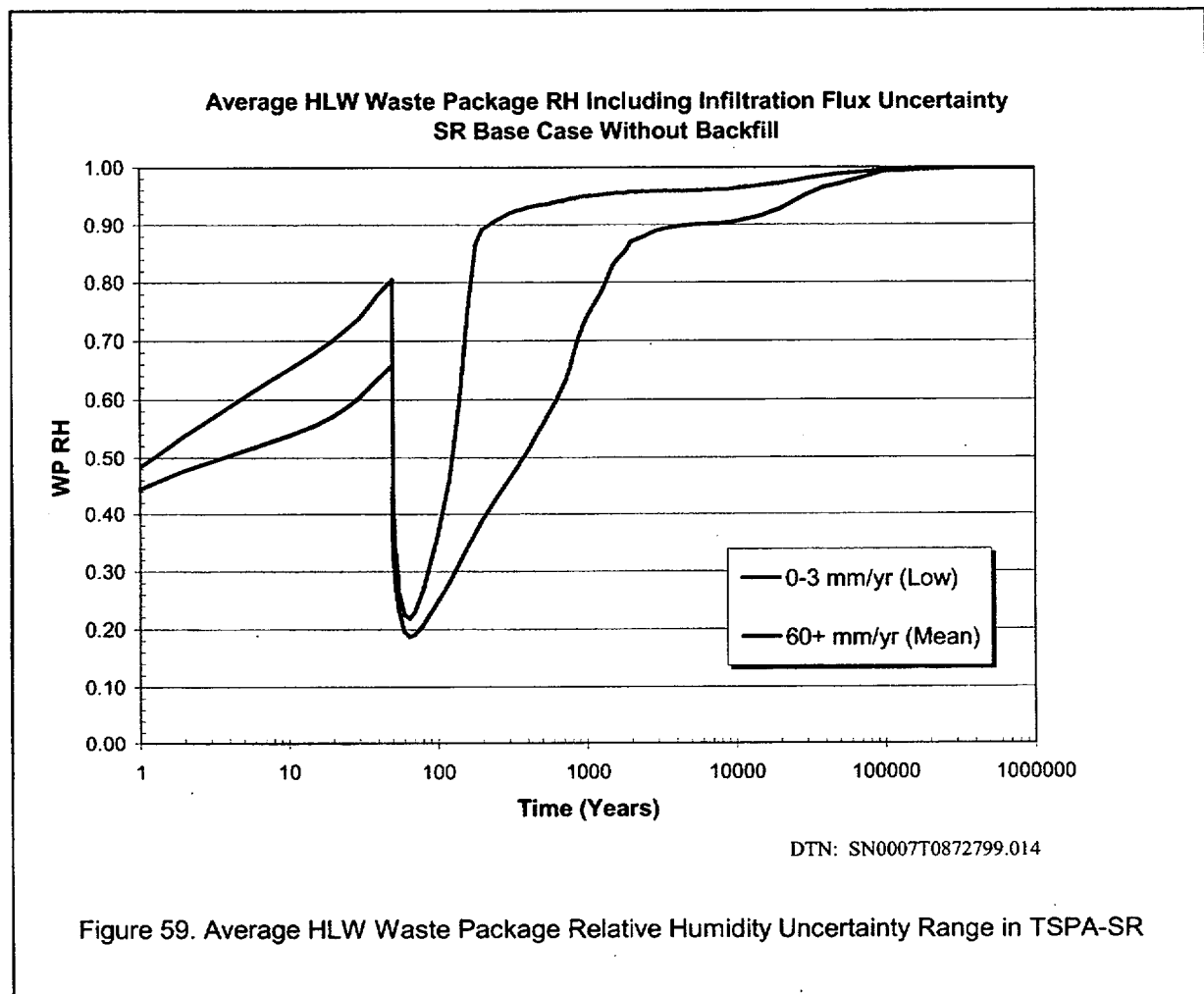
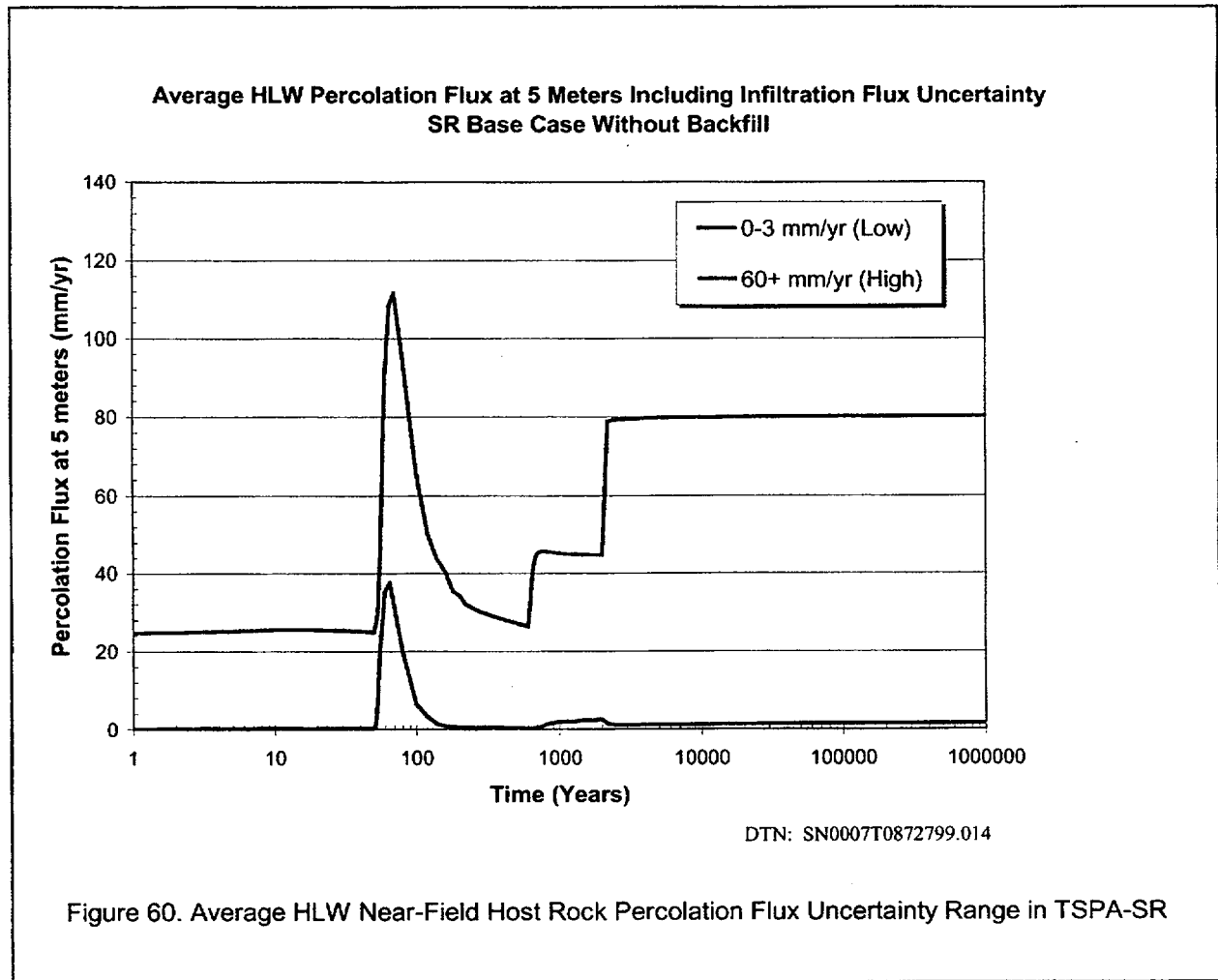


Figure 59 illustrates the average waste package RH for the HLW. Unlike the previous fuel type, the average upper bound for the RH remains the 60+ mm/yr mean infiltration flux case time-history curve.

Since the HLW drops through the boiling point somewhat more rapidly than the CSNF for this upper (RH) bound infiltration bin (e.g., 60+ mm/yr mean infiltration flux case), the RH increases much more rapidly and to higher values in the case of the HLW. The rapid increase in RH for the mean infiltration flux case (shown in Figure 59 beginning at approximately 100 years after waste emplacement) is such that it and the 60+ mm/yr high infiltration flux case are essentially identical at late times. Only one bounding curve is shown in the figure.



The average uncertainty in the percolation flux 5 meters above the crown of the emplacement drift for the HLW is shown in Figure 60. The bounding time-history fracture flow curve is representative of the average 0-3 mm/yr (low infiltration flux case) bin for a lower bound and the average 60+ mm/yr (high infiltration flux case) bin for an upper bound. Figure 60 illustrates the potential range in fracture flow above the HLW including the same uncertainty incorporated into the UZ flow and transport model. From the figure it is noted that the bounding curves shown are those expected for the infiltration flux cases considered in the TSPA.



### 6.3.12 Post-10k-Year Climates for TSPA

Some TSPA simulations will include additional climate states after 10,000 years. Recall that the abstracted TH results developed in this AMR and applied in the total system model are for 0 to 600 years present day climate, 600 to 2,000 years monsoonal climate, and from 2,000 years on,



glacial-transition climate (refer to Section 6.3.8 for an example of this sequence of climates related to the percolation flux at 5 meters). That is, no additional changes in climate after 2,000 years. Additional full-glacial climate states are now being added to the total system model after 10,000 years. The full-glacial climates occur at various times after 10,000 years and include each of the three infiltration flux cases (low, mean, and high infiltration flux). The first full-glacial climate occurs after 38,000 years. A number of others occur after that. Since the full-glacial climates occur at late times, only emplacement drift seepage and UZ flow fields are modified for the full-glacial climates occurring after 10,000 years. Three (future) full-glacial stages are identified for TSPA, and each contains a low, medium, and high representation for the amount of infiltration and flow (CRWMS M&O 2000f, Section 6.3). As indicated in the table in Section 6.3 of CRWMS M&O 2000f, only the low infiltration flux case for Glacial Stage 10/8 (defined in the table in CRWMS M&O 2000f, Section 6.3) will be considered in this abstraction.

Although both drift seepage and UZ flow fields are modified for the new future climate states, the present discussion focuses only on the seepage component. Specifically, the seepage component associated with the low infiltration flux case at late times. The TH abstraction AMR provides input (percolation flux at 5 meters) to the drift seepage model. That input must be modified to reflect the new climates. Consequently, the percolation flux at 5 meters is modified for the full-glacial climates. This section describes the modification (of the percolation flux at 5 meters) of the low infiltration flux case for the Glacial Stage 10/8 future climate. The percolation fluxes used as boundary conditions in the abstracted seepage model for each of the remaining infiltration flux cases and full-glacial climates are described in Section 6.3 of CRWMS M&O 2000f. This abstraction AMR (e.g., Section 6.3) also produces the in-drift thermodynamic environment.

The TH variables that describe the in-drift environment, including waste package temperature and relative humidity or drip shield temperature and relative humidity, are not modified (for the full-glacial climates) from previous abstractions (of the low, mean, and high infiltration flux cases described in Sections 6.3.1 through 6.3.11). This is considered appropriate because these variables (e.g., at the initial time of full-glacial climate and all subsequent full glacial climates thereafter) are near their ambient values (e.g., refer to Figures 38 and 39) at late times. Additionally, the differences in these thermodynamic variables driven by infiltration flux (which also includes changes in climate state as described in this AMR) are negligible based on the time-histories shown in Section 6.3 of this AMR (e.g., Figures 38 and 39 show, at late times, that the temperature curves for the low, mean, and high infiltration flux cases are within a few degrees of each other and that the relative humidities are within a few percent of each other). Therefore, any full-glacial climate specified (after 30,000 years or later) for an infiltration flux case (e.g., low, mean, and high) uses the thermodynamic (but not flux) variable time-histories developed for that infiltration flux case from the abstraction results in Sections 6.3.1 through 6.3.11.

The TH abstraction described in this AMR does not influence the UZ flow fields. Therefore, no TH modifications to the full glacial climate flow fields are necessary.

For the infiltration flux case considered here (low infiltration flux), the first full-glacial climate at 38,000 years uses the existing high infiltration flux case glacial-transition climate percolation fluxes as a proxy for the percolation fluxes assigned to the low infiltration flux case during this full-glacial state. This requires mapping the percolation flux time-history curves from the high infiltration flux case (contained in four infiltration bins) into two bins for the low infiltration flux case. The percolation flux curves are represented at each of the repository coordinate locations (610 total as described in Section 6.2 and Table 5 for no backfill). The repository locations for the low infiltration flux bins (refer to Figure 18) define the final destinations of the 610 percolation flux curves that are mapped from high bins to low.

That is, the percolation flux curves from the high infiltration flux case are reassigned from their placement in the high infiltration flux bins to the low infiltration flux bins based on the repository locations shown in Figure 18. This abstraction results in percolation fluxes (as a function of location) for a full-glacial climate (beginning at 38,000 years) of the low infiltration flux case represented by the elevated percolation fluxes from the glacial-transition high flux case. The routines developed to provide this abstraction are discussed in Attachment VIII. The routines and output are found in DTN: SN0010T0872799.015.

This abstraction analysis is required to provide TSPA with climate states (full-glacial) after 10,000 years for the low infiltration flux case (Glacial Stage 10/8). The AMR referenced in CRWMS M&O 2000f provides all other future climate state data for the TSPA model. This abstraction is an appropriate representation of a future full-glacial climate for the low infiltration flux case since the average net infiltration for the low flux (Glacial Stage 10/8) case is analogous to that of the high infiltration flux case glacial-transition climate. The TH variables are not modified at late times for the reasons described above.

## **6.4 TH ABSTRACTION RESULTS FOR THE BACKFILLED REPOSITORY (ALTERNATIVE) DESIGN**

### **6.4.1 CSNF Temperature Profiles**

There is considerable variability in the peak waste package temperatures throughout the repository for different glacial infiltration flux cases. The highest, the mean, and the lowest peak waste package temperatures for all of the bins and infiltration flux cases for both HLW and CSNF are presented in Table 9. The peak waste package temperatures all occurred during the first 10 years after closure (50-60 year simulation times). The highest peak waste package temperature of 316°C was a CSNF waste package in the 0-3 mm/year bin of the low infiltration flux case. The lowest maximum waste package temperature of 235°C was for a HLW waste package in the 20-60 mm/year bin in the high infiltration flux case. These temperatures are much higher than those for the TSPA-SR base case design. The peak waste package temperatures range from the TSPA-SR base case was from 127 to 186°C; this is a difference of over 100°C between the two cases. The lower temperatures are the result of removing the backfill, reducing the heat into the system by 6% at all times, and increasing the thermal conductivity of the invert. Most of the temperature change is due to removing the low thermal conductivity backfill and allowing heat from the waste package to radiate to the drift wall.

The bin averaged CSNF waste package peak temperatures for the backfill alternative design case were between 14 and 21°C higher than the corresponding bin averaged HLW waste package peak temperatures. This table illustrates the variability in the peak temperature contained inside individual bins as well as the variability in thermal response throughout the repository.

Table 9. The Minimum, Mean, and Maximum of the Peak CSNF and HLW Waste Package Temperatures (°C) for All Bins for the Three Infiltration Flux Backfill Design Alternative Cases

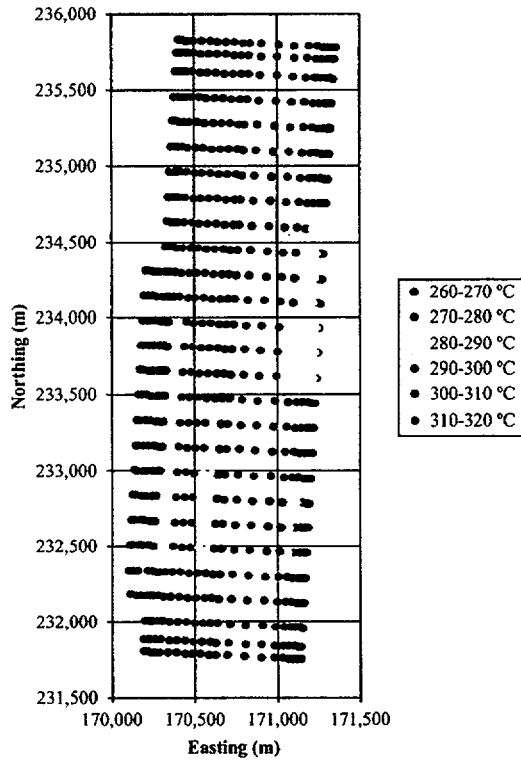
Bin (mm/yr)	Infiltration Rate Map	HLW Min (°C)	HLW Mean (°C)	HLW Max (°C)	CSNF Min (°C)	CSNF Mean (°C)	CSNF Max (°C)
0-3	High	-	-	-	-	-	-
	Mean	259	273	286	276	288	299
	Low	246	279	298	263	296	316
3-10	High	242	271	283	259	285	296
	Mean	243	278	287	261	292	300
	Low	254	278	301	273	299	319
10-20	High	240	269	284	257	283	296
	Mean	239	267	287	257	282	300
	Low	-	-	-	-	-	-
20-60	High	235	254	283	253	270	296
	Mean	240	268	287	257	283	299
	Low	-	-	-	-	-	-
60+	High	249	252	258	266	269	274
	Mean	256	256	257	274	274	275
	Low	-	-	-	-	-	-
Overall	High	235	256	284	253	272	296
	Mean	235	269	287	257	284	300
	Low	246	279	301	263	297	319
Overall	Overall	235	268	301	253	284	319

DTN: SN0001T0872799.006

NOTE: A Dash in the Table Means that There Were No Waste Package Locations in that Infiltration Flux Bin.

Figures 61-63 contain the peak temperature of the backfill design alternative 623 CSNF waste package locations in the repository for the three infiltration flux cases. Note that the peak temperatures are higher for the lower infiltration flux cases. Peak temperatures are also higher at the center repository locations and lower at edge repository locations. The average temperature difference between the low and the high infiltration flux case waste package peak temperatures at 623 locations was 26°C.

Maximum Waste Package Temperature, DSPS,  
Low Infiltration, TSPA-SR Backfill Design Alternative



DTN: LL000113904242.089

Figure 61. The Peak Waste Package Temperatures for All 623 Waste Package Locations for the Low Infiltration Flux Backfill Design Alternative Case

Maximum Waste Package Temperature, DSPS,  
Mean Infiltration, TSPA-SR Backfill Design Alternative

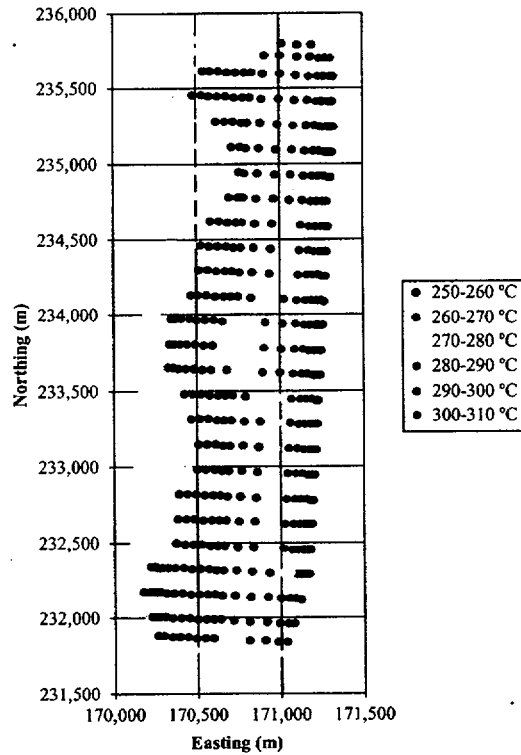


Figure 62. The Peak Waste Package Temperatures for All 623 Waste Package Locations for the Mean Infiltration Flux Backfill Design Alternative Case

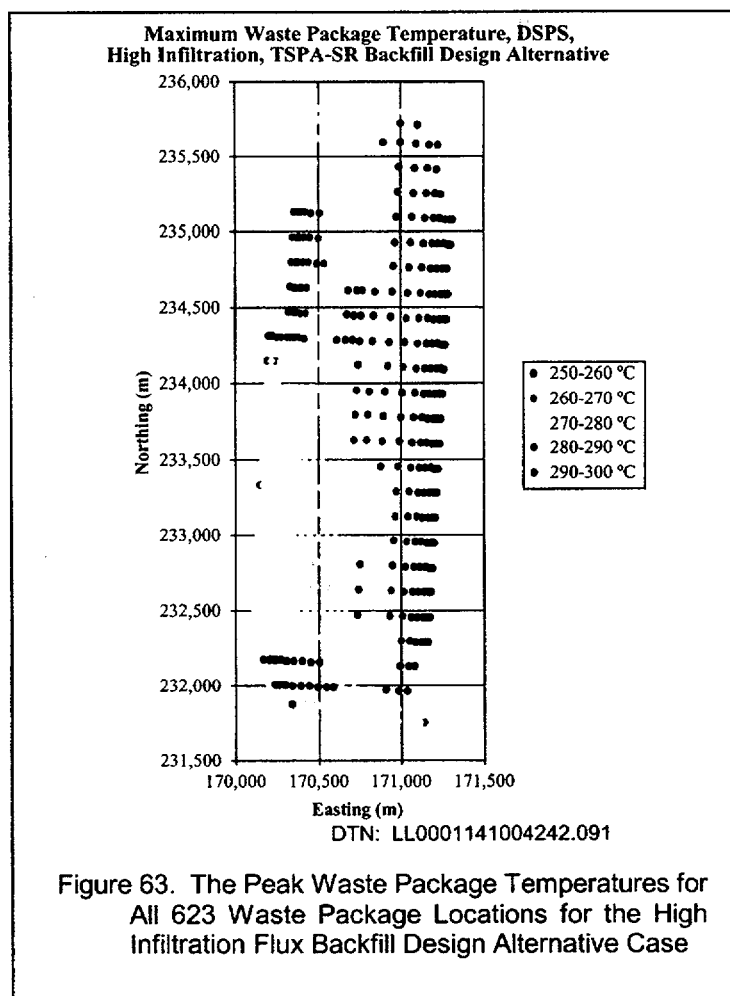


Table 10 contains the difference between the highest and lowest peak waste package temperature for each of the bins. The variability within each bin was as high as 52°C (HLW) and 53°C (CSNF) for the 0-3 mm/year in the low infiltration flux case. The small variability (1°C) in the 60+ mm/year mean infiltration flux bin is directly attributable to there being only three waste packages in this bin. They were also adjacent to each other with nearly identical local infiltration fluxes.

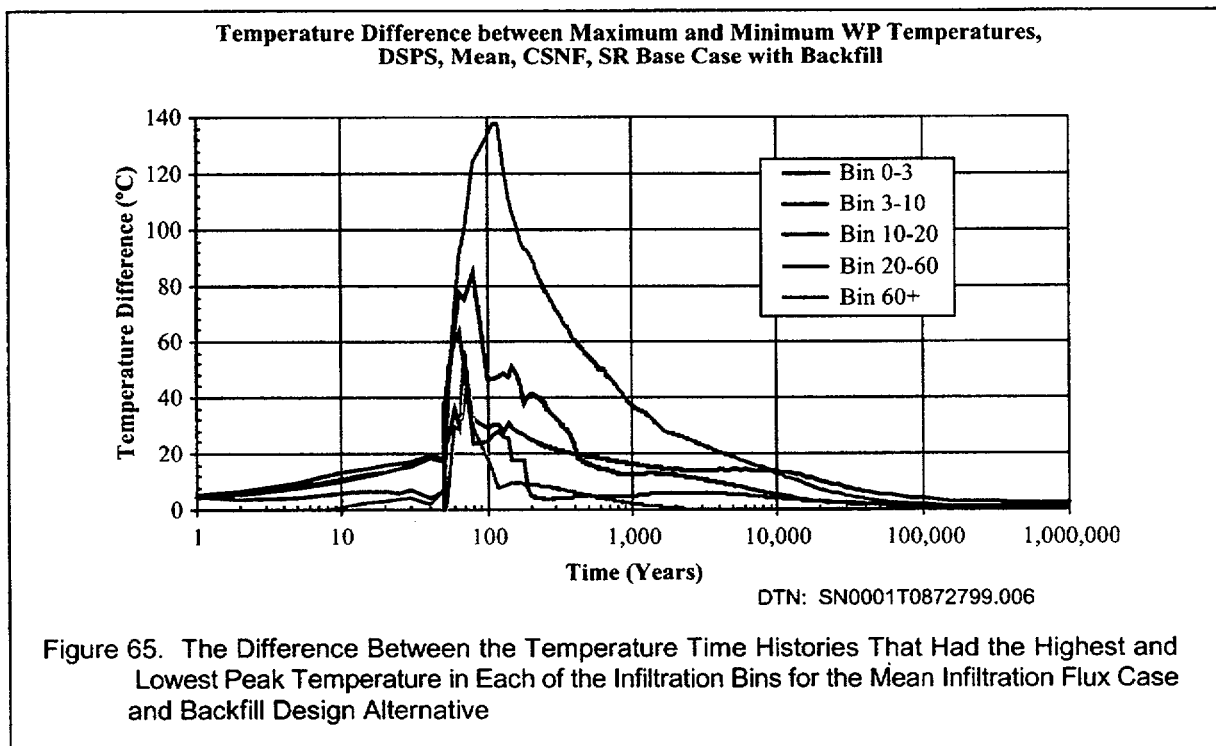
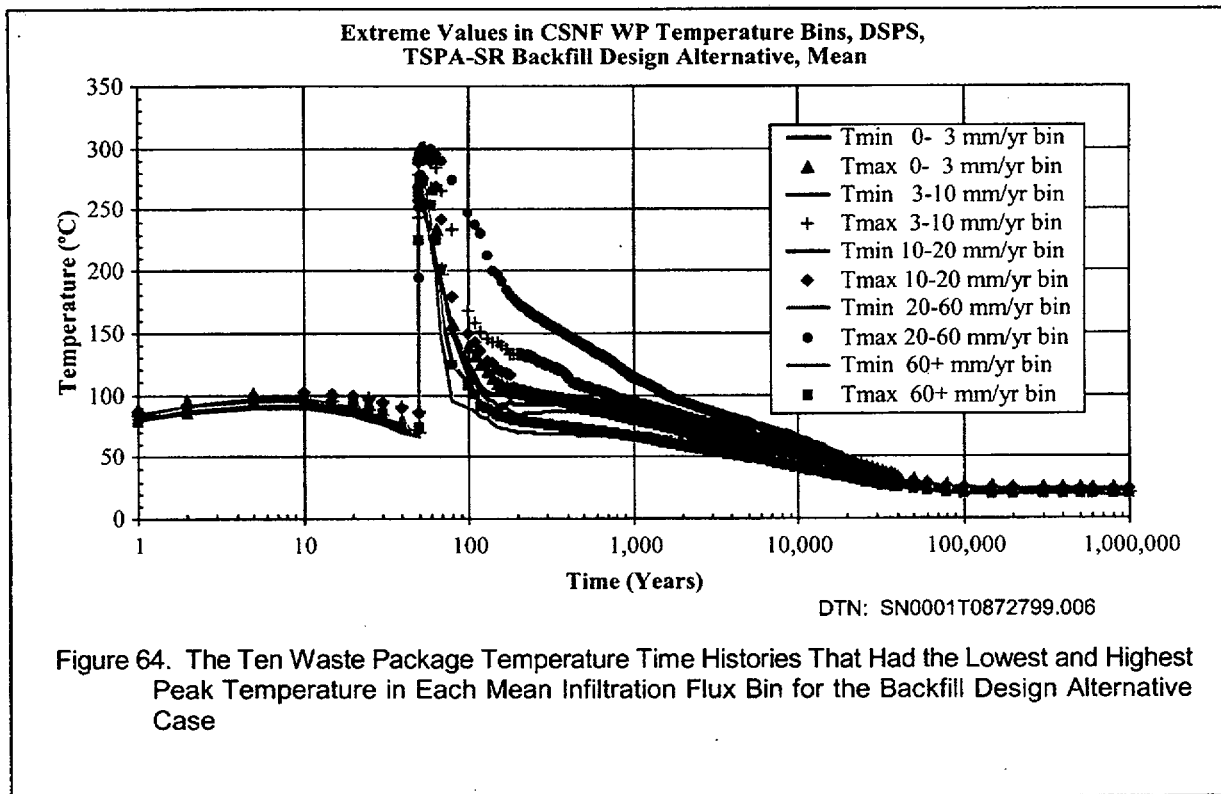
Table 10. The Difference Between the Highest and the Lowest Maximum Temperature (°C) in Each Bin for Each Infiltration Flux as well as the Overall Temperature Difference for Each Infiltration Flux and for the Backfill Design Alternative Case

Bin mm/yr	Infiltration Rate	HLW (°C)	CSNF (°C)	CSNF+HLW (°C)
0-3	High	-	-	-
	Mean	27	23	41
	Low	52	53	69
3-10	High	41	37	55
	Mean	44	39	57
	Low	47	47	66
10-20	High	44	39	56
	Mean	48	43	61
	Low	-	-	-
20-60	High	48	43	61
	Mean	47	42	60
	Low	-	-	-
60+	High	9	8	25
	Mean	1	1	18
	Low	-	-	-
Overall	High	48	48	61
	Mean	52	52	65
	Low	54	54	73
Overall	Overall	65	65	84

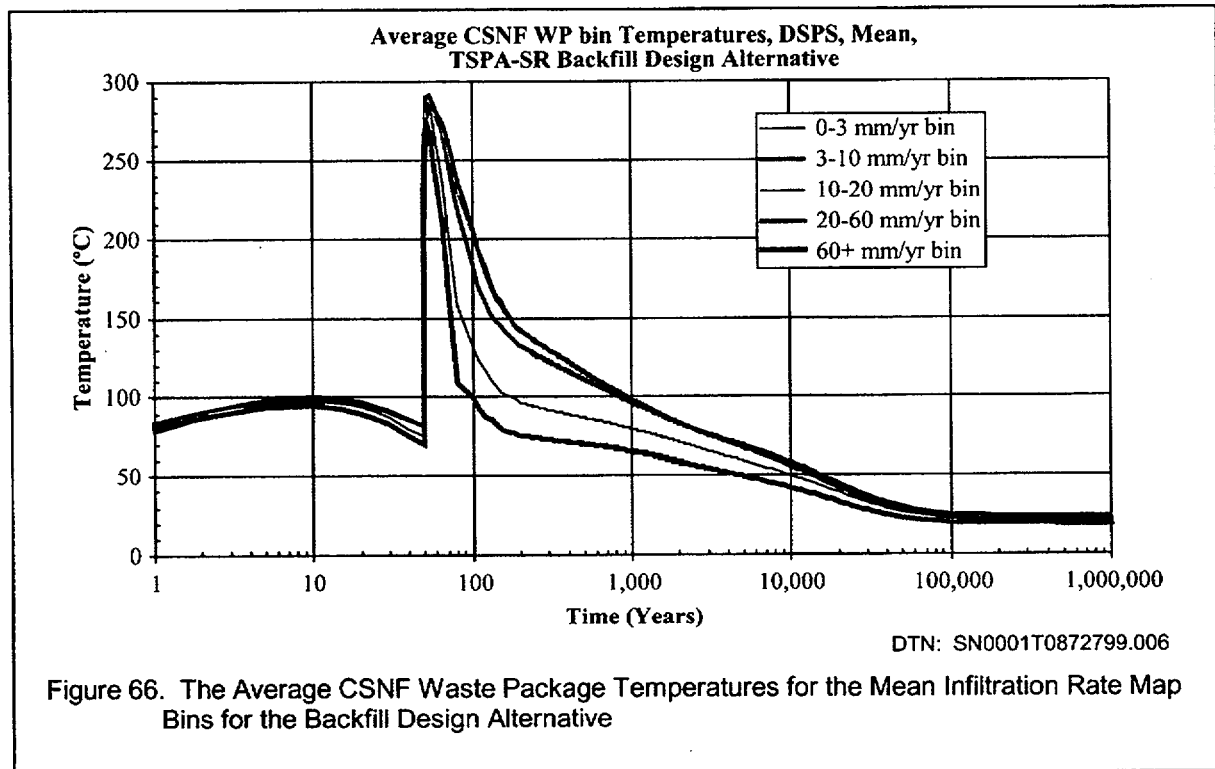
DTN: SN0001T0872799.006

Figure 64 shows the CSNF waste package temperature time history for the highest and lowest peak temperature curves in each of the five infiltration case bins for the mean infiltration flux case. Figure 65 shows the difference between the highest and lowest infiltration flux time-history curves for each of the bins. The largest difference between curves was 138°C just after 100 years for the 20-60 mm/year infiltration bin. The difference is still present after 1000 years at which time there is a 38°C difference between the two time-histories in the 20-60 mm/year infiltration bin. The largest bin averaged temperature difference does not drop below 10°C until after 20,000 years.





The five bin averaged waste package temperature time-histories for the mean infiltration flux case is presented in Figure 66. The maximum temperature for the bins were reached between 52 and 55 years and ranged from a low of 274°C for the 60+ mm/year bin to a high of 292°C for the 3-10 mm/year infiltration rate bin. The 0-3 and 60+ mm/year infiltration rate waste package bins cooled off the quickest as a result of the waste packages all being at the edges of the repository. The average temperatures returned to ambient conditions within 100,000 years.



#### 6.4.2 CSNF and HLW Waste Package Bin Temperature Comparison

The average CSNF and HLW waste package bin temperatures for the mean infiltration rate are presented in Figure 67. There is a steep rise in temperatures at the time of repository closure (50 years) with peak maximum bin averaged temperatures of between 250 and 300°C. At 100 years after waste emplacement, there is much variability in the bin averaged temperatures from a low of 80°C (60+ mm/year HLW bin) to a high of 200°C (3-10 mm/year CSNF bin).

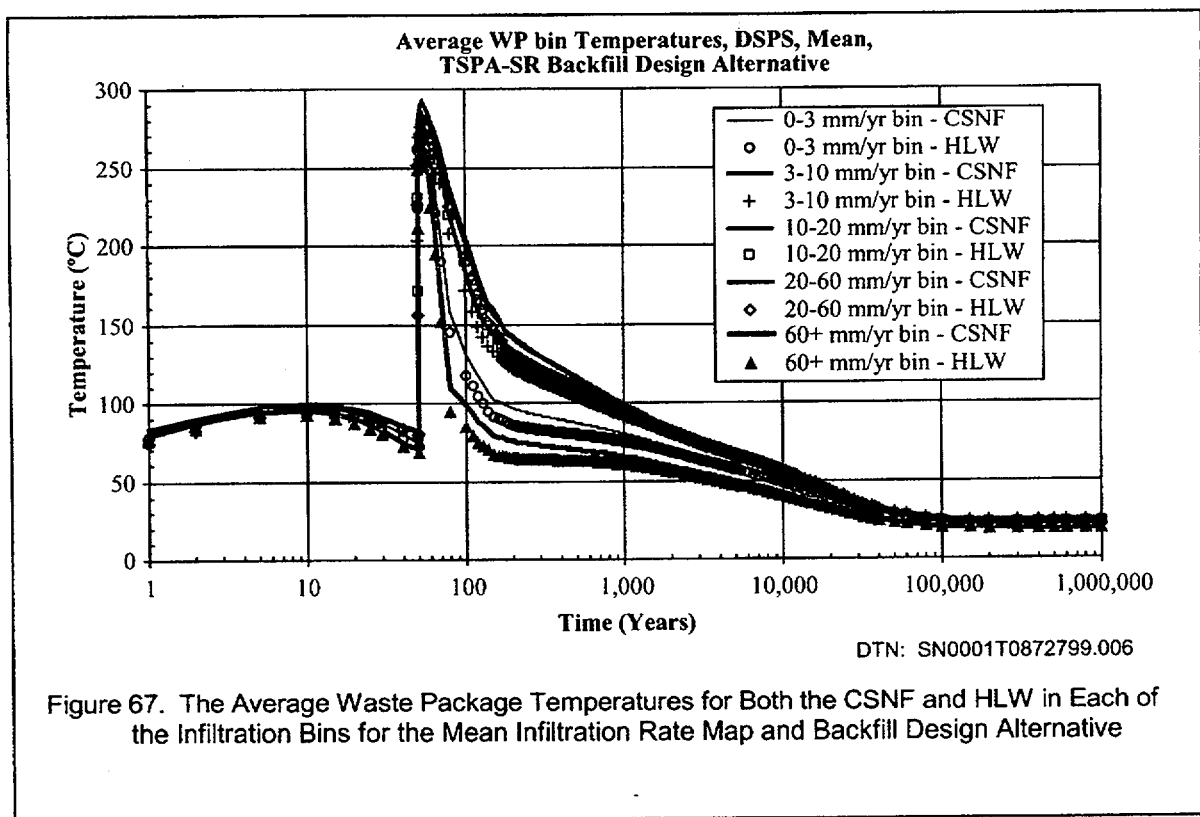
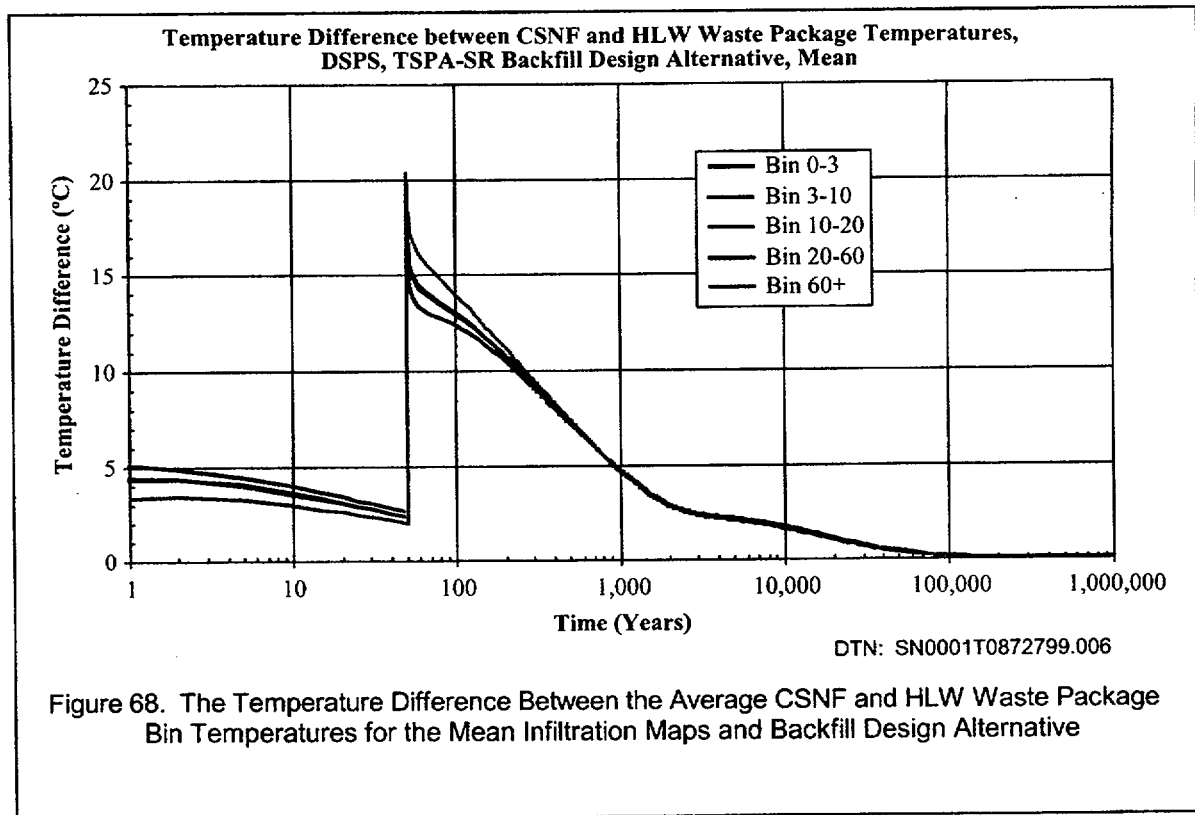


Figure 68 contains the difference between the bin averaged CSNF and HLW waste package temperatures. The maximum difference between the CSNF and HLW packages is between 20 and 21°C for all three bins just after 50 years. After 100 years, the average CSNF waste package bin temperatures were 12 to 14°C higher than bin averaged HLW temperatures. This difference decreased to 10°C after 250 years, 5°C after 900 years and to 1°C after 22,000 years.



### 6.4.3 CSNF and HLW Waste Package Bin Relative Humidity Comparison

Figure 69 contains the relative humidity of the bin averaged CSNF and HLW waste packages for the mean infiltration flux map. The relative humidities reach a minimum right after closure between 50 and 70 years. The 0-3 mm/year and the 60+ mm/year bin relative humidities return to above 90% after between 780 and 1450 years. The last bin (3-10 mm/year CSNF bin) reaches 90% relative humidity after 6000 years.

Since the temperatures of the CSNF waste packages are always higher than those of the HLW waste packages, the relative humidity of the HLW waste packages is always higher than that for the corresponding CSNF waste package (see Figure 70). The difference between the HLW and the CSNF relative humidities is small at the time of closure when the absolute value of the relative humidities are at a minimum. The difference then increases reaching a maximum for different bins of 10% to 23% between 400 and 800 years. By 1200 years, the difference between all sets of curves dropped below 6%. At 10,000 years, the bin averaged RH differences varied between a high of 3.5% for the 3-10 mm/year bin to a low of 1.1% for the 60+ mm/year bin. After 100,000 years of simulation time, the differences had dropped below 0.23% in all five bins.

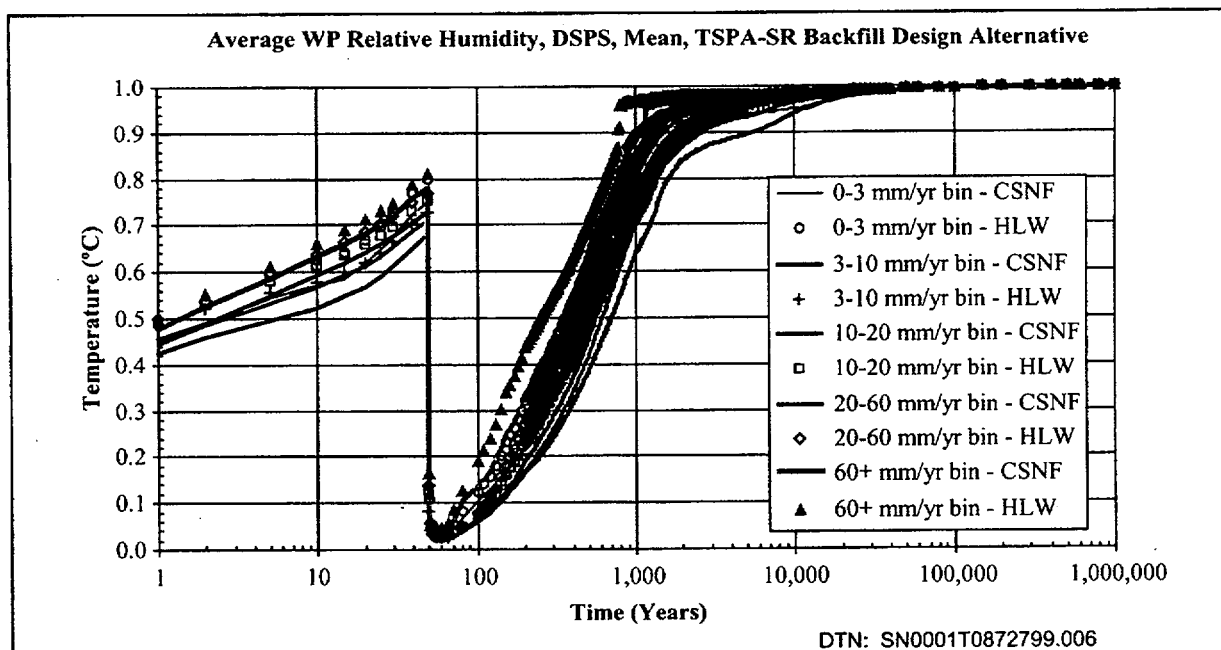


Figure 69. The Average Waste Package Relative Humidity for Both the CSNF and HLW in Each of the Infiltration Bins for the Mean Infiltration Rate Map and Backfill Design Alternative

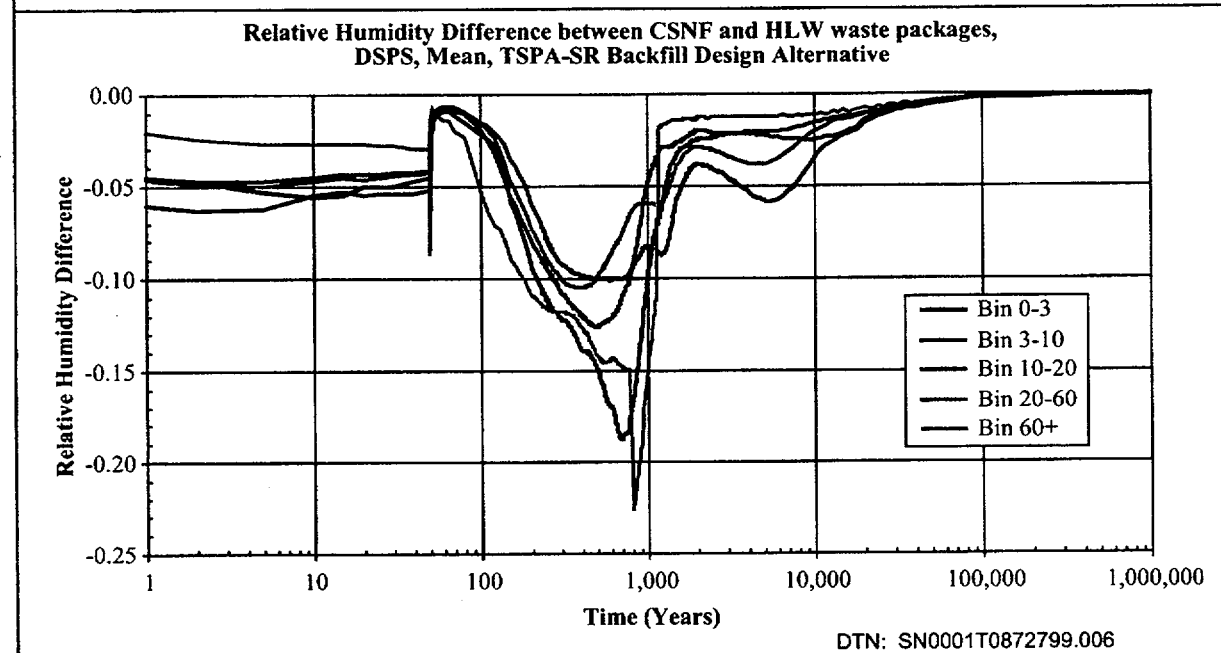
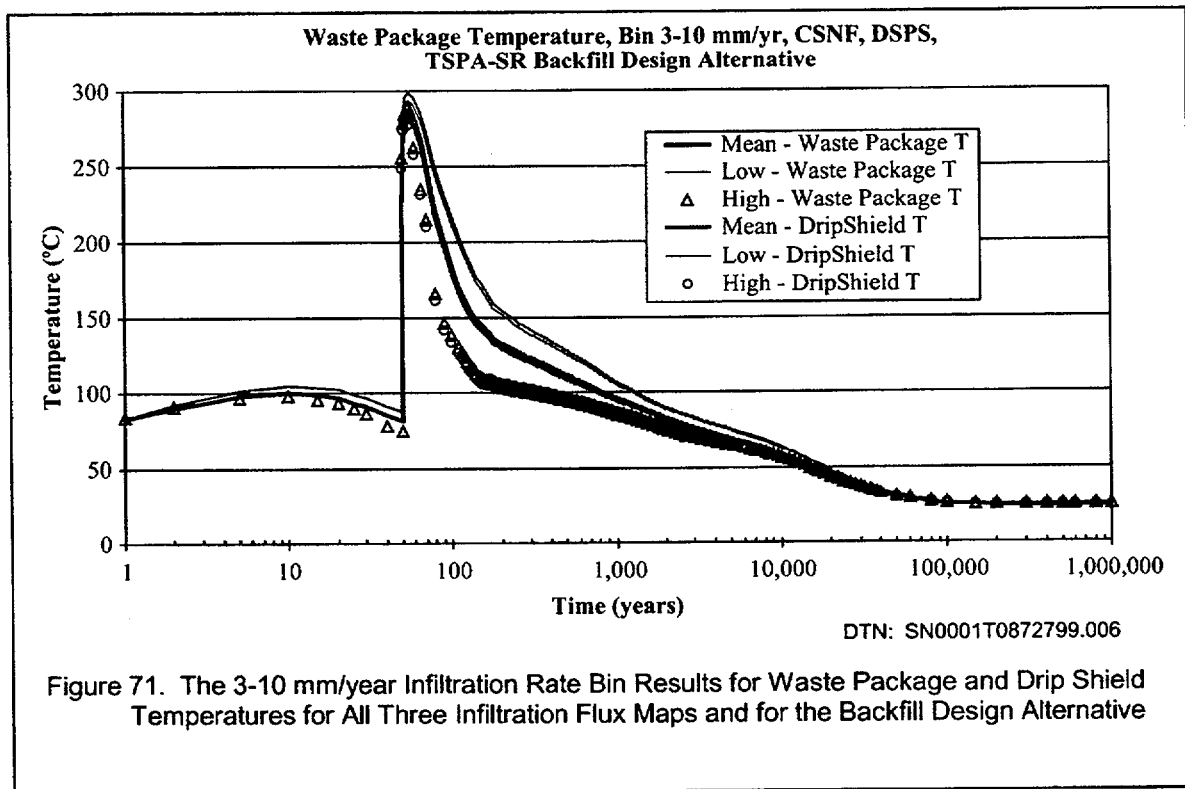
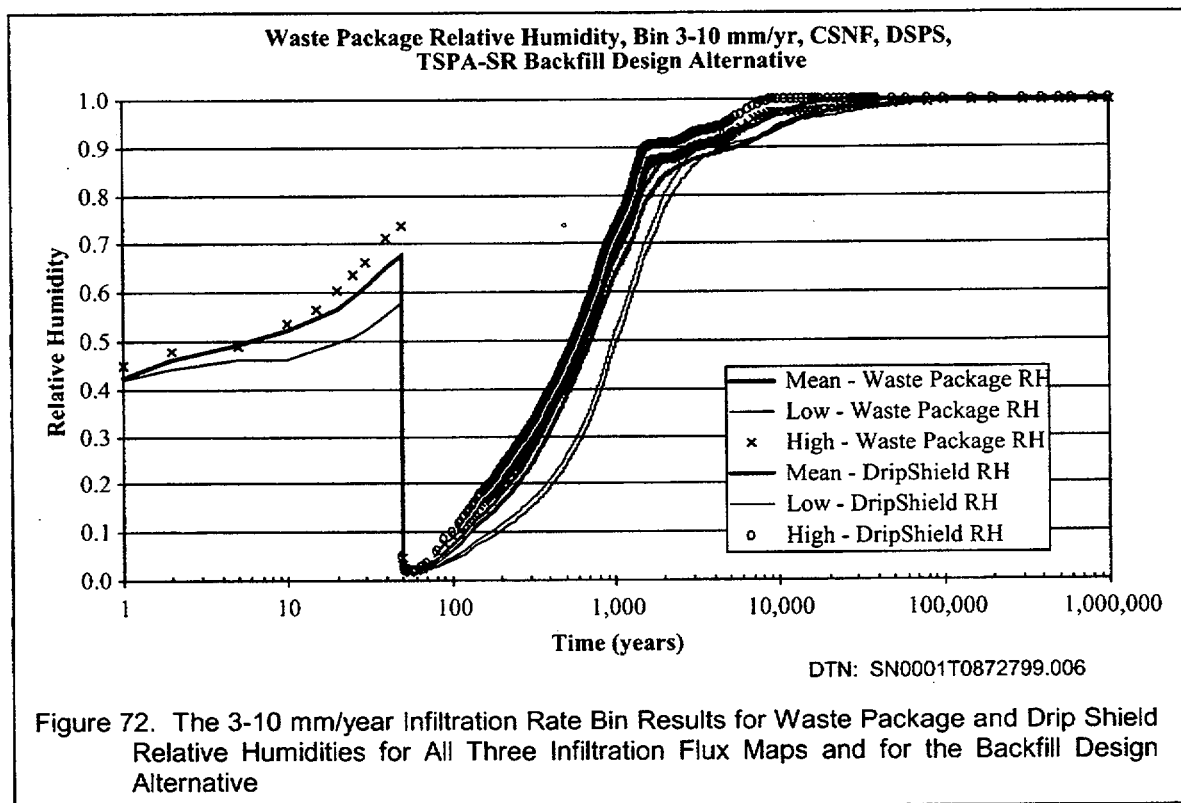


Figure 70. The Difference in Relative Humidity Between the Average CSNF and HLW Waste Package Bin Temperatures for the Mean Infiltration Maps and Backfill Design Alternative

#### 6.4.4 Comparison of Waste Package 3-10 mm/year Bin Averaged Temperatures and Relative Humidity for All Infiltration Flux Cases

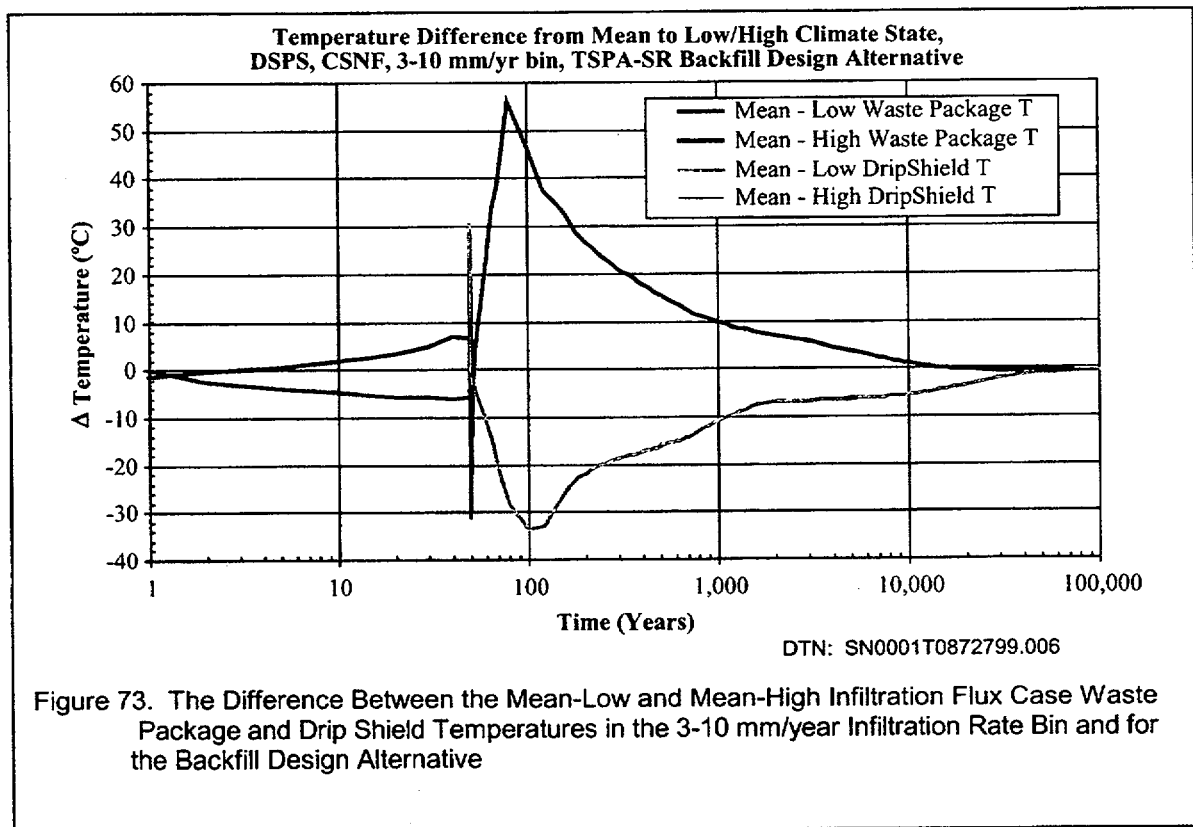
The average waste package temperature and relative humidity time-histories for the 3-10 mm/year infiltration flux bin for all three infiltration cases are presented in Figure 71 and Figure 72. The 3-10 mm/year bin was the only infiltration flux bin that contained waste packages for each of the three infiltration flux cases.





In Figure 71, the bin averaged waste package temperatures were higher for the drier infiltration flux cases. This result is caused by the spatial distribution of the waste packages in the three bins with the waste packages from the high infiltration flux case all concentrated next to the edge of the repository, the waste packages from the mean infiltration flux case having some in the center of the repository and others near the edge of the repository, and the waste packages from the low infiltration flux case having a large fraction of waste packages near the center and edge of the repository. The waste package relative humidity time histories for the 3-10 mm/year infiltration bins for all three infiltration maps are presented in Figure 72. The relative humidities bin averages all have minima between 1.74% to 1.96% at 55 to 60 years of simulation time. The bin averaged relative humidity curves are almost always higher for the higher infiltration maps.

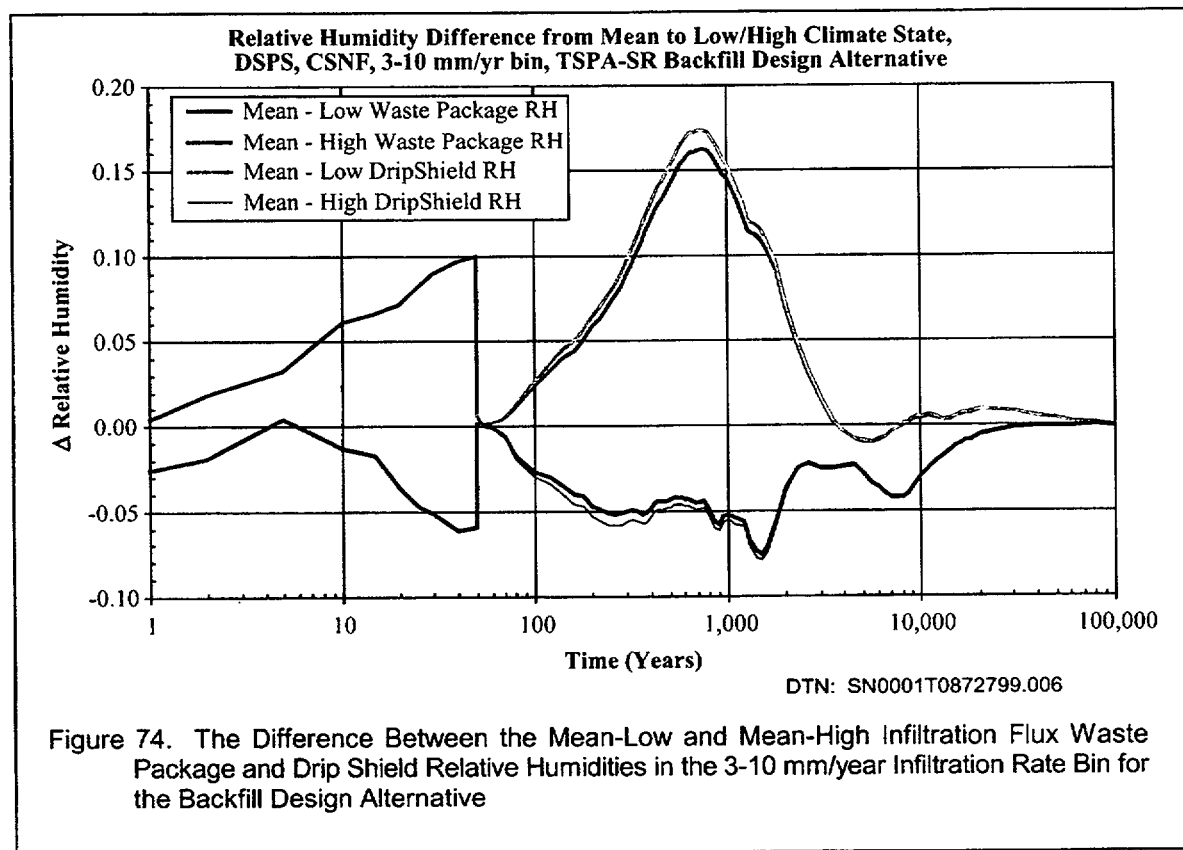
The difference between the bin averaged waste package and drip shield temperatures from the high and low to the mean infiltration maps are shown in Figure 73. The respective curves directly overlay each other (both curves for the mean-high overlay each other greater than zero, same for the mean-low less than zero). The maximum difference between the 3-10 mm/year bin averaged waste package temperatures from the mean and low and the mean and high infiltration maps was 55.9°C at 80 years and 33.5°C at 100 years, respectively. The difference between the high and low infiltration map temperatures drops to 20°C after 1000 years and to 10°C after 5000 years. These plots illustrate that there is considerable variability in the temperature time-histories within the same bin for different infiltration maps. The variability in temperature is a direct result of infiltration rate uncertainty (e.g., three infiltration flux cases).



The difference in relative humidity between the 0-3 mm/year bins is presented in Figure 74. The difference between the mean and the low bin averaged relative humidity curve was usually greater than the difference between the mean and the high bin averaged relative humidity curve. At repository closure with backfill (e.g., 50 years), the difference between the curves were within 0.2% of each other. The greatest bin averaged waste package relative humidity difference between the mean and the low curves was 16% at 750 years and the largest difference between the mean and high curves was 7.6% at 1500 years. The largest difference between the low and high curves was 21%

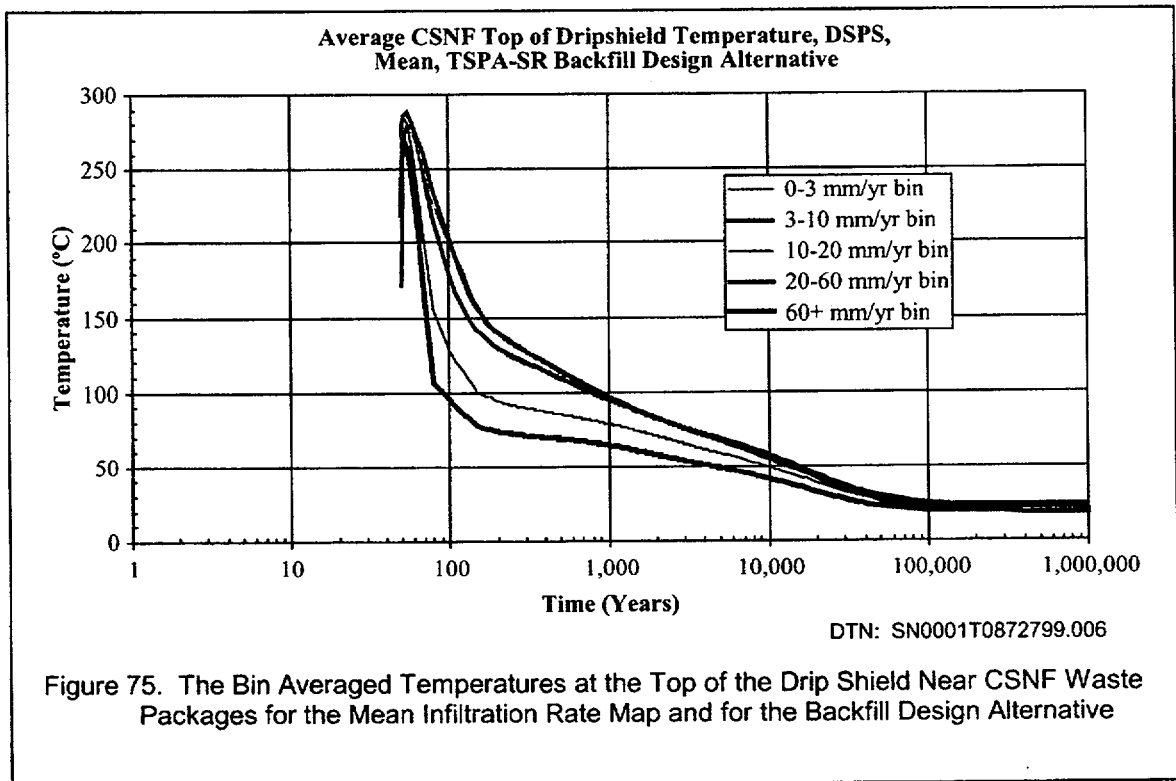


at 850 years. The difference between the RH curves drops below 5% by 3000 years. These results show the variability between the same relative humidity infiltration bin for different infiltration rate maps. The variability in relative humidity is a direct result of infiltration rate uncertainty (e.g., three infiltration flux cases).



#### 6.4.5 Temperature at the Top of the Drip Shield

The bin averaged temperature at the top of the CSNF drip shield for the mean infiltration flux case is presented in Figure 75. The temperature time-histories are similar to those for the CSNF waste packages only a few degrees cooler.



#### 6.4.6 Invert Thermodynamic Variables

The bin averaged CSNF invert temperatures for the mean infiltration flux case are presented in Figure 76. The invert temperature time-histories are cooler but contain the same trends that the waste package temperature curves. The peak temperatures for the five bins were between 236 and 243°C, which is approximately 40°C lower than those of the waste packages. The time that it takes for the invert to cool to 96°C range from 110 years for the 60+ mm/year infiltration bin to 1165 years for the 10-20 mm/year infiltration bin. The bin averaged CSNF invert relative humidity curves (Figure 77) also show the same trends as the waste package relative humidity curves. The bins all reach a minimum ranging from 0.026 and 0.031 between 55 and 60 years and all increase to 90% relative humidity within 1900 years.

Since the invert temperatures are lower than the waste package temperatures, it is expected that the relative humidity for the invert would recover to ambient values faster than the waste package values.

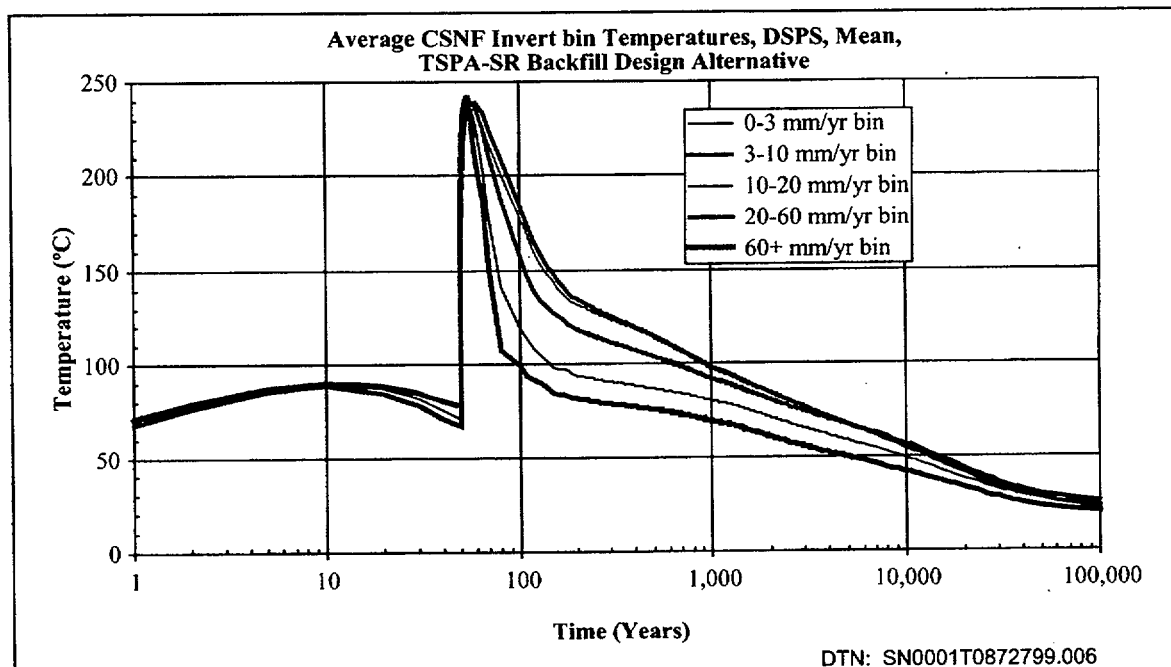


Figure 76. The Bin Averaged Invert Temperatures Near CSNF Waste Packages for the Mean Infiltration Rate Map and for the Backfill Design Alternative

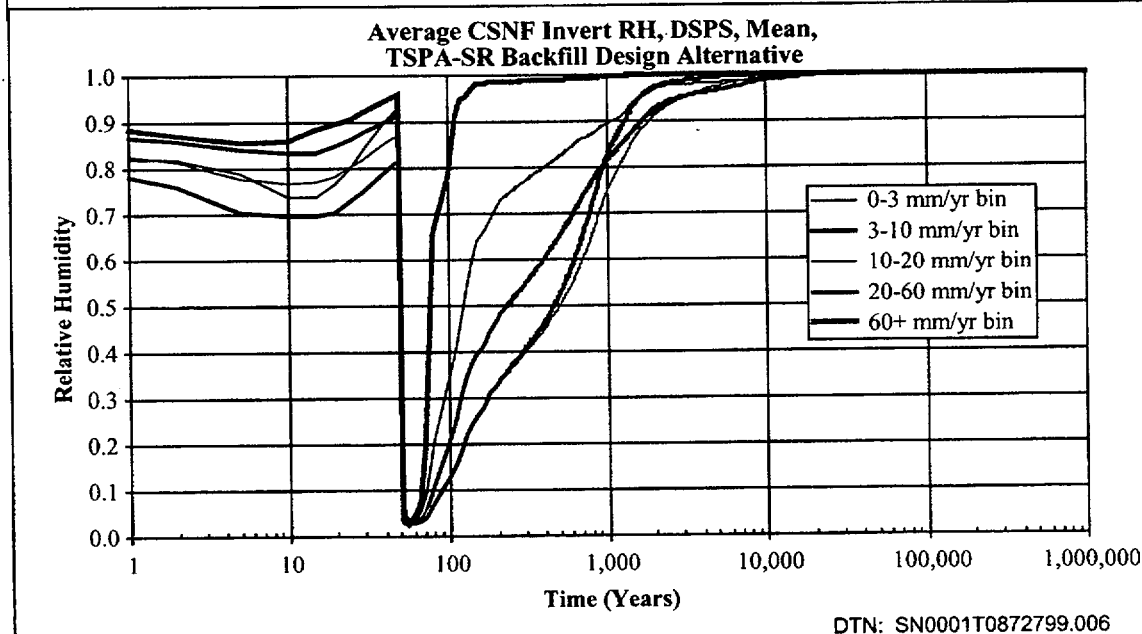
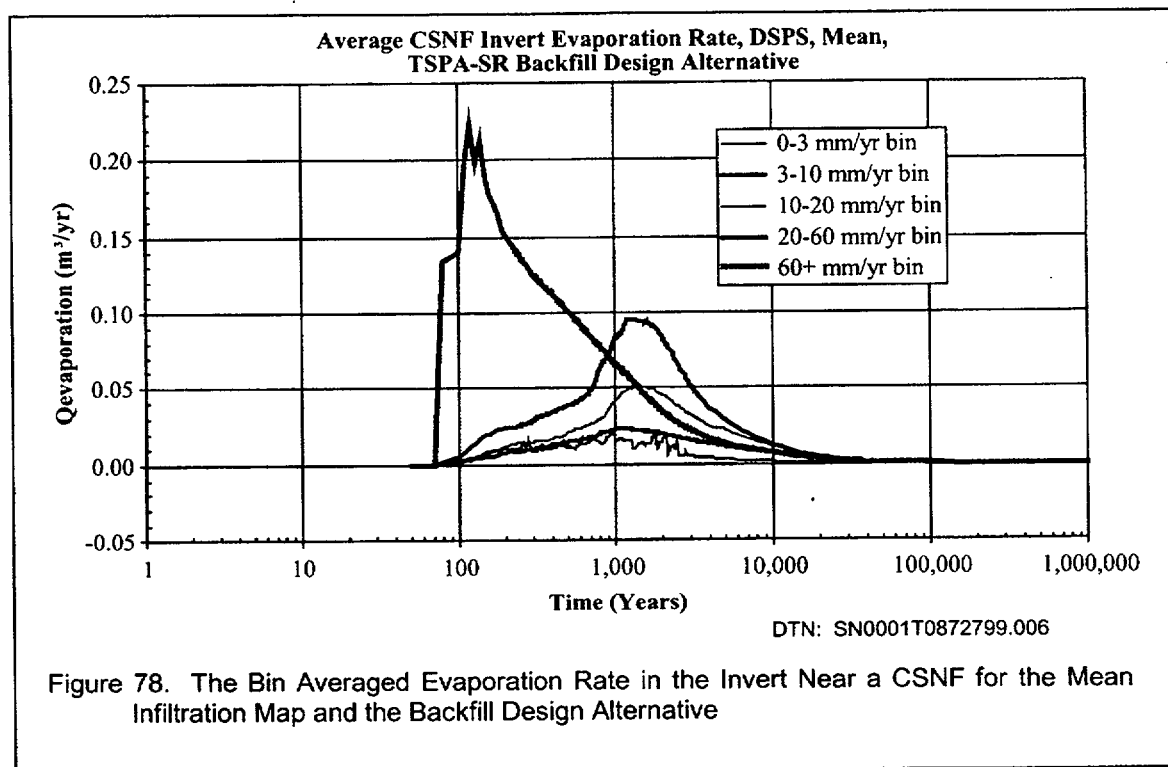
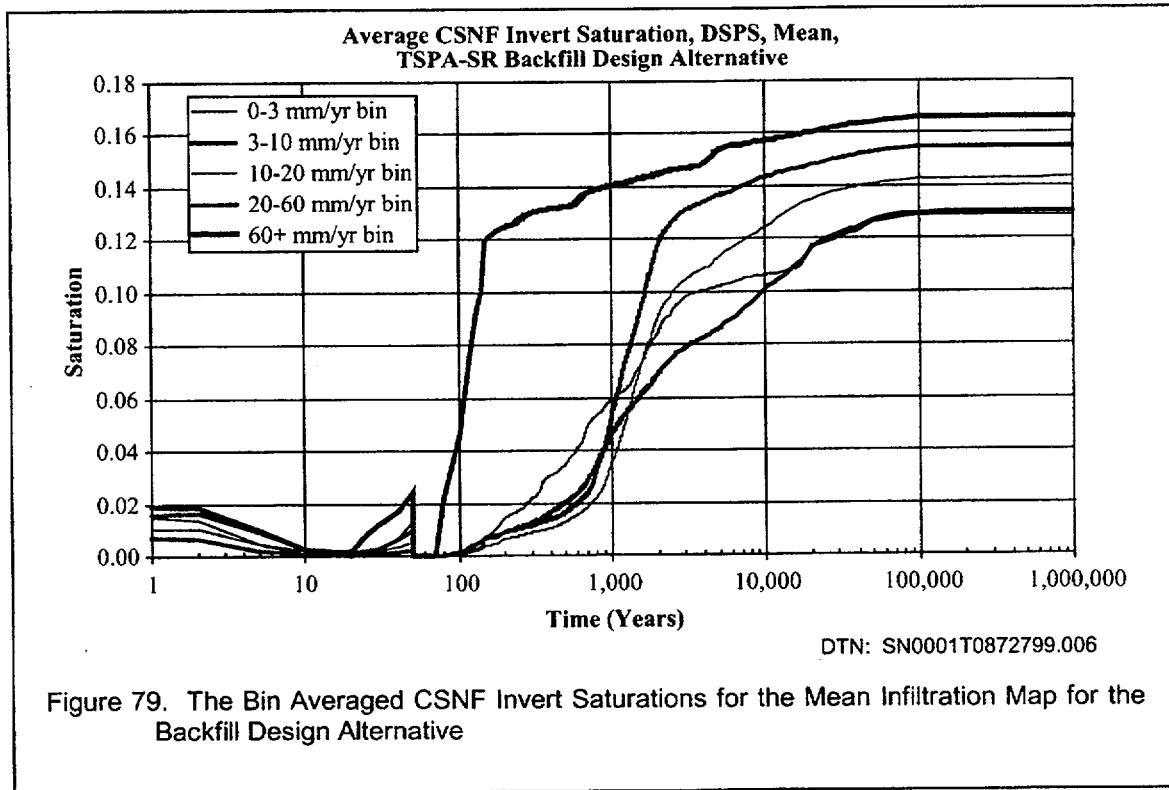


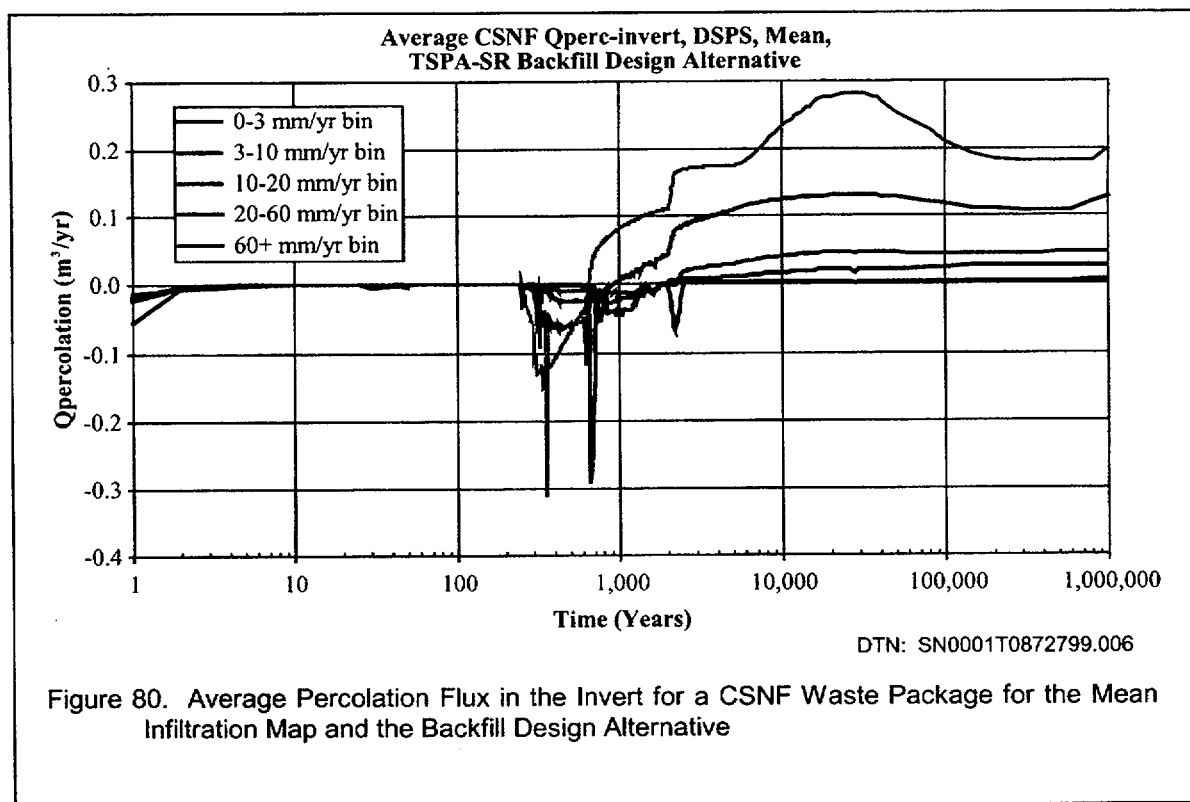
Figure 77. The Averaged CSNF Invert Relative Humidity for the Mean Infiltration Map for the Backfill Design Alternative

The CSNF bin averaged invert evaporation rate and invert saturations for the mean infiltration case are presented in Figures 78 and 79. The invert evaporation rate immediately jumps when water is introduced into the invert (Figure 78). The evaporation rate for the 60+ mm/year infiltration rate bin peaks at  $0.223 \text{ m}^3/\text{year}/\text{m-drift}$  ( $610 \text{ ml}/\text{day}/\text{m-drift}$ ) at 120 years. The invert saturation drops during the first 20 years as a result of evaporation in the invert (Figure 79). The invert saturation time-histories recover just before 50 years but all drop to zero immediately following closure. The invert liquid saturation in all of the bins starts to rise at 80 years although the 60+ mm/year bin liquid saturation rose to 4.5% at 100 years while the other four bins are all still below 0.2% after 100 years. The final invert saturations for the bins are different. This is a result of the higher percolation fluxes requiring higher saturations to allow the water to flow through the system. It takes the 60+ mm/year bin only 130 years to reach 50% of the final saturation, while it takes between 1290 and 1800 years for the other four bins to reach 50% of their final saturations. After 10,000 years, the evaporation rates have all dropped to below  $0.013 \text{ m}^3/\text{year}/\text{m-drift}$  ( $36 \text{ ml}/\text{day}/\text{m-drift}$ ).



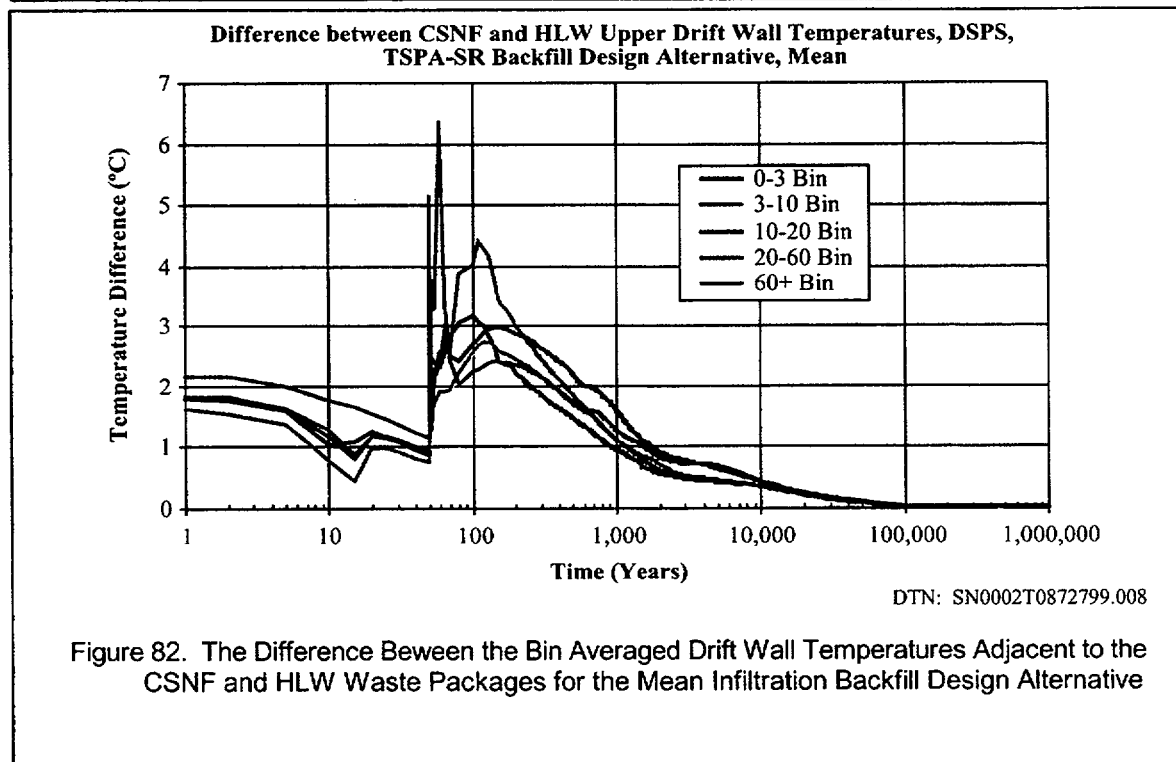
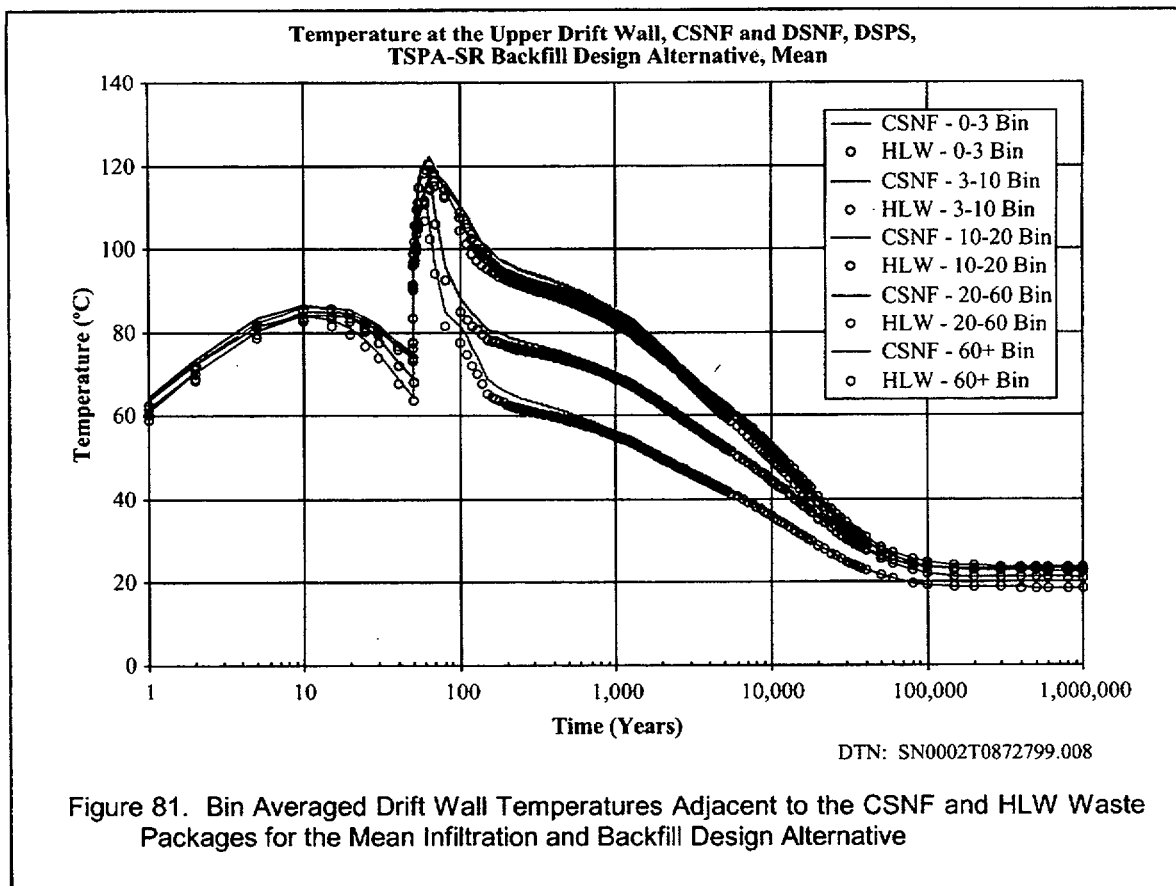


The bin averaged CSNF percolation flux in the invert is presented in Figure 80. The invert flux is small for the first 200 years after waste emplacement. The percolation flux is negative for the following several hundred years as water moves vertically upward to replace water that had evaporated in the invert. As the invert saturates, the percolation flux becomes positive as water begins to flow downward through the invert. The jump at 2000 years corresponds to the climate change from monsoonal climate to the higher infiltration rate of the glacial-transition climate.



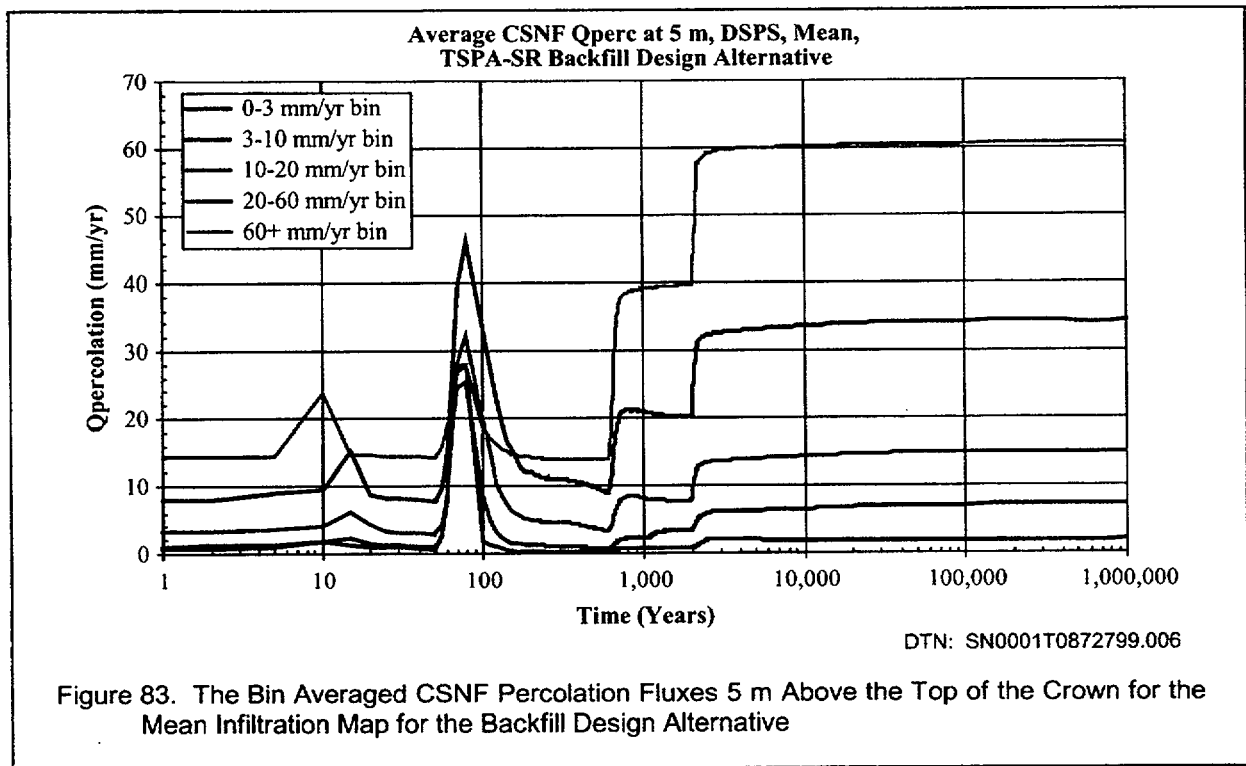
#### 6.4.7 Drift Wall Temperatures

The bin averaged wall temperatures adjacent to the CSNF and HLW waste packages for the mean infiltration flux, backfill design alternative case are presented in Figure 81. The difference between the bin averaged temperatures are presented in Figure 82. These figures show that there is only a small difference in drift wall temperatures due to the variability in heat output from HLW and CSNF waste packages in the drift. The peak temperature differences were less than 6.5°C after repository closure and these dropped to under 4.5°C at 100 years and less than 1°C after 2000 years.



#### 6.4.8 CSNF Percolation Flux 5 Meters Above Drift

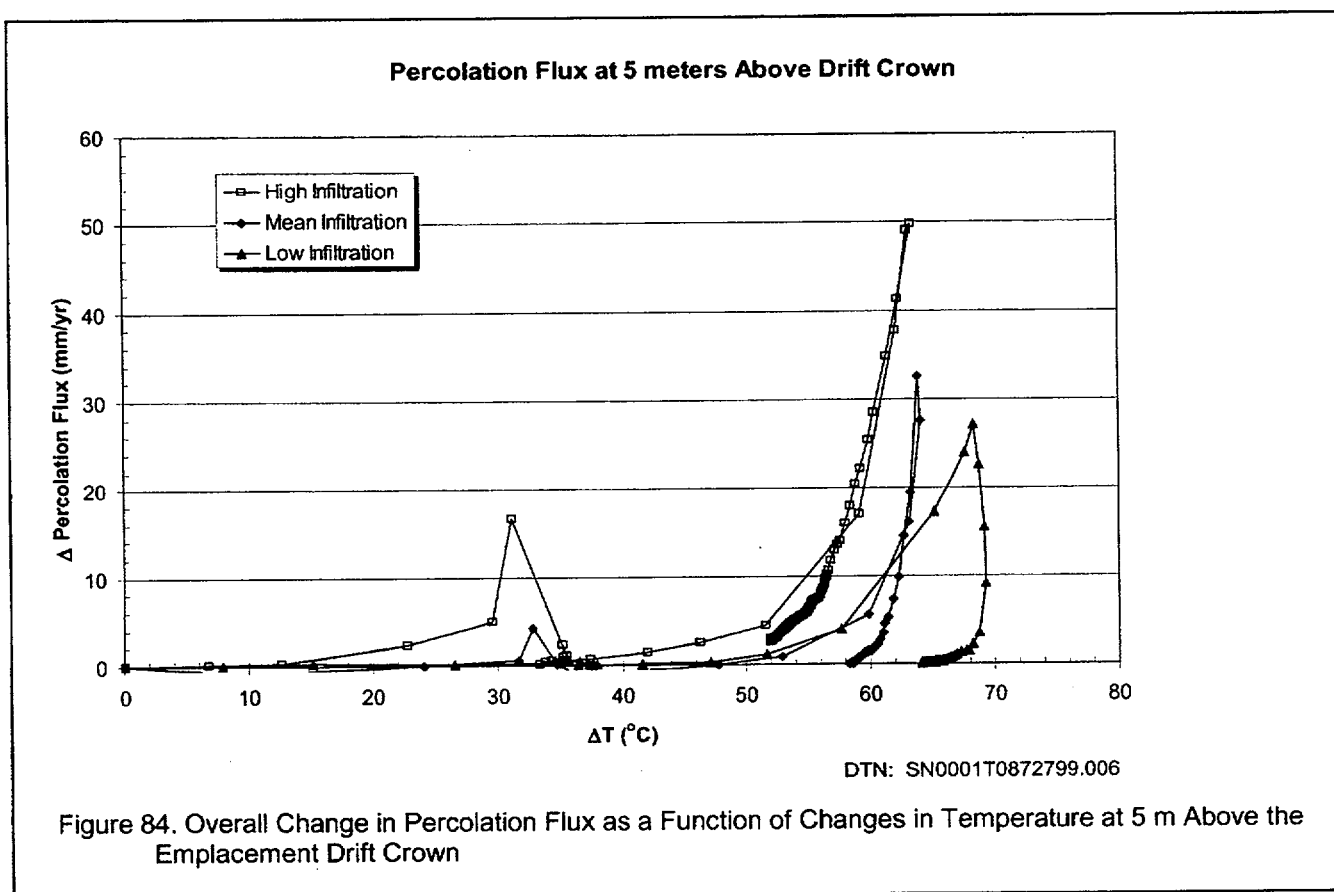
The bin averaged CSNF percolation flux 5 m above the drift is presented in Figure 83. This variable is used to provide input into the seepage model in TSPA. The percolation flux has peaks both before and after closure and two jumps corresponding to the monsoonal climate change at 600 years and the glacial transition climate at 2000 years.



Since seepage onto the waste package is related to the percolation flux, it is important to understand how the thermal pulse from the waste packages affect the percolation flux. Figure 84 shows the change in percolation flux at 5 m versus the change in temperature at 5 m for each of the three infiltration flux cases (e.g., low, mean, and high). The change in percolation flux is defined as the percolation flux minus the ambient (present day) percolation flux and the change in temperature is defined as the temperature minus the ambient temperature. It is noted that this curve is representative of the present day climate only (the first 600 years after waste emplacement are plotted in the figure). This is primarily because the future climate states overwhelm the changes in percolation flux at about their onset. That is, heat driven processes are flooded by the increases in percolation flux due to climate change. The overall average result for each infiltration flux case (low, mean, and high) shown in the figure is based on each of the individual infiltration bins using the repository area



fractions given in Table 6. Therefore, the variability associated with each of the curves in Figure 84 is described by a set of curves representative of the infiltration bins in a given infiltration rate case (e.g., the low infiltration rate case contains two curves that form the basis of the overall average curve given in the figure). A specific infiltration bin (e.g., 0-3 mm/yr curve in the low infiltration rate case) is representative of an average of a family of curves that reside at locations that have a glacial-transition climate infiltration rate that places them in a specific bin (e.g., 368 total curves reside in the 0-3 mm/yr bin for the low infiltration rate case with one curve as the resulting average for the bin). Consequently, the range given in the figure is representative of the overall average uncertainty in the increase in percolation flux (at this location in the host rock) driven by heat addition due to the repository output.

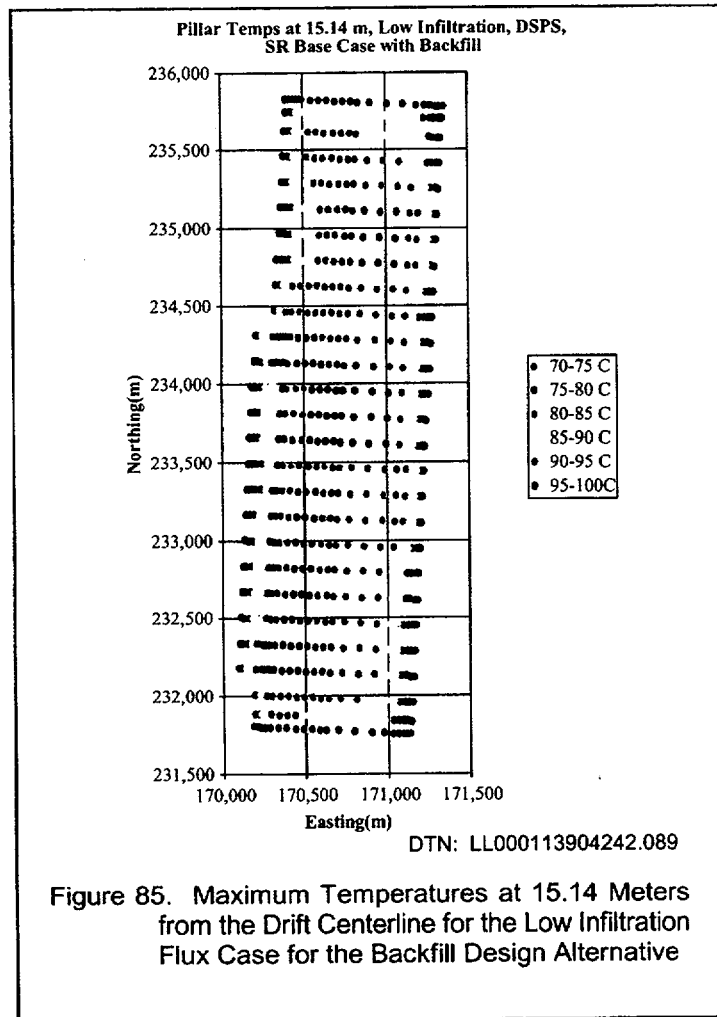


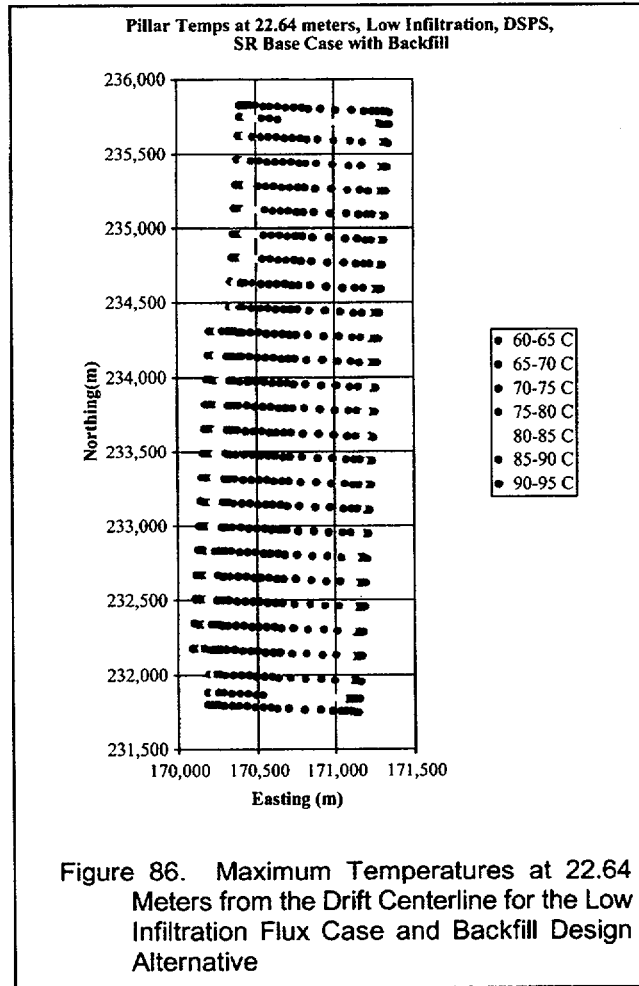
This figure illustrates how much (more or less than ambient) water flows through this location as a result of heat addition to the host rock. (Only the changes in percolation flux greater than or equal to ambient are shown in the figure—the positive changes that indicate enhanced percolation flux driven only by the thermal perturbation.) This curve indicates two pulses of water through the system. The first occurs when the temperature difference is between 30 and 35°C, the second when the temperature difference is between 50 and 70°C above ambient. The first pulse of water occurs at 10 to 20 years at this location in the host rock and represents initial heating during the preclosure

period. The second pulse occurs after backfill is emplaced and full power heating commences, between 50 and 200 years. After the first future climate change occurs at 600 years, the thermal perturbation maintains elevated temperatures in the host rock. The future climate change drives the percolation rate at 5 m above the crown of the emplacement drift up to ambient values approximately 200 years after the change in climate. It is this overall average variability (and uncertainty from differing infiltration flux cases) shown in Figure 83 that is input directly into the TSPA seepage model used to compute the seepage volume flow rate and the fraction contacted by seeps. Therefore, the enhanced seepage driven by heat input is included in the TSPA model calculation of seepage volume flow rate.

#### **6.4.9 Pillar Temperatures in Repository**

The pillar temperatures indicate how quickly the heat from the waste packages is able to diffuse into the rock. If the temperature of the rock goes above the local boiling temperature of 96°C, then water, either condensate or infiltrating, may not be able to drain through the superheated pillar as easy as it would in a subcooled pillar. Figures 85 and 86 show the maximum pillar temperature at the 623 waste package locations at two different pillar locations (15.14 and 22.64 meters from the center of the drift) for the low infiltration map. The low infiltration case map is shown here since the pillar temperatures are the highest for this case. The half-distance between drift centerlines is 40.5 meters so the two different pillar locations lie on each side of the quarter-pillar location.





At the 15.14 meter pillar location, the maximum pillar temperatures reach the highest values of 97°C at the center of the repository and the lowest value of 72°C at the edge of the repository. The temperatures reach maximum values at the edge of the repository between 55 and 70 years while closer to the center of the repository, the maximum temperatures are reached at a much later time of between 400 and 700 years. At the 22.64 meter location, the maximum pillar temperatures range from 61 to 91°C. The maximum temperatures are lower for the 22.64 meter location because of a larger volume of rock being heated. The time to maximum temperatures are somewhat higher as a result of the longer distance that the waste package heat needs to diffuse. Taken together, these plots show that less than half of every pillar is expected to ever exceed the local boiling temperature.

## 6.5 ANALYSIS CONFIDENCE FOR INTENDED USE

The use of infiltration rate bin averaged TH values (see Table 4) obtained from the TH abstraction routines described in the Attachments of this AMR is considered a valid abstraction approach for the following reasons: (1) The infiltration bin averaged values preserve and highlight the overall variability and uncertainty in the variables used to describe the thermal-hydrologic performance of a geologic repository (refer to all figures in Sections 6.3 and 6.4). The basis resides in the fact that the areal weighting assigned to the process model results (for each of the 610 (or 623) data locations) and applied in the development of a single time-history curve representative of a particular bin retains the dominate features of the data that happen to be included in that bin. (Data locations fall into a particular infiltration bin based on the infiltration rate at the location of the data. Recall that a data location contains temperature, relative humidity, liquid saturation, percolation flux at 5 meters, etc., pertinent to a specific location within the repository footprint. Since radionuclide dissolution and release are primarily dependent on the infiltration rate, the initial division of the process model data is by the infiltration rate.) Averages are computed for locations with similar infiltration rates (e.g., 3-10 mm/yr). Consequently, if most of the locations for a given range of infiltration happen to represent repository edge like conditions, this will be represented in the average applied in the TSPA model since it represents the dominant processes that may be occurring at similar infiltration rates. If for a different infiltration range the locations are primarily repository center, this will also be represented in the averages associated with that infiltration rate bin. (2) In the instances where the infiltration bin average value may overwhelm salient features of a TH variable (e.g., the maximum waste package temperature in a bin), the process model results are also input directly into the TSPA model. For example, in addition to the average waste package temperature curve computed for a bin, the abstraction routine also determines the maximum peak and the minimum peak waste package temperature curves residing in each of the predefined infiltration bins. Subsequently, the waste package temperature variability within each of the infiltration bins is included in the abstraction. Variability in the abstraction is displayed by the division of the repository into infiltration bins. The uncertainty in the abstraction is displayed by applying the same division of the repository to each infiltration flux case. Since each infiltration flux case (3 total) is included in this abstraction, uncertainty defined in the UZ flow fields is identically maintained in the thermal hydrology results. (3) The percolation flux at five meters above the crown of the drift is input into the TSPA model as location dependent (e.g., 610 locations) data. An average value is not used for the percolation flux so that complete variability (repository location, repository host unit, and proximity to repository edge) and uncertainty (infiltration flux cases: low, mean, and high) may be incorporated in the TSPA seepage model. (4) The TSPA corrosion models use the process-level TH model results directly (not averaged) as input, thus capturing the entire variability and uncertainty included in the process model. Direct location dependent inputs to the TSPA model are given in Table 3.

## 7. CONCLUSIONS

This AMR provides the abstraction of the process-level model that determines the in-drift thermodynamic environment and percolation flux at the crown of the drift (multiscale TH model). The in-drift environment (temperature, relative humidity, etc.) is an essential component for the drip shield and waste package corrosion model, the in-drift geochemical environment, the waste form degradation model including cladding degradation, and the engineered barrier system transport model (all contained within the TSPA model). Additionally, the abstracted crown percolation flux (includes both ambient and thermally driven) five meters above the drift provides input into the TSPA seepage model that is used to calculate the seepage volume flow rate and fraction of waste packages (or drip shield) contacted by seeps. The TSPA model uses both location dependent TH data (Table 3) and infiltration rate bin averaged TH data (Table 4).

The abstraction results of this AMR provide an indication of both the variability and uncertainty in the TH parameters used to describe the geologic and engineered barrier systems during a thermal perturbation resulting from two different repository designs. These TH parameters drive the eventual corrosion of the components within the EBS. Abstraction variability is obtained at 610 (or 623 in the case of backfill) different locations within the repository footprint. It includes edge effects, infiltration rate variability (included as a boundary condition), host rock variability, different waste package heat output, and overburden thickness variability. TH abstraction uncertainty is captured in the three infiltration flux cases considered by TSPA (including two future climate states in each flux case). Each infiltration flux case for the present day climate represents a potential ambient UZ flow solution of the geologic system. The three infiltration flux cases form the basis for TH calculations using specified (by UZ flow and transport) hydrologic property sets and infiltration rates. The range of possible outcomes in EBS temperature and NFE percolation flux span a broad range from low to high infiltration flux cases (refer to Section 6.3 for the no backfill repository design results and Section 6.4 for the backfill repository design results). This AMR focuses specifically on a 50 year preclosure ventilation repository design with 70% heat removal efficiency. If the design includes backfill, the backfill material and drip shield emplacement occur at repository closure at 50 years (for no backfill, only the drip shield is emplaced at the time of repository closure).

In order to determine how corrosion may occur for waste packages at different repository locations, the footprint of the repository is subdivided into zones (610 total contained in five infiltration rate bins) in which the abstraction analyses are performed. Because of the importance of the variability in waste package failure times, the environmental conditions at each of the 610 locations (623 in the case of backfill) are made available to the waste package and drip shield degradation models. The same amount of abstracted data is made available for the seepage model input as well, again to ensure reasonable portrayal of variability associated with seepage volume flow rate. In other instances (e.g., waste form degradation model), a single representative curve would suffice. In this case, the zones, defined by infiltration rate ranges, were selected so that each range (called a bin) would represent the averaged waste package location TH characteristics based on the potential percolation fluxes at the emplacement drifts. The bin averaged TH values represent the dominate features that occur within an infiltration bin since the averaged result is based on its resident parts, each with its own areal weight.

Therefore, the infiltration rate bins result in averaged and waste package location dependent (represented by area fraction weight) TH data that can be used to characterize the impact of heat addition on a geologic system and the EBS. The bins inherently include the variability discussed above (e.g., the 610 or 623 different location dependent results and their averages). As is expected, the waste package surface temperatures are, on average, hotter for the low infiltration rate case and cooler for the high infiltration rate case. Since the waste package relative humidity is correlated to the temperature, higher temperatures result in lower relative humidities. The alternative repository designs also give predictable results. For the no backfill repository design, waste package surface temperatures are not as high as in the backfill design (e.g., 100°C or more lower). Subsequently, the in-drift relative humidity increases more rapidly for the no backfill repository design. At locations in the repository where EBS components remain hot for long periods of time and that may also have a high relative humidity (e.g., waste package location dependent regions near the repository center in which the percolation flux may be high), an environment most conducive to the onset of corrosion may readily be available for the drip shields and waste packages.

The differences in repository environments can be categorized into edge or center-like responses. The differences in response typically result in extreme temperature drops at the edge when compared to the center. The infiltration-binned averages preserve the influence of edge cooling on the average waste package temperature. If in assessing the temperature time-histories for the mean infiltration flux case one notes that the average waste package surface temperature curve for the 0-3 mm/yr bin cools at a faster rate than the 10-20 mm/yr bin, one may correctly draw the conclusion that the residents in the 0-3 mm/yr bin are primarily located near the edge of the repository. At late times (greater than  $10^5$  years), the average waste package temperature curves distribute according to infiltration rate (e.g., the 0-3 mm/yr is greater than 3-10 mm/yr is greater than 10-20 mm/yr and so on). Similarly, in both the mean and the high infiltration flux cases, the lowest infiltration rate bin (0-3 mm/yr bin mean and the 3-10 mm/yr bin high) averaged waste package temperatures peak at high temperatures (due to the low infiltration rate) yet drop sharply thereafter due to lateral heat loss to surrounding unheated rock masses. For the highest infiltration bin, 60+ mm/yr, in the mean infiltration rate case (all edge locations and high infiltration rates), the peak average waste package temperature is lower than the 0-3 mm/yr bin with an even more rapid drop-off in temperature thereafter. This is expected for an extreme edge location situated under a very high infiltration rate. Edge cooling plays an important part in the abstraction and the downstream models that use this abstraction and it is maintained in the infiltration bin averaging scheme as described above and shown in Sections 6.3 and 6.4. At the repository edges, the temperatures peak sooner. Cooling is rapid such that relative humidity is high for longer time periods and liquid saturations at edge locations are also higher (much less dryout such that liquid saturations remain elevated at the edge or at locations with high infiltration rates). For the 60+ mm/yr bin in the high infiltration rate case, the average temperature peaks as one of the lowest of the four bin averaged results; however, the cooling trend is not as rapid as some of the other bins due to the fact that many of the entries in this bin for this uncertainty case are located near the center of the repository. The long-term relative humidity of these locations will be important in the corrosion model. For this bin in the high infiltration rate case, the temperature may remain high for a long period while its relative humidity rapidly increases.

Section 6.2 describes the selection of the infiltration rate bins based on percolation-flux thresholds for three sets of seepage curves. The percolation-flux thresholds for each of the three seepage curves are defined in DTN: SN9912T0511599.002. The TH results given in Tables 7 and 8 and in Figures 27 through 54 characterize the abstraction data included in DTN: SN0007T0872799.014 for the no backfill repository design (referred to as the base case design in the AMR). The TH results given in Tables 9 and 10 and in Figures 61 through 86 characterize the abstraction data included in DTN: SN0001T0872799.006 and SN0002T0872799.008 for the backfilled repository design (referred to as an alternative repository design). The abstraction of a full-glacial climate percolation flux for the low infiltration flux case is described in Section 6.3.12 with abstraction output found in DTN: SN0010T0872799.015. The TH abstraction of the full-glacial climate does not influence the UZ flow fields since the full-glacial climates occur at very late times (>38,000 years) after waste emplacement. Therefore, no TH modifications to the full glacial climate flow fields are necessary.

The abstraction data as presented in this AMR and contained in the DTNs includes variability in infiltration rate as it varies over the repository footprint, variability in repository host rock (3 host units included in the results), variability in overburden thickness, and variability due to proximity to repository edges. Uncertainty included in the abstraction of TH data is specified by UZ flow and transport and is for infiltration rate and hydrologic property uncertainty (3 infiltration flux cases and property sets: low, mean, and high). Uncertainties in thermal properties are neglected since their measured uncertainties are much smaller than the estimates of hydrologic property and infiltration rate uncertainties. For example, laboratory measurements of rock thermal conductivity are far more precisely measured than the uncertainty range can be characterized for the fracture van Genuchten alpha parameter. The abstracted data for the infiltration rate bin averages of drift wall temperature and relative humidity are contained in DTN: SN0002T0872799.008 for the backfilled repository design. These data also characterize the same variability and uncertainty as described above.

This document may be affected by technical product input information that requires confirmation. Any changes to the document that may occur as a result of completing the confirmation activities will be reflected in subsequent revisions. The status of the technical product input information quality may be confirmed by review of the DIRS database. The abstraction data developed as a result of this AMR is used directly in the total system model. Any changes to the input data (Table 2, Section 4) may result in changes in the abstraction. An assessment as to how this may impact the total system model may be required depending on the extent and duration of a potential change.



## 8. INPUTS AND REFERENCES

### 8.1 REFERENCES CITED

Andrews, R.W. 2000. "AP-SV.1Q Control of the Electronic Management of Data Evaluation for Natural Systems Analysis/Model Reports." Letter from R.W. Andrews (CRWMS M&O) to S.P. Mellington (DOE/YMSCO), April 11, 2000, LV.PA.RWA.04/00-039, with enclosure. ACC: MOL.20000412.0785.

CRWMS M&O 1998a. "Thermal Hydrology." Chapter 3 of *Total System Performance Assessment-Viability Assessment (TSPA-VA) Analyses Technical Basis Document*. B00000000-01717-4301-00003 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981008.0003.

CRWMS M&O 1998b. "Summary and Conclusions." Chapter 11 of *Total System Performance Assessment-Viability Assessment (TSPA-VA) Analyses Technical Basis Document*. B00000000-01717-4301-00011 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981008.0011.

CRWMS M&O 1999a. *Abstraction of NFE Drift Thermodynamic Environment and Percolation Flux (E0130)*. TDP-EBS-HS-000003 REV. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990831.0080.

CRWMS M&O 1999b. *Conduct of Performance Assessment*. Activity Evaluation, September 30, 1999. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991028.0092.

CRWMS M&O 2000a. *Multiscale Thermohydrologic Model*. ANL-EBS-MD-000049 Rev 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000609.0267.

CRWMS M&O 2000b. *Abstraction of Drift Seepage*. ANL-NBS-MD-000005 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000322.0671.

CRWMS M&O 2000c. *Heat Decay Data and Repository Footprint for Thermal-Hydrologic and Conduction-Only Models for TSPA-SR*. CAL-MGR-HS-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000516.0007.

CRWMS M&O 2000d. *CRWMS M&O 2000. Multiscale Thermohydrologic Model*. ANL-EBS-MD-000049 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001208.0062.

CRWMS M&O 2000e. *Site Recommendation Design Baseline*. Technical Change Request T2000-0133. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000503.0159.

CRWMS M&O 2000f. *Abstraction of Flow Fields for TSPA*. ANL-NBS-HS-000023 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. URN-0715

DOE (U.S. Department of Energy) 2000. *Quality Assurance Requirements and Description*. DOE/RW-0333P, Rev. 10. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000427.0422.

Dyer, J.R. 1999. "Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01, July 22, 1999), for Yucca Mountain, Nevada." Letter

from J.R. Dyer (DOE/YMSCO) to D.R. Wilkins (CRWMS M&O), September 3, 1999, OL&RC:SB-1714, with enclosure, "Interim Guidance Pending Issuance of New NRC Regulations for Yucca Mountain (Revision 01)." ACC: MOL.19990910.0079.

NRC (U.S. Nuclear Regulatory Commission) 1998. *Issue Resolution Status Report Key Technical Issue: Total System Performance Assessment and Integration*. Rev. 1. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: MOL.19990105.0083.

NRC (U.S. Nuclear Regulatory Commission) 2000. *Issue Resolution Status Report Key Technical Issue: Total System Performance Assessment and Integration*. Rev. 2. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 247614.

## **8.2 DATA INPUT, LISTED BY DATA TRACKING NUMBER**

LL000113904242.089. TSPA-SR Lower Calculations. Submittal date: 01/28/2000.

LL000114004242.090. TSPA-SR Mean Calculations. Submittal date: 01/28/2000.

LL000114104242.091. TSPA-SR Upper Calculations. Submittal date: 01/28/2000.

LL000509012312.002. TSPA-SR Multiscale TH Results (E0120) Lower Calculations Using Drift Scale Property Set. Submittal date: 05/18/2000.

LL000509112312.003. TSPA-SR Multiscale TH Results (E0120) Mean Calculations Using Drift Scale Property Set. Submittal date: 05/18/2000.

LL000509212312.004. TSPA-SR Multiscale TH Results (E0120) Upper Calculations Using Drift Scale Property Set. Submittal date: 05/18/2000.

SN9907T0872799.001. Heat Decay Data and Repository Footprint for Thermal-Hydrologic and Conduction-Only Models for TSPA-SR (Total System Performance Assessment-Site Recommendation). Submittal date: 07/29/99.

SN0007T0872799.014. Abstraction Of Thermal Hydrologic (TH) Data For TSPA-SR for the No Backfill Repository Design. Submittal date: 07/05/2000. (Note: used as an input only in Rev 00 ICN 02 of this AMR.)

## **8.3 DATA OUTPUT, LISTED BY DATA TRACKING NUMBER**

SN0001T0872799.006. In-Drift Thermodynamic Environment and Percolation Flux. Submittal date: 01/27/2000. (Note: output of Rev 00.)

SN0002T0872799.008. Infiltration Bin Averaged Drift Wall Temperature And Relative Humidity. Submittal date: 02/01/2000. (Note: output of Rev 00.)

SN9912T0511599.002. Revised Seepage Abstraction Results For TSPA-SR (Total System Performance Assessment-Site Recommendation). Submittal date: 12/15/1999.

SN0007T0872799.014. Abstraction Of Thermal Hydrologic (TH) Data For TSPA-SR for the No Backfill Repository Design. Submittal date: 07/05/2000. (Note: output of Rev 00 ICN 01.)

SN0010T0872799.015. Abstraction of Thermal Hydrology Percolation Flux for Post-10K-Year Climates for TSPA-SR. Submittal date: 10/13/2000. (Note: output of Rev 00 ICN 02.)

#### **8.4 SOFTWARE ROUTINES**

TH-msmabs\_ver\_1. Version 1.0. (Included with DTN: SN0001T0872799.006).

maxtwp. Versions 1.00, 1.01, 1.02. (Included with DTN: SN0001T0872799.006).

pillart. Version 1.00. (Included with DTN: SN0001T0872799.006).

TH-msmabs\_ver\_2. Version 2.0. (Included with DTN: SN0007T0872799.014).

maxtwp. Versions 1.03, 1.04, 1.05. (Included with DTN: SN0007T0872799.014).

pillart. Version 1.02, 1.03, 1.04. (Included with DTN: SN0007T0872799.014).

extinf. Version 1.00, 1.01, 1.02, 1.03, 1.04, 1.05. (Included with DTN: SN0007T0872799.014).

extinf2. Version 1.00, 1.01, 1.02. (Included with DTN: SN0007T0872799.014).

evapds\_wobackfill. Version 1.0. (Included with DTN: SN0007T0872799.014).

future\_cs-csnf, Version 1.0 and future\_cs-hlw, Version 1.0. (Included with DTN: SN0010T0872799.015).

#### **8.5 PROCEDURES**

AP-3.10Q, Rev. 2, ICN 0. *Analysis and Models*. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000217.0246.

AP-3.10Q, Rev. 2, ICN 3. *Analysis and Models*. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000918.0282.

AP-SI.1Q, Rev. 2, ICN 4. *Software Management*. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000223.0508.

AP-SI.1Q, Rev. 2, ICN 4, ECN 1. *Software Management*. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20001019.0023.

AP-SV.1Q Rev. 0 ICN 0. *Control of the Electronic Management of Data*. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000329.1181.

QAP-2-0, Rev. 5, ICN 0. *Conduct of Activities*. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980826.0209.

QAP-2-3, Rev. 10. *Classification of Permanent Items*. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990316.0006.

NLP-2-0, Rev. 5. *Determination of Importance Evaluations*. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981116.0120.

## 9. ATTACHMENTS

Table 11. List of Attachments

ATTACHMENT	TITLE	NUMBER OF PAGES
I	TH Abstraction Routine (TH-msmabs_ver_1) (Backfill Repository Design)	45
II	TH Abstraction Routine (pillart)	12
III	TH Abstraction Routine (maxtwp)	15
IV	Abstraction Routine Testing and Verification (TH-msmabs_ver_2) (No Backfill Repository Design)	91
V	Testing and Verification of the Drip Shield Evaporation Rate Abstraction (No Backfill Repository Design)	10
VI	TH Abstraction Routine (extinf)	13
VII	TH Abstraction Routine (extinf2)	10
VIII	TH Abstraction Routine Post-10k-Year Climates for TSPA	30

**Attachment I**  
**TH Abstraction Routine**  
**(TH-msmabs\_ver\_1)**  
**(Backfill Repository Design)**

The following is the listing of the software routine TH-msmabs\_ver\_1 (Version 1.0) which is used to abstract the multiscale TH data. The compilation and execution of the software routine is to be performed on a SUN UNIX OS (5.7 or higher) using the FORTRAN 77 compiler. The source code for the routine can be found in DTN: SN0001T0872799.006 in the compressed file source\_routine.ZIP. This routine needs the following input files to run properly: inputs\_for\_routines.ZIP. For example, the mean infiltration flux case requires the file names csnfmean and THabstraction.fil to run. Note the ZIP file contains the file name THabstraction.fil-csnfmean to denote it from the other cases. The variable name (-csnfmean) should be removed before running the routine. The routine produces the output files contained in the ZIP files submitted to the TDMS: csnf\_low-RIP.ZIP, csnf\_mean-RIP.ZIP, csnf\_high-RIP.ZIP, hlw\_low-RIP.ZIP, hlw\_mean-RIP.ZIP, hlw\_high-RIP.ZIP, abs\_qliq\_inv.ZIP, and T\_rh-dw.zip. So, an example for using the routine is the following (continuing with the csnf mean infiltration flux case for illustration purposes):

- Go to the TDMS with DTN: SN0001T0872799.006 to obtain the source\_routine.ZIP and inputs\_for\_routines.ZIP files.
  - Use TH-msmabs\_ver\_1 (Version 1.0) with the parameter npts (in the parameter statement in the routine itself) set equal to 352 (Note: this requires that the routine be compiled as indicated above for the SUN system. Also note: Table 3 in the AMR indicates what the parameter npts must be set to for the low (npts=442) and high (npts=457) flux cases as well).
  - The 625 input files required for the routine (for the mean case) are the following:
    - csnfmean (note: this file contains the list of input filenames, 623 total, starting with the word csnf ending with the word end).
    - THabstraction.fil (note that -csnfmean was removed from the extension). The filenames contained in this "driver" file must be given in the exact order in which they are found in this file contained within the TDMS.
- 623 input files for the (csnf) case obtained from LL000114004242.090.
- The routine prompts the user for the infiltration ranges by: 'Enter bin ranges starting from lowest mm/yr.' The user should enter 0, the prompt again, then enter, 3, etc. until 60 (refer to Section 5.1.1). The prompt occurs five times (e.g., the number of infiltration bins). Additionally, the routine prompts the user (during runtime) for the rate of change factor: enter 3 (for 3%) for the mean and high infiltration flux cases, 5% for the low infiltration flux case.
  - The output files generated by the routine are the following:
    - bin0-3
    - bin3-10
    - bin10-20
    - bin20-60
    - bin-60
    - binmembers.dat

csnf\_d0010500\_bin0-3\_mean\_avg  
RIP\_csnf\_d0010500\_bin0-3\_mean  
RIP\_csnf\_qperc\_d0010500\_bin0-3\_mean  
csnf\_d0010500\_bin3-10\_mean\_avg  
RIP\_csnf\_d0010500\_bin3-10\_mean  
RIP\_csnf\_qperc\_d0010500\_bin3-10\_mean  
csnf\_d0010500\_bin10-20\_mean\_avg  
RIP\_csnf\_d0010500\_bin10-20\_mean  
RIP\_csnf\_qperc\_d0010500\_bin10-20\_mean  
csnf\_d0010500\_bin20-60\_mean\_avg  
RIP\_csnf\_d0010500\_bin20-60\_mean  
RIP\_csnf\_qperc\_d0010500\_bin20-60\_mean  
csnf\_d0010500\_bin-60\_mean\_avg  
RIP\_csnf\_d0010500\_bin-60\_mean  
RIP\_csnf\_qperc\_d0010500\_bin-60\_mean  
RIP\_Tavg\_csnf\_d0010500\_bin0-3\_mean  
RIP\_SLavg\_csnf\_d0010500\_bin0-3\_mean  
RIP\_qpercavg\_csnf\_d0010500\_bin0-3\_mean  
RIP\_Tmax\_csnf\_d0010500\_bin0-3\_mean  
RIP\_Tmin\_csnf\_d0010500\_bin0-3\_mean  
RIP\_Tinvavg\_csnf\_d0010500\_bin0-3\_mean  
RIP\_RHinvavg\_csnf\_d0010500\_bin0-3\_mean  
RIP\_Qevap\_invavg\_csnf\_d0010500\_bin0-3\_mean  
RIP\_TtopDSavg\_csnf\_d0010500\_bin0-3\_mean  
RIP\_qpercinvavg\_csnf\_d0010500\_bin0-3\_mean  
RIP\_Tavg\_csnf\_d0010500\_bin3-10\_mean  
RIP\_SLavg\_csnf\_d0010500\_bin3-10\_mean  
RIP\_qpercavg\_csnf\_d0010500\_bin3-10\_mean  
RIP\_Tmax\_csnf\_d0010500\_bin3-10\_mean  
RIP\_Tmin\_csnf\_d0010500\_bin3-10\_mean  
RIP\_Tinvavg\_csnf\_d0010500\_bin3-10\_mean  
RIP\_RHinvavg\_csnf\_d0010500\_bin3-10\_mean  
RIP\_Qevap\_invavg\_csnf\_d0010500\_bin3-10\_mean  
RIP\_TtopDSavg\_csnf\_d0010500\_bin3-10\_mean  
RIP\_qpercinvavg\_csnf\_d0010500\_bin3-10\_mean  
RIP\_Tavg\_csnf\_d0010500\_bin10-20\_mean  
RIP\_SLavg\_csnf\_d0010500\_bin10-20\_mean  
RIP\_qpercavg\_csnf\_d0010500\_bin10-20\_mean  
RIP\_Tmax\_csnf\_d0010500\_bin10-20\_mean  
RIP\_Tmin\_csnf\_d0010500\_bin10-20\_mean  
RIP\_Tinvavg\_csnf\_d0010500\_bin10-20\_mean  
RIP\_RHinvavg\_csnf\_d0010500\_bin10-20\_mean  
RIP\_Qevap\_invavg\_csnf\_d0010500\_bin10-20\_mean  
RIP\_TtopDSavg\_csnf\_d0010500\_bin10-20\_mean  
RIP\_qpercinvavg\_csnf\_d0010500\_bin10-20\_mean

RIP\_Tavg\_csnf\_d0010500\_bin20-60\_mean  
 RIP\_SLavg\_csnf\_d0010500\_bin20-60\_mean  
 RIP\_qpercavg\_csnf\_d0010500\_bin20-60\_mean  
 RIP\_Tmax\_csnf\_d0010500\_bin20-60\_mean  
 RIP\_Tmin\_csnf\_d0010500\_bin20-60\_mean  
 RIP\_Tinvavg\_csnf\_d0010500\_bin20-60\_mean  
 RIP\_RHinvavg\_csnf\_d0010500\_bin20-60\_mean  
 RIP\_Qevap\_invavg\_csnf\_d0010500\_bin20-60\_mean  
 RIP\_TtopDSavg\_csnf\_d0010500\_bin20-60\_mean  
 RIP\_qpercinvavg\_csnf\_d0010500\_bin20-60\_mean  
 RIP\_Tavg\_csnf\_d0010500\_bin-60\_mean  
 RIP\_SLavg\_csnf\_d0010500\_bin-60\_mean  
 RIP\_qpercavg\_csnf\_d0010500\_bin-60\_mean  
 RIP\_Tmax\_csnf\_d0010500\_bin-60\_mean  
 RIP\_Tmin\_csnf\_d0010500\_bin-60\_mean  
 RIP\_Tinvavg\_csnf\_d0010500\_bin-60\_mean  
 RIP\_RHinvavg\_csnf\_d0010500\_bin-60\_mean  
 RIP\_Qevap\_invavg\_csnf\_d0010500\_bin-60\_mean  
 RIP\_TtopDSavg\_csnf\_d0010500\_bin-60\_mean  
 RIP\_qpercinvavg\_csnf\_d0010500\_bin-60\_mean  
 RIP\_qpercinvavg\_ABS\_csnf\_d0010500\_bin0-3\_mean  
 RIP\_qpercinvavg\_ABS\_csnf\_d0010500\_bin3-10\_mean  
 RIP\_qpercinvavg\_ABS\_csnf\_d0010500\_bin10-20\_mean  
 RIP\_qpercinvavg\_ABS\_csnf\_d0010500\_bin20-60\_mean  
 RIP\_qpercinvavg\_ABS\_csnf\_d0010500\_bin-60\_mean

- The bin\* (e.g., bin3-10, etc.) file is a printout by the routine that indicates what input files (read in from the filename: csnfmean) get sorted into the predefined infiltration bins. Note: the number of infiltration rate bins (ninf=5 in this TH abstraction) can be changed to any number in the parameter statement (ninf=?), but the input file THabstraction.fil has to be modified for the additional filenames that would be required if there are more than 5 infiltration bins predefined by the user. A runtime message is printed to the screen indicating how many filenames need to be provided (in THabstraction.fil) to the routine when the number ninf is selected.
- The binmembers.dat file gives a number count (of total input files) that fall within each bin. The sum of all populated bins is 623. This file is specified to ensure that all input files are processed by the routine during the abstraction.
- The RIP\* files (e.g., RIP\_Qevap\_invavg\_csnf\_d0010500\_bin-60\_mean, etc.) are the files passed by this AMR to the TSPA model. This assemblage of files is found in the TDMS under SN0001T0872799.006 in the ZIP file: csnf\_mean-RIP.ZIP.
- The csnf\*avg files (e.g., csnf\_d0010500\_bin-60\_mean\_avg) represent averaged information not used by the TSPA model but that may be used for various data visualization purposes. This assemblage of files is found in the TDMS under SN0002T0872799.008 in the file name t\_rh-dw.zip.

An analogous sequence of steps is followed for the hlw for the mean flux case, and the csnf & hlw from the low and the csnf & hlw for the high flux cases. It is re-emphasized here that version 1.0 of this routine is **ONLY** applicable to the with backfill process-level model results. The abstraction routine to be used for the no backfill results is given in detail in Attachment IV.

So, to summarize, the TH abstraction routine follows these general steps:

- 1) User predefines the number of infiltration bins and bin ranges (TDMS files are set-up for 5 infiltration bins as specified in Section 5.1.1 in the AMR).
- 2) Read in the input files obtained from the process-level model and sort them into appropriate predefined infiltration bins.
- 3) Perform, on a per bin basis, computation of variable averages, variable reformatting, variable sorting, and calculation of the bin fractions.
- 4) Print, on a per bin basis, the outputs for general results and the abstraction results passed to the TSPA model.

The source code for this TH abstraction routine is given below.

```
c23456789012345678901234567890123456789012345678901234567890123456789012
c....This computes averages directly from the multiscale model results
c   for TSPA-SR. This will place resultant files into appropriate
c   infiltration bins as specified by the TCT.
c   raw values given by LLNL
c   ndf 4/3/98-original file for TSPA-VA, LADS
c....ndf 10/12/99-modified for TSPA-SR
c....ndf 10/99-12/99 various changes for RIP including time stepping
c   control based on rates of changes on T and q.liquid 5m
c   change top dripshield and invert q.liquid to volume flow rate
c
c
c
c   Input the number of time points in the LLNL file so that
c   the correct number of data points within the file can be
c   processed.
c
c....The required input is a value for $npts$. This value must be
c   input before compilation of the source code
c
c....The required input is a value for $ninf$. This value specifies
c   the number of infiltration bins and it must be input before
c   compilation of the source code. An example: is for ninf =2.
c   in this case the bins may look like 0 - 25 mm/yr for the bin 1
c   and > 25 mm/yr for bin 2
c
c
c   parameter(npts=442, ninf=5, nbinm=650)
c
c   implicit double precision (a-h,l,o-z)
c   character*4 name
c   character*10 label
c   character*80 infile1
c   character*80 infile2
c   character*80 infile3
c   character*80 infile4
c   character*80 outfile(ninf)
c   character*80 resultsbinfile(ninf)
```



```

character*80 resultsbinfile2(ninf)
character*80 resultsbinfile2p(ninf)
character*80 resultsbinfile3(ninf)
character*80 resultsbinfile3a(ninf)
character*80 resultsbinfile3b(ninf)
character*80 resultsbinfile4(ninf)
character*80 resultsbinfile5(ninf)
character*80 resultsbinfile6(ninf)
character*80 resultsbinfile7(ninf)
character*80 resultsbinfile8(ninf)
character*80 resultsbinfile9(ninf)
character*80 resultsbinfile10(ninf)
character*80 resultsbinfile11(ninf)

character*12 nmeinf
character*80 xinfllabel
character*80 ch

c
c.....infile1 opens the large file containing waste packages of the same type
c  infile2 file names contained within an infiltration bin for bin averages
c  infile3 file names contained within the large file
c  infile4 file names contained within an infiltration bin for bin area weight
c  outfile file names sorted into appropriate infiltration bins
c  resultsbinfile name of the resulting file for average quantities
c  resultsbinfile2 name of the resulting file for raw values for RIP
c  resultsbinfile3 name of the resulting file for average values for RIP
c
c
c
c.....The format of value X(i,j) is the following:
c  i = the number of entries in an infiltration bin
c  j = the number of time entries within an input file inside the
c      the infiltration bin
c
c23456789012345678901234567890123456789012345678901234567890123456789012
c  dimension timeyr(npts), PAwpT(nbinm,npts), PAwpRH(nbinm,npts),
c  @ PAdST(nbinm,npts), PAdSRH(nbinm,npts), PAwpT1a(npts),
c  @ PAwpRH2a(npts),
c  @ PAdST3a(npts), PAdSRH4a(npts), T_wp(nbinm,npts),
c  @ T_5m(nbinm,npts),
c  @ T_bfpk(nbinm,npts), T_ds(nbinm,npts), T_dw(nbinm,npts),
c  @ T_inv(nbinm,npts), T_dwlow(nbinm,npts), RH_dw(nbinm,npts),
c  @ RH_bfp(nbinm,npts), RH_ds(nbinm,npts), RH_wp(nbinm,npts),
c  @ RH_inv(nbinm,npts), Sl_dw(nbinm,npts), Sl_ds(nbinm,npts),
c  @ Sl_inv(nbinm,npts), ql_5m(nbinm,npts), ql_3m(nbinm,npts),
c  @ ql_dw(nbinm,npts), ql_dsT(nbinm,npts), ql_dsS(nbinm,npts),
c  @ ql_inv(nbinm,npts), xa_ds(nbinm,npts), P_ds(nbinm,npts),
c  @ Pc_ds(nbinm,npts), Pc_inv(nbinm,npts), PcM_dw(nbinm,npts),
c  @ PcF_dw(nbinm,npts), qw_dw(nbinm,npts), qa_dw(nbinm,npts),
c  @ qvpdsT(nbinm,npts), qvpdsP(nbinm,npts), qvpbfp(nbinm,npts),
c  @ qvpinv(nbinm,npts), T_wp1a(npts), T_5m2a(npts), T_bfpk3a(npts),
c  @ T_ds4a(npts), T_dw5a(npts), T_inv6a(npts), T_dwlow7a(npts),
c  @ RH_dw1a(npts), RH_bfp2a(npts), RH_ds3a(npts), RH_wp4a(npts),
c  @ RH_inv5a(npts), Sl_dw1a(npts), Sl_ds2a(npts), Sl_inv3a(npts),
c  @ ql_5m1a(npts), ql_3m2a(npts), ql_dw3a(npts), ql_dsT4a(npts),
c  @ ql_dsS5a(npts), ql_inv6a(npts), xa_dsl1a(npts), P_dsl1a(npts),
c  @ Pc_dsl1a(npts), Pc_inv2a(npts), PcM_dw3a(npts), PcF_dw4a(npts),
c  @ qw_dw1a(npts), qa_dw2a(npts), qvpdsT1a(npts), qvpdsP2a(npts),
c  @ qvpbfp3a(npts), qvpinv4a(npts), qinf0(ninf), facttb(ninf),
c  @ factbin(ninf,nbinm), PAwpTf(nbinm,npts), PAwpRHf(nbinm,npts),
c  @ PAdSTf(nbinm,npts), PAdSRHf(nbinm,npts), T_wpf(nbinm,npts),
c  @ T_5mf(nbinm,npts),
c  @ T_bfpkf(nbinm,npts), T_dsf(nbinm,npts), T_dwf(nbinm,npts),
c  @ T_invf(nbinm,npts), T_dwlowf(nbinm,npts), RH_dwf(nbinm,npts),
c  @ RH_bfpf(nbinm,npts), RH_dsf(nbinm,npts), RH_wpf(nbinm,npts),
c  @ RH_invf(nbinm,npts), Sl_dwf(nbinm,npts), Sl_dsf(nbinm,npts),
c  @ Sl_invf(nbinm,npts), ql_5mf(nbinm,npts), ql_3mf(nbinm,npts),
c  @ ql_dwf(nbinm,npts), ql_dsTf(nbinm,npts), ql_dsSf(nbinm,npts),
c  @ ql_invf(nbinm,npts), xa_dsf(nbinm,npts), P_dsf(nbinm,npts),
c  @ Pc_dsf(nbinm,npts), Pc_invf(nbinm,npts), PcM_dwf(nbinm,npts),
c  @ PcF_dwf(nbinm,npts), qw_dwf(nbinm,npts), qa_dwf(nbinm,npts),
c  @ qvpdsTf(nbinm,npts), qvpdsPf(nbinm,npts), qvpbfpf(nbinm,npts),
c  @ qvpinvf(nbinm,npts), TavgRIP(ninf,npts), S_lavgRIP(ninf,npts),
c  @ ql_5mavgRIP(ninf,npts), noent(ninf), Tdstop(nbinm,npts),

```

```

@ Tdstopf(nbinm,npts), Tdstop8a(npts), ql_dsTagf(nbinm,npts),
@ ql_dsTag(nbinm,npts), ql_dsTag7a(npts), Tpl299f(nbinm,npts),
@ Tpl299(nbinm,npts), Tpl369f(nbinm,npts), Tpl369(nbinm,npts),
@ Tpl489f(nbinm,npts), Tpl489(nbinm,npts),
@ Tpl689f(nbinm,npts), Tpl689(nbinm,npts), Tpl1014f(nbinm,npts),
@ Tpl1014(nbinm,npts), Tpl11514f(nbinm,npts), Tpl11514(nbinm,npts),
@ Tpl2264f(nbinm,npts), Tpl2264(nbinm,npts), Tpl3382f(nbinm,npts),
@ Tpl3382(nbinm,npts), Tpl2991a(npts), Tpl3692a(npts),
@ Tpl4893a(npts), Tpl6894a(npts), Tpl10145a(npts), Tpl15146a(npts),
@ Tpl22647a(npts), Tpl33828a(npts), coord1(ninf,nbinm),
@ coord2(ninf,nbinm), Tmaxrip(ninf,npts), RHavgRIPin(ninf,npts),
@ TavgrIPinv(ninf,npts), qvpavgRIPinv(ninf,npts), Tmax_min(nbinm),
@ Tminrip(ninf,npts), TavgrIPdstop(ninf,npts)
@ T_dwtopf(nbinm,npts), T_dwtop(nbinm,npts),
@ T_dwtop9a(npts), ql_invavgRIP(ninf,npts),ql_invavgabs(ninf,npts)

integer iinf(ninf)
real *8 xinf, finf(ninf,nbinm)
c.....density of water
c drip shield top flow area
c invert flow area

rho=1000.
a_dsT=0.57
a_inv=0.92

c.....This counter will specify the number of entries in each
c of the infiltration bins--note: for k=ninf is the high infiltration
c bin while for k=1 iinf is the low infiltration bin
c
do k = 1,ninf
iinf(k)=0
end do

write(*,*)
write(*,*) '*****'
write(*,*) '***The TH abstraction routine for TSPA-SR***'
write(*,*) '*****Performance Assessments Operations*****'
write(*,*) '*****'
write(*,*)
write(*,*)
write(*,*) '*****'
write(*,*) 'This version of the code will require an input deck'
write(*,*) 'for the names of the i/o files.'
write(*,*) 'Input Deck Filename is required: THabstraction.fil'
write(*,*)
write(*,*) 'The total required file names is a function of ninf'
write(*,*) '*** ninf is the number of infiltration bins ***'
write(*,*)
write(*,*) '*****'
write(*,*) '*****'
write(*,*)
write(*,*) 'The input deck is a name list in a single column:'
write(*,*)
write(*,*) 'bin1'
write(*,*) 'bin2'
write(*,*) '...'
write(*,*) 'ninf'
write(*,*) 'File name containing WP type file names from LLNL'
write(*,*) 'bin1 results-average file'
write(*,*) 'bin1 results-RIP raw values file'
write(*,*) 'bin1 results-RIP Qperc-only values file'
write(*,*) 'bin2 results-average file'
write(*,*) 'bin2 results-RIP raw values file'
write(*,*) 'bin2 results-RIP Qperc-only values file'
write(*,*) '...'
write(*,*) 'ninf results-average file'
write(*,*) 'ninf results-RIP raw values file'
write(*,*) 'ninf results-RIP Qperc-only values file'
write(*,*) 'bin1RIP-Tavg file'
write(*,*) 'bin1RIP-S_L avg file'
write(*,*) 'bin1RIP-Q_perc avg file'

```

```

write(*,*) 'binlRIP-Tmax file'
write(*,*) 'binlRIP-Tmin file'
write(*,*) 'binlRIP-Tinvavg file'
write(*,*) 'binlRIP-RHinvavg file'
write(*,*) 'binlRIP-Qevap_invavg file'
write(*,*) 'binlRIP-Top DS file'
write(*,*) 'binlRIP-qperc_invavg file'
write(*,*) '....'
write(*,*) 'ninfRIP-Tavg file'
write(*,*) 'ninfRIP-S_L avg file'
write(*,*) 'ninfRIP-Q_perc avg file'
write(*,*) 'ninfRIP-Tmax file'
write(*,*) 'ninfRIP-Tmin file'
write(*,*) 'ninfRIP-Tinvavg file'
write(*,*) 'ninfRIP-RHinvavg file'
write(*,*) 'ninfRIP-Qevap_invavg file'
write(*,*) 'ninfRIP-Top DS file'
write(*,*) 'ninfRIP-qperc_invavg file'
write(*,*) 'binl ABS qprec inv avg'
write(*,*) '....'
write(*,*) 'ninf ABS qprec inv avg'

write(*,*)
write(*,*) 'So, as an example for ninf = '
write(*,*) ninf
  ifiles = ninf+1+3*ninf+11*ninf
write(*,*) 'There are a total of file names required:'
write(*,*) ifiles
write(*,*)

write(*,*)
write(*,*) 'Enter the rate of change factor'
read(*,*) prntfac
write(*,*)

      open(3,file='THabstraction.fil', status='old')

c.....Begin to read in the ranges of infiltration bins
      do k = 1, ninf
        write(*,*) 'Enter bin ranges starting from lowest mm/yr'
        read(*,*) qinf0(k)
        end do
      do k = 1,ninf
        read(3,'(a)') outfile(k)
        end do
c.....open the resulting infiltration bin files for later processing
c      write the appropriate file names that belong in the bin
c
      do k = 1,ninf
        open (106-k, file=outfile(k),status='new')
        if (k .eq. ninf) then
          write(106-k,1) qinf0(k)
1          format('qinf >', 1x,f5.1,1x, 'mm/yr ')
          else
            write(106-k,11) qinf0(k+1), qinf0(k)
11          format(f5.1, 1x,'> qinf >', 1x,f5.1, 1x,'mm/yr ')
            end if
          end do

c
c      Read in the large files (2 total) that contain all of the results for
c      a single run. An example is each waste package location
c      for a specific type (e.g., csnf) from the mean infiltration
c      case multiscale model run
c.....Note: The input file must contain a label as the first line
c      an example may be csnf, hlw and the last line should be end
c
c      write(*,*) 'What is the name of the large input file?'
      read(3,'(a)') infile1
      open(51,file=infile1,status='old')
      read(51,'(a)') label
      write(*,*)
      write(*,*) '*****'

```

```

write(*,*) 'now reading input file for LLNL files:'
write(*,*) label
write(*,*) '*****'
write(*,*)
write(*,*)

55      read(51,'(a)') infile3
         if (infile3 .eq. 'end') goto 44
         open(999,file=infile3,status='old')
4       read (999,45) nmeinf
45      format(a12)
         if (nmeinf .ne. 'Infiltration') goto 4
         read (999, '(a)') ch
         read (ch(26:),*) xinf
         close(999)

c.....check each infiltration rate in each file to determine the
c      appropriate infiltration rate bin placement
c
         do k = 1,ninf
            j=ninf+1-k
            if (xinf .ge. qinf0(j) ) goto 33
         end do

c.....write each file name to the appropriate infiltration bin
c      file name for later processing on an infiltration rate bin
c      basis
c
33      open (106-j, file=outfile(j),status='old')
         write (106-j,31) infile3
31      format(a70)
         iinf(j) = iinf(j)+1
         goto 55

c.....keep track of the number of entries in each infiltration
c      bin for later processing
c
44      open (555, file='binmembers.dat', status='new')
         write(555,*) 'The entries in infiltration bin:from lo to hi'
         do k =1,ninf
            write(555,*) iinf(k)
         end do
         close(555)

         do k = 1,ninf
            close(106-k)
         enddo

         close(51)

c.....end the portion of the routine that builds the infiltration bins
c.....The infiltration bins have now been assembled. The remainder of
c      routine will build the average quantities and reformat the data
c
c
c.....This section will build the average quantities for each infiltration
c      bin as specified by the above portion of this routine
c
c      Each sub-section in the multiscale model results will
c      be handled as an averaging process----
c
c
c.....Nomenclature for this processor
c      timeyr--time in years as taken from the multiscale results
c      T_wp--the waste package temperature
c      T_5m--the temperature at 5 meters into host rock
c      T_bfpk--the temperature at the backfill spoil peak
c      T_ds--the temperature at the dripshield
c      T_dw--the temperature at the drift wall
c      T_inv--the invert temperature
c      T_dwlow--the drift wall lower temperature
c      RH_dw--the relative humidity of the drift wall

```

```

c      RH_bfp--the relative humidity of the backfill spoil peak
c      RH_ds--the relative humidity of the dripshield
c      RH_wp--the relative humidity of the waste package
c      RH_inv--the relative humidity of the invert
c      Sl_dw--the liquid saturation of the drift wall
c      Sl_ds--the liquid saturation of the dripshield
c      Sl_inv--the liquid saturation of the invert
c      ql_5m--the liquid flow in fracture 5m into host rock
c      ql_3m--the liquid flow in fracture 3m into host rock
c      ql_dw--the liquid flow in fracture at drift wall
c      ql_dsT--the liquid flow at the top of the dripshield
c      ql_dsS--the liquid flow at the side of the dripshield
c      ql_inv--the liquid flow in the invert
c      xa_ds--the air mass fraction at the dripshield
c      P_ds--gas pressure at the dripshield
c      Pc_ds--the capillary pressure at dripshield
c      Pc_inv--the capillary pressure at invert
c      PcM_dw--matrix capillary pressure at drift wall
c      PcF_dw--fracture capillary pressure at drift wall
c      qw_dw--the water flux in the gas phase at the drift wall
c      qa_dw--the air flux in the gas phase at the drift wall
c      qvpdsT--the evaporation rate at the top of the drip shield
c      qvpdsP--the evaporation rate at the perimeter of the drip shield
c      qvpbfp--the evaporation rate at backfill spoil peak
c      qvpinv--the evaporation rate at the invert
c      PAwpT--waste package temperature
c      PAwpRH--waste package relative humidity
c      PADsT--dripshield temperature
c      PADsRH--dripshield relative humidity

```

```

c
c
c
c

```

```

      do k1=1,ninf
        facttb(k1) = 0.
      enddo

```

```

      do ii=1,ninf
        noent(ii)=0
      enddo

```

```

c
c
c
c

```

```

c.....open the results files for the average values within a bin
c      this information will require the number of infiltration bins
c

```

```

      do k = 1,ninf

```

```

        Tmaxo = 0.

```

```

c.....compute the infiltration rate bin factor so that a bin
c      averaged value can be computed
c

```

```

      open(106-k,file=outfile(k),status='old')
      read(106-k,'(a)') xinfllabel

      do m = 1,iinf(k)
        read(106-k,'(a)') infile4
        open(666,file=infile4,status='old')
21      read(666,6) name
6      format(a4)
        if(name .ne. 'frac') goto 21
        read(666,10) factbin(k,m)
10      format(29x,f8.6)
        facttb(k) = factbin(k,m)+facttb(k)
      end do
      close (106-k)

```

```

c.....re-open the files to obtain the coordinate locations
c
      open(106-k,file=outfile(k),status='old')
      read(106-k,'(a)') xinfllabel

      do m = 1,iinf(k)
      read(106-k,'(a)') infile4
      open(667,file=infile4,status='old')
81      read(667,6) name
      if(name .ne. 'Loca') goto 81
      read(667,41) coord1(k,m)
      read(667,41) coord2(k,m)
41      format(23x,f9.2)
      end do
      close (106-k)

      open(106-k,file=outfile(k),status='old')
      read(106-k,'(a)') xinfllabel

      do m = 1,iinf(k)
      read(106-k,'(a)') infile4
      open(668,file=infile4,status='old')
82      read(668,6) name
      if(name .ne. 'Infi') goto 82
      read (668, '(a)') ch
      read (ch(26:),*) finf(k,m)
      end do
      close (106-k)

c
c
c.....Name and open the output files
c
c

      write (*,*) 'Computing all averages for E0130'
c
      write (*,*) k

      read(3,'(a)') resultsbinfile(k)

      open(206-k,file=resultsbinfile(k),status='new')

      open(106-k,file=outfile(k),status='old')
      read(106-k,'(a)') xinfllabel
      write(206-k,*) 'Infiltration Bin:'
      write(206-k,*) xinfllabel
      write(206-k,*) resultsbinfile(k)
      if(iinf(k) .eq. 0) then
      write(206-k,*) 'No Entries in this Bin'
      end if

      write (*,*) 'Computing the RIP raw values'
c @ --this is the raw value file for RIP
c
      write (*,*) k

      read(3,'(a)') resultsbinfile2(k)

      open(306-k,file=resultsbinfile2(k),status='new')

      write(306-k,*) 'Infiltration Bin:'

      write(306-k,*) xinfllabel

      write(306-k,*) resultsbinfile2(k)
c2345678901234567890123456789012345678901234567890123456789012
      write(306-k,*) 'Time (yr), Waste Pack Temp.(C), Drip shield temp.
      @ (C), Drift wall temp.(C), Invert temp. (C), Waste pack RH, Drip

```

```

@ shield RH, Drift wall RH, Backfill RH, Invert RH, Liquid Satr. @
@ Drip Shield, Liquid Satr.@Invert, Air mass Frac, Water Vapor flux
@ at Dwall (kg/yr/m of drift), Air flux at Dwall(kg/yr/m of drift),
@ A Drip Shield Evapo. rate (m3/yr), Backfill Evapo. Rate (m3/yr),
@ Invert Evapo. Rate (m3/yr), Percolation Flux at 5 m (mm/yr), Vol
@ume flow at top dripshield (m3/yr), volume flow at invert (m3/yr),
@ Top of the dripshield Temp (C)'

      if(iinf(k) .eq. 0) then
        write(306+k,*) 'No Entries in this Bin'
      end if

      write (*,*) 'Computing the RIP raw Qperc-only values'.
c    @ --this is the raw value file for RIP'
c
      write (*,*) k

      read(3,'(a)') resultsbinfile2p(k)

      open(306+k,file=resultsbinfile2p(k),status='new')

      write(306+k, *) 'Infiltration Bin:'

      write(306+k,*) xinfillabel

      write(306+k,*) resultsbinfile2p(k)
c23456789012345678901234567890123456789012345678901234567890123456789012

      write(306+k,*) ' Time (yr), Percolation Flux at 5 m (mm/yr),
@Percolation Flux at 3 m (mm/yr)'

      if(iinf(k) .eq. 0) then
        write(306+k,*) 'No Entries in this Bin'
      end if

c
c.....read each entry within an infiltration bin (e.g., ninf=1)
c    which may be the low infiltration bin as the following
c    (0-5 mm/yr)
c
      do i=1,iinf(k)

        Tmxmno = 0.

        read(106-k,'(a)') infile2
        open(777,file=infile2,status='old')
        write(206-k,*) infile2

2      read(777,6) name
        if(name .ne. 'frac') goto 2
        read(777,10) fact
        fact=fact/facttb(k)
c
c801      read(777,6) name
        if(name .ne. 'time') goto 801

c
c.....This will read the first block of data in the raw files
c    resulting from the multiscale model--TSPA data
c
      do j = 1,npts
        read(777,*) timeyr(j), PAwpT(i,j), PAwpRH(i,j),
@ PAdST(i,j),PAdSRH(i,j)

        PAwpTf(i,j) = PAwpT(i,j)*fact

```

```

      PAwpRHf(i,j) = PAwpRH(i,j)*fact
      PAdstf(i,j) = PAdst(i,j)*fact
      PAdsRHf(i,j) = PAdsRH(i,j)*fact
      end do

c
c.....continue reading the raw file for other variables
c      read the second block--temperature data
c

802      read(777,6) name
      if(name .ne. 'time') goto 802

      do j = 1,npts
      read(777,*) timeyr(j), T_dw(i,j), T_5m(i,j), T_bfpk(i,j),
@      T_ds(i,j), Tdstop(i,j), T_wp(i,j), T_inv(i,j), T_dwlow(i,j)
@      , T_dwtop(i,j)

      T_wpf(i,j) = T_wp(i,j)*fact
      T_5mf(i,j) = T_5m(i,j)*fact
      T_bfpkf(i,j) = T_bfpk(i,j)*fact
      T_dsf(i,j) = T_ds(i,j)*fact
      T_dwf(i,j) = T_dw(i,j)*fact
      T_invf(i,j) = T_inv(i,j)*fact
      T_dwlowf(i,j) = T_dwlow(i,j)*fact
      Tdstopf(i,j) = Tdstop(i,j)*fact
      T_dwtopf(i,j) = T_dwtop(i,j)*fact

      Tmaxn = DMAX1(T_wp(i,j), Tmaxo)
      if (Tmaxn .gt. Tmaxo) then
        mark=i
        Tmaxo=Tmaxn
      endif
      Tmax_min(i) = DMAX1(T_wp(i,j), Tmaxnno)
      Tmaxnno = Tmax_min(i)

      end do

c
c.....continue reading the raw file for other variables
c      read the third block--Relative Humidity data
c

803      read(777,6) name
      if(name .ne. 'time') goto 803

      do j = 1,npts
      read(777,*) timeyr(j), RH_dw(i,j), RH_bfp(i,j),
@      RH_ds(i,j), RH_wp(i,j), RH_inv(i,j)

      RH_dwf(i,j) = RH_dw(i,j)*fact
      RH_bfpf(i,j) = RH_bfp(i,j)*fact
      RH_dsf(i,j) = RH_ds(i,j)*fact
      RH_wpf(i,j) = RH_wp(i,j)*fact
      RH_invf(i,j) = RH_inv(i,j)*fact
      end do

c
c.....continue reading the raw file for other variables
c      read the fourth block--Liquid Saturation data
c

804      read(777,6) name
      if(name .ne. 'time') goto 804

      do j = 1,npts
      read(777,*) timeyr(j), Sl_dw(i,j), Sl_ds(i,j), Sl_inv(i,j)

      Sl_dwf(i,j) = Sl_dw(i,j)*fact

```



```

      Sl_dsf(i,j) = Sl_ds(i,j)*fact
      Sl_invf(i,j) = Sl_inv(i,j)*fact
      end do

c
c.....continue reading the raw file for other variables
c      read the fifth block--liquid flux data
c
805      read(777,6) name
      if(name .ne. 'time') goto 805

      do j = 1,npts
      read(777,*) timeyr(j), ql_5m(i,j), ql_3m(i,j),
@      ql_dw(i,j), ql_dsT(i,j), ql_dsTag(i,j), ql_dsS(i,j),
@      ql_inv(i,j)

      ql_5mf(i,j) = ql_5m(i,j)*fact
      ql_3mf(i,j) = ql_3m(i,j)*fact
      ql_dwf(i,j) = ql_dw(i,j)*fact
      ql_dsTf(i,j) = ql_dsT(i,j)*fact
      ql_dsSf(i,j) = ql_dsS(i,j)*fact
      ql_invf(i,j) = ql_inv(i,j)*fact
      ql_dsTagf(i,j) = ql_dsTag(i,j)*fact
      end do

c
c.....continue reading the raw file for other variables
c      read the sixth block--air mass fraction data
c
806      read(777,6) name
      if(name .ne. 'time') goto 806

      do j = 1,npts
      read(777,*) timeyr(j), xa_ds(i,j)

      xa_dsf(i,j) = xa_ds(i,j)*fact
      end do

c
c.....continue reading the raw file for other variables
c      read the seventh block--Gas-phase pressure data
c
807      read(777,6) name
      if(name .ne. 'time') goto 807

      do j = 1,npts
      read(777,*) timeyr(j), P_ds(i,j)

      P_dsf(i,j) = P_ds(i,j)*fact
      end do

c
c.....continue reading the raw file for other variables
c      read the eighth block--Capillary pressure data
c
808      read(777,6) name
      if(name .ne. 'time') goto 808

      do j = 1,npts
      read(777,*) timeyr(j), Pc_ds(i,j), Pc_inv(i,j),
@      PcM_dw(i,j), PcF_dw(i,j)

      Pc_dsf(i,j) = Pc_ds(i,j)*fact
      Pc_invf(i,j) = Pc_inv(i,j)*fact
      PcM_dwf(i,j) = PcM_dw(i,j)*fact
      PcF_dwf(i,j) = PcF_dw(i,j)*fact

```

```

        end do

c
c.....continue reading the raw file for other variables
c      read the ninth block--gas flux data
c
809      read(777,6) name
         if(name .ne. 'time') goto 809

         do j = 1,npts
            read(777,*) timeyr(j), qw_dw(i,j), qa_dw(i,j)

            qw_dwf(i,j) = qw_dw(i,j)*fact
            qa_dwf(i,j) = qa_dw(i,j)*fact
         end do

c
c.....continue reading the raw file for other variables
c      read the tenth block--evaporation rate data
c
810      read(777,6) name
         if(name .ne. 'time') goto 810

         do j = 1,npts
            read(777,*) timeyr(j), qvpdsT(i,j), qvpdsP(i,j),
@          qvpbfp(i,j), qvpinv(i,j)

            qvpdsTf(i,j) = qvpdsT(i,j)*fact
            qvpdsPf(i,j) = qvpdsP(i,j)*fact
            qvpbfpf(i,j) = qvpbfp(i,j)*fact
            qvpinvf(i,j) = qvpinv(i,j)*fact
         end do

c
c.....continue reading the raw file for other variables
c      read the eleventh block--pillar temperature data
c
811      read(777,6) name
         if(name .ne. 'time') goto 811

         do j = 1,npts
            read(777,*) timeyr(j), Tpl299(i,j), Tpl369(i,j),
@          Tpl489(i,j), Tpl689(i,j), Tpl1014(i,j), Tpl1514(i,j),
@          Tpl2264(i,j), Tpl3382(i,j)

            Tpl299f(i,j) = Tpl299(i,j)*fact
            Tpl369f(i,j) = Tpl369(i,j)*fact
            Tpl489f(i,j) = Tpl489(i,j)*fact
            Tpl689f(i,j) = Tpl689(i,j)*fact
            Tpl1014f(i,j) = Tpl1014(i,j)*fact
            Tpl1514f(i,j) = Tpl1514(i,j)*fact
            Tpl2264f(i,j) = Tpl2264(i,j)*fact
            Tpl3382f(i,j) = Tpl3382(i,j)*fact
         end do

c.....the raw data has been processed for an infiltration bin
c      **close the i loop**
c

        end do

c.....Now-Assemble the max & min WP temperature data for the bin
c

```

```

        if(iinf(k) .ne. 0) then
            do j = 1, npts
                Tmaxrip(k,j) = T_wp(mark,j)
            enddo

            Tmino = 1.E+10
            do i = 1,iinf(k)
                Tminn= DMIN1(Tmax_min(i), Tmino)
                if(Tminn .lt. Tmino) then
                    imin = i
                    Tmino=Tminn
                endif
            enddo

            do j = 1, npts
                Tminrip(k,j) = T_wp(imin,j)
            enddo
        endif

c.....Indicate that the bin has no entries
c

        if(iinf(k) .eq. 0) then
            noent(k)=1
            goto 998
        end if

c
c.....compute the infiltration bin averages of the PA variables
c    for WP T, RH and DS T, RH
c    This is for a particular infiltration bin
c

        do j = 1,npts

            s1PAwpT = 0.
            s2PAwpRH = 0.
            s3PAdst = 0.
            s4PAdsrH = 0.

            do i = 1,iinf(k)
                s1PAwpT= s1PAwpT + PAwpTf(i,j)
                s2PAwpRH=s2PAwpRH + PAwpRHf(i,j)
                s3PAdst=s3PAdst + PAdstf(i,j)
                s4PAdsrH = s4PAdsrH + PAdsrHf(i,j)
            end do

            PAwpT1a(j) = s1PAwpT
            PAwpRH2a(j) = s2PAwpRH
            PAdst3a(j)= s3PAdst
            PAdsrH4a(j) = s4PAdsrH
        end do

c
c
c.....compute the averages of the temperature data
c

        do j = 1,npts

            s1T_wp = 0.
            s2T_5m = 0.
            s3T_bfpk = 0.
            s4T_ds = 0.
            s5T_dw = 0.
            s6T_inv = 0.
            s7T_dwlow = 0.
            s8Tdstop = 0.
            s9T_dwtop = 0.

            do i = 1,iinf(k)

```

```

s1T_wp = s1T_wp + T_wpf(i,j)
s2T_5m = s2T_5m + T_5mf(i,j)
s3T_bfpk = s3T_bfpk + T_bfpkf(i,j)
s4T_ds = s4T_ds + T_dsf(i,j)
s5T_dw=s5T_dw+T_dwf(i,j)
s6T_inv=s6T_inv+T_invf(i,j)
s7T_dwlow=s7T_dwlow+T_dwlowf(i,j)
s8Tdstop= s8Tdstop+Tdstopf(i,j)
s9T_dwtop = s9T_dwtop + T_dwtopf(i,j)
end do

```

```

T_wpl1a(j) = s1T_wp
TavgRIP(k,j)=s1T_wp
T_5m2a(j) = s2T_5m
T_bfpk3a(j)= s3T_bfpk
T_ds4a(j) = s4T_ds
T_dw5a(j) = s5T_dw
T_inv6a(j) = s6T_inv
TavgRIPinv(k,j)=s6T_inv
T_dwlow7a(j) = s7T_dwlow
Tdstop8a(j) = s8Tdstop
T_dwtop9a(j) = s9T_dwtop
TavgRIPdstop(k,j) = s8Tdstop
end do

```

```

c
c
c.....compute the averages of the relative humidity data
c

```

```

do j = 1,npts

s1RH_dw = 0.
s2RH_bfp = 0.
s3RH_ds = 0.
s4RH_wp = 0.
s5RH_inv = 0.

do i = 1,iinf(k)
s1RH_dw = s1RH_dw + RH_dwf(i,j)
s2RH_bfp = s2RH_bfp + RH_bfpf(i,j)
s3RH_ds = s3RH_ds + RH_dsf(i,j)
s4RH_wp = s4RH_wp + RH_wpf(i,j)
s5RH_inv=s5RH_inv + RH_invf(i,j)
end do

RH_dw1a(j) = s1RH_dw
RH_bfp2a(j) = s2RH_bfp
RH_ds3a(j)= s3RH_ds
RH_wp4a(j) = s4RH_wp
RH_inv5a(j) = s5RH_inv
RHavgRIPin(k,j)=s5RH_inv
end do

```

```

c
c
c.....compute the averages of the liquid saturation data
c

```

```

do j = 1,npts

s1Sl_dw = 0.
s2Sl_ds = 0.
s3Sl_inv = 0.

do i = 1,iinf(k)
s1Sl_dw = s1Sl_dw + Sl_dwf(i,j)
s2Sl_ds = s2Sl_ds + Sl_dsf(i,j)
s3Sl_inv = s3Sl_inv + Sl_invf(i,j)
end do

S_lavgRIP(k,j) = s3Sl_inv
Sl_dw1a(j) = s1Sl_dw
Sl_ds2a(j) = s2Sl_ds
Sl_inv3a(j)= s3Sl_inv

```

```

end do

c
c
c.....compute the averages of the liquid flux data
c
do j = 1,npts

s1ql_5m = 0.
s2ql_3m = 0.
s3ql_dw = 0.
s4ql_dsT = 0.
s5ql_dsS = 0.
s6ql_inv = 0.
s7ql_dsTag = 0.
s66ql_inv = 0.

do i = 1,iinf(k)
s1ql_5m = s1ql_5m + ql_5mf(i,j)
s2ql_3m = s2ql_3m + ql_3mf(i,j)
s3ql_dw = s3ql_dw + ql_dwf(i,j)
s4ql_dsT = s4ql_dsT + ql_dsTf(i,j)
s5ql_dsS = s5ql_dsS + ql_dsSf(i,j)
s6ql_inv = s6ql_inv + ql_invf(i,j)
s7ql_dsTag = s7ql_dsTag + ql_dsTagf(i,j)
s66ql_inv = s66ql_inv + abs( ql_invf(i,j) )
end do

ql_5m1a(j) = s1ql_5m
ql_5mavgRIP(k, j) = s1ql_5m
ql_3m2a(j) = s2ql_3m
ql_dw3a(j) = s3ql_dw
ql_dsT4a(j) = s4ql_dsT
ql_dsS5a(j) = s5ql_dsS
ql_inv6a(j) = s6ql_inv
ql_invavgRIP(k, j) = s6ql_inv
ql_invavgabs(k, j) = s66ql_inv
ql_dsTag7a(j) = s7ql_dsTag
end do

c
c
c.....compute the averages of the air mass fraction data
c
do j = 1,npts

s1xa_ds = 0.

do i = 1,iinf(k)
s1xa_ds = s1xa_ds + xa_dsf(i,j)
end do

xa_ds1a(j) = s1xa_ds
end do

c
c
c.....compute the averages of the gas pressure data
c
do j = 1,npts

s1P_ds = 0.

do i = 1,iinf(k)
s1P_ds = s1P_ds + P_dsf(i,j)
end do

P_ds1a(j) = s1P_ds
end do

c
c
c.....compute the averages of the capillary pressure data
c

```

```

do j = 1,npts

s1Pc_ds = 0.
s2Pc_inv = 0.
s3PcM_dw = 0.
s4PcF_dw = 0.

do i = 1,iinf(k)
  s1Pc_ds = s1Pc_ds + Pc_dsf(i,j)
  s2Pc_inv = s2Pc_inv + Pc_invf(i,j)
  s3PcM_dw = s3PcM_dw + PcM_dwf(i,j)
  s4PcF_dw = s4PcF_dw + PcF_dwf(i,j)
end do

Pc_dsl1a(j) = s1Pc_ds
Pc_inv2a(j) = s2Pc_inv
PcM_dw3a(j) = s3PcM_dw
PcF_dw4a(j) = s4PcF_dw
end do

c
c
c.....compute the averages of the gas flux data
c

do j = 1,npts

s1qw_dw = 0.
s2qa_dw = 0.

do i = 1,iinf(k)
  s1qw_dw = s1qw_dw + qw_dwf(i,j)
  s2qa_dw = s2qa_dw + qa_dwf(i,j)
end do

qw_dw1a(j) = s1qw_dw
qa_dw2a(j) = s2qa_dw
end do

c
c
c.....compute the averages of the evaporation rate data
c

do j = 1,npts

s1qvpdsT = 0.
s2qvpdsP = 0.
s3qvpbfp = 0.
s4qvpinv = 0.

do i = 1,iinf(k)
  s1qvpdsT = s1qvpdsT + qvpdsTf(i,j)
  s2qvpdsP = s2qvpdsP + qvpdsPf(i,j)
  s3qvpbfp = s3qvpbfp + qvpbfpf(i,j)
  s4qvpinv = s4qvpinv + qvpinvf(i,j)
end do

qvpdsT1a(j) = s1qvpdsT
qvpdsP2a(j) = s2qvpdsP
qvpbfp3a(j) = s3qvpbfp
qvpinv4a(j) = s4qvpinv
qvpavgRIPinv(k,j)=s4qvpinv
end do

c
c
c....compute the average pillar temperatures
c

do j = 1,npts

s1Tpl299 = 0.
s2Tpl369 = 0.

```

```

s3Tpl489 = 0.
s4Tpl689 = 0.
s5Tpl1014 = 0.
s6Tpl11514 = 0.
s7Tpl12264 = 0.
s8Tpl13382 = 0.

```

```

do i = 1,iinf(k)
  s1Tpl299 = s1Tpl299 + Tpl299f(i,j)
  s2Tpl369 = s2Tpl369 + Tpl369f(i,j)
  s3Tpl489 = s3Tpl489 + Tpl489f(i,j)
  s4Tpl689 = s4Tpl689 + Tpl689f(i,j)
  s5Tpl1014 = s5Tpl1014 + Tpl1014f(i,j)
  s6Tpl11514 = s6Tpl11514 + Tpl11514f(i,j)
  s7Tpl12264 = s7Tpl12264 + Tpl12264f(i,j)
  s8Tpl13382 = s8Tpl13382 + Tpl13382f(i,j)
end do

```

```

Tpl2991a(j) = s1Tpl299
Tpl3692a(j) = s2Tpl369
Tpl4893a(j) = s3Tpl489
Tpl6894a(j) = s4Tpl689
Tpl10145a(j) = s5Tpl1014
Tpl115146a(j) = s6Tpl11514
Tpl122647a(j) = s7Tpl12264
Tpl133828a(j) = s8Tpl13382
end do

```

```

c
c.....write the infiltration bin raw information for RIP
c.....control the number of time prints
c

```

```

do i=1,iinf(k)
  jcount=0
  do j = 1,npts

    if (j .eq. 1) then

      jcount = jcount + 1
      jtag = j
    else if (j .eq. npts) then

      jcount = jcount + 1
    else

      if (ql_5m(i,j) .eq. 0.) then
        jcount = jcount + 1
        imark0 = j
      else

        chl = ql_5m(i,jtag)
        if(chl .eq. 0.) then
          jcount = jcount + 1
          jtag = j
          go to 89
        endif

        crate = (( ql_5m(i,j) - ql_5m(i,jtag) )/ ql_5m(i,jtag) )*100.
        crate1 = (( T_wp(i,j) - T_wp(i,jtag) )/ T_wp(i,jtag) )*100.

        if (abs(crate) .ge. prntfac .or. j-1 .eq. imark0 .or.
          abs(crate1) .ge. prntfac) then
          jcount = jcount+1
          jtag = j
        end if
      endif
    endif

    89

  end do

end do

```

```

925     write(306-k,925) jcount
      format('The number of Rows = ', i3)
      write(306-k,926) factbin (k,i)
926     format('The fraction of this history=',f8.6)

      write(306-k,*) 'Coordinate Location:'

      write(306-k,128) coord1(k,i)
128     format('The easting coordinate = ', f9.2, ' m')

      write(306-k,129) coord2(k,i)
129     format('The northing coordinate = ', f9.2, ' m')
      write(306-k,*) 'Infiltration rate:'
      write(306-k,130) finf(k,i)
130     format('qinf = ', f9.5, ' mm/yr')
927     format(f10.2, 21(2x, E13.6))
c2345678901234567890123456789012345678901234567890123456789012

```

```

do j = 1,npts
  if (j .eq. 1) then

    if (qvpdsT(i,j) .eq. -99.9 .or. qvpbfp(i,j)
@      .eq. -99.9 ) then

      write(306-k,927) timeyr(j), T_wp(i,j), T_ds(i,j), T_dw(i,j),
@      T_inv(i,j), RH_wp(i,j), RH_ds(i,j), RH_dw(i,j), RH_bfp(i,j),
@      RH_inv(i,j), Sl_ds(i,j), Sl_inv(i,j), xa_ds(i,j), qw_dw(i,j),
@      qa_dw(i,j), qvpdsT(i,j), qvpbfp(i,j),
@      qvpinv(i,j), ql_5m(i,j), ql_dsT(i,j), ql_inv(i,j)*
@      (a_inv/1000.),Tdstop(i,j)
      jtag = j

    else

      write(306-k,927) timeyr(j), T_wp(i,j), T_ds(i,j), T_dw(i,j),
@      T_inv(i,j), RH_wp(i,j), RH_ds(i,j), RH_dw(i,j), RH_bfp(i,j),
@      RH_inv(i,j), Sl_ds(i,j), Sl_inv(i,j), xa_ds(i,j), qw_dw(i,j),
@      qa_dw(i,j), qvpdsT(i,j)/rho, qvpbfp(i,j)/rho,
@      qvpinv(i,j)/rho, ql_5m(i,j), ql_dsT(i,j)*(a_dsT/1000.),
@      ql_inv(i,j)*(a_inv/1000.), Tdstop(i,j)
      jtag = j

    end if

  else if (j .eq. npts) then

    write(306-k,927) timeyr(j), T_wp(i,j), T_ds(i,j), T_dw(i,j),
@      T_inv(i,j), RH_wp(i,j), RH_ds(i,j), RH_dw(i,j), RH_bfp(i,j),
@      RH_inv(i,j), Sl_ds(i,j), Sl_inv(i,j), xa_ds(i,j), qw_dw(i,j),
@      qa_dw(i,j), qvpdsT(i,j)/rho, qvpbfp(i,j)/rho,
@      qvpinv(i,j)/rho, ql_5m(i,j), ql_dsT(i,j)*(a_dsT/1000.),
@      ql_inv(i,j)*(a_inv/1000.), Tdstop(i,j)

    else

      if(ql_5m(i,j) .eq. 0.) then

        if (qvpdsT(i,j) .eq. -99.9 .or. qvpbfp(i,j)
@          .eq. -99.9 ) then

          write(306-k,927) timeyr(j), T_wp(i,j), T_ds(i,j), T_dw(i,j),
@          T_inv(i,j), RH_wp(i,j), RH_ds(i,j), RH_dw(i,j), RH_bfp(i,j),
@          RH_inv(i,j), Sl_ds(i,j), Sl_inv(i,j), xa_ds(i,j), qw_dw(i,j),

```



```

@   qa_dw(i,j), qvpdsT(i,j), qvpbfp(i,j),
@   qvpinv(i,j), ql_5m(i,j), ql_dsT(i,j), ql_inv(i,j)
@   *(a_inv/1000.), Tdstop(i,j)
      imark0 = j

      else

      write(306-k,927) timeyr(j), T_wp(i,j), T_ds(i,j), T_dw(i,j),
@   T_inv(i,j), RH_wp(i,j), RH_ds(i,j), RH_dw(i,j), RH_bfp(i,j),
@   RH_inv(i,j), Sl_ds(i,j), Sl_inv(i,j), xa_ds(i,j), qw_dw(i,j),
@   qa_dw(i,j), qvpdsT(i,j)/rho, qvpbfp(i,j)/rho,
@   qvpinv(i,j)/rho, ql_5m(i,j), ql_dsT(i,j)*(a_dsT/1000.),
@   ql_inv(i,j)*(a_inv/1000.), Tdstop(i,j)
      imark0 = j
      end if

      else

      chl = ql_5m(i,jtag)
      if(chl .eq. 0.) then

      .if (qvpdsT(i,j) .eq. -99.9 .or. qvpbfp(i,j)
@   .eq. -99.9 ) then

c23456789012345678901234567890123456789012345678901234567890123456789012
      write(306-k,927) timeyr(j), T_wp(i,j), T_ds(i,j), T_dw(i,j),
@   T_inv(i,j), RH_wp(i,j), RH_ds(i,j), RH_dw(i,j), RH_bfp(i,j),
@   RH_inv(i,j), Sl_ds(i,j), Sl_inv(i,j), xa_ds(i,j), qw_dw(i,j),
@   qa_dw(i,j), qvpdsT(i,j), qvpbfp(i,j),
@   qvpinv(i,j), ql_5m(i,j), ql_dsT(i,j), ql_inv(i,j)*(a_inv/1000.)
@   , Tdstop(i,j)
      jtag=j
      goto 71

      else

c23456789012345678901234567890123456789012345678901234567890123456789012
      write(306-k,927) timeyr(j), T_wp(i,j), T_ds(i,j), T_dw(i,j),
@   T_inv(i,j), RH_wp(i,j), RH_ds(i,j), RH_dw(i,j), RH_bfp(i,j),
@   RH_inv(i,j), Sl_ds(i,j), Sl_inv(i,j), xa_ds(i,j), qw_dw(i,j),
@   qa_dw(i,j), qvpdsT(i,j)/rho, qvpbfp(i,j)/rho,
@   qvpinv(i,j)/rho, ql_5m(i,j), ql_dsT(i,j)*(a_dsT/1000.),
@   ql_inv(i,j)*(a_invT/1000.), Tdstop(i,j) .
      jtag=j
      goto 71

      end if

      endif

c23456789012345678901234567890123456789012345678901234567890123456789012
      crate = (( ql_5m(i,j) - ql_5m(i,jtag) )/ ql_5m(i,jtag) )*100.
      cratel = (( T_wp(i,j) - T_wp(i,jtag) )/ T_wp(i,jtag) )*100.

      if (abs(crate) .ge. prntfac .or. j-1 .eq. imark0 .or.
@   abs(cratel) .ge. prntfac) then

      if (qvpdsT(i,j) .eq. -99.9 .or. qvpbfp(i,j)
@   .eq. -99.9 ) then

      write(306-k,927) timeyr(j), T_wp(i,j), T_ds(i,j), T_dw(i,j),

```

```

@ T_inv(i,j), RH_wp(i,j), RH_ds(i,j), RH_dw(i,j), RH_bfp(i,j),
@ RH_inv(i,j), Sl_ds(i,j), Sl_inv(i,j), xa_ds(i,j), qw_dw(i,j),
@ qa_dw(i,j), qvpdsT(i,j), qvpbfp(i,j),
@ qvpinv(i,j), ql_5m(i,j), ql_dsT(i,j), ql_inv(i,j)*(a_inv/1000.)
@ , Tdstop(i,j)
    jtag = j

    else

        write(306-k,927) timeyr(j), T_wp(i,j), T_ds(i,j), T_dw(i,j),
@ T_inv(i,j), RH_wp(i,j), RH_ds(i,j), RH_dw(i,j), RH_bfp(i,j),
@ RH_inv(i,j), Sl_ds(i,j), Sl_inv(i,j), xa_ds(i,j), qw_dw(i,j),
@ qa_dw(i,j), qvpdsT(i,j)/rho, qvpbfp(i,j)/rho,
@ qvpinv(i,j)/rho, ql_5m(i,j), ql_dsT(i,j)*(a_dsT/1000.),
@ ql_inv(i,j)*(a_inv/1000.), Tdstop(i,j)
        jtag = j

    endif

    end if
71   endif

endif

end do

c.....write the percolation flux specific files. This does not use
c      a predetermined set of time prints for use in the seepage
c      model--prints eacg point to extreme variability in q.liquid
c

    write(306+k,925) npts
    write(306+k,926) factbin (k,i)

    write(306+k,*) 'Coordinate Location:'

    write(306+k,128) coord1(k,i)

    write(306+k,129) coord2(k,i)

    write(306+k,*) 'Infiltration rate:'
    write(306+k,130) finf(k,i)
    939   format(f10.2, 2x, E13.6, 2x, E13.6)
c23456789012345678901234567890123456789012345678901234567890123456789012

    do j = 1, npts
        write(306+k,939) timeyr(j), ql_5m(i,j),ql_3m(i,j)
    enddo

c.....close the i loop for writing RIP raw values
c

    end do

c
c
c
c.....write the infiltration bin **averages** for each quantity
c      including time
c

    write(206-k,*) 'infiltration bin file:'
    write(206-k,*) outfile(k)
    write(206-k,*) 'average value outputs:'

```

```

write(206-k,*) resultsbinfile(k)
write(206-k,*)
write(206-k,*)
write(206-k,*) 'The average TSPA Variables'
write(206-k,*) 'Time (yr), WP-T (C), WP-RH, DS-T(C), DS-RH'

do j = 1,npts
write(206-k,901) timeyr(j),PAwpT1a(j), PAwpRH2a(j),
@ PAdst3a(j), PAdsrH4a(j)

901 format(f10.2,5x,E13.6,5x,E13.6,5x,E13.6,5x,E13.6)
enddo

write(206-k,*)
write(206-k,*)
write(206-k,*) 'The average Temperature Variables'
c23456789012345678901234567890123456789012345678901234567890123456789012
write(206-k,*) 'Time (yr), WP temp (C), temp at 5m (C), temp at
@ backfill peak(C), dripshield temp(C), drift wall temp (C), invert
@ temp(C), lower drift wall (C), dripshield top temp (C), drift wal
@1 top temp (C)'

do j = 1,npts
write(206-k,902) timeyr(j), T_wpl1a(j), T_5m2a(j),
@ T_bfpk3a(j), T_ds4a(j), T_dw5a(j), T_inv6a(j),
@ T_dwlow7a(j), Tdstop8a(j)
@, T_dwtop9a(j)

902 format(f10.2,5x,E13.6,5x,E13.6,5x,E13.6,5x,E13.6,
@ 5x, E13.6, 5x, E13.6, 5x, E13.6, 5x, E13.6, 5x, E13.6)
enddo

write(206-k,*)
write(206-k,*)
write(206-k,*) 'The average Relative Humidity Variables'
c2345678901234567890123456789012345678901234567890123456789012
write(206-k,*) 'Time (yr), drift wall RH, backfill RH, dripshield
@ RH, waste package RH, invert RH'

do j = 1,npts
write(206-k,903) timeyr(j), RH_dw1a(j), RH_bfp2a(j),
@ RH_ds3a(j), RH_wp4a(j), RH_inv5a(j)

903 format(f10.2,5x,E13.6,5x,E13.6,5x,E13.6,5x,E13.6,
@ 5x, E13.6)
enddo

write(206-k,*)
write(206-k,*)
write(206-k,*) 'The average Liquid Saturation Variables'
c2345678901234567890123456789012345678901234567890123456789012
write(206-k,*) 'Time (yr), drift wall liq sat, dripshield liq sat
@, invert liq sat'

do j = 1,npts
write(206-k,904) timeyr(j), Sl_dw1a(j), Sl_ds2a(j),
@ Sl_inv3a(j)

904 format(f10.2,5x,E13.6,5x,E13.6,5x,E13.6)
enddo

write(206-k,*)
write(206-k,*)
write(206-k,*) 'The average liquid flux Variables'
c2345678901234567890123456789012345678901234567890123456789012
write(206-k,*) 'Time (yr), liquid flux 5m (mm/yr), liquid flux 3m
@ (mm/yr), liquid flux drift W (mm/yr), liquid flux top Dshield
@ (mm/yr), liquid flux side Dshield (mm/yr), liquid flux invert
@ (mm/yr), liquid flux top DS average (mm/yr)'

```

```

do j = 1,npts
write(206-k,905) timeyr(j), ql_5mla(j), ql_3m2a(j),
@ ql_dw3a(j), ql_dsT4a(j), ql_dsS5a(j), ql_inv6a(j),
@ ql_dsTag7a(j)

905   format(f10.2,5x,E13.6,5x,E13.6,5x,E13.6,5x,E13.6,
@      5x, E13.6, 5x, E13.6, 5x, E13.6)
enddo

write(206-k,*)
write(206-k,*)
write(206-k,*) 'The average air mass fraction Variables'
write(206-k,*) 'Time (yr), air mass fraction Dshield'

do j = 1,npts
write(206-k,906) timeyr(j), xa_dsla(j)

906   format(f10.2,5x,E13.6)
enddo

write(206-k,*)
write(206-k,*)
write(206-k,*) 'The average gas-phase pressure Variables'
write(206-k,*) 'Time (yr), gas pressure (Pa)'

do j = 1,npts
write(206-k,907) timeyr(j), P_dsla(j)

907   format(f10.2,5x,E13.6)
enddo

write(206-k,*)
write(206-k,*)
write(206-k,*) 'The average capillary pressure Variables'
c23456789012345678901234567890123456789012345678901234567890123456789012
write(206-k,*) 'Time (yr), Cap pressure Dshield (Pa), Cap press
@ure @ invert (Pa), Cap pressure Dwall-Matrix (Pa), Cap pressure
@Dwall-fracture (Pa)'

do j = 1,npts
write(206-k,908) timeyr(j), Pc_dsla(j), Pc_inv2a(j),
@ PcM_dw3a(j), PcF_dw4a(j)

908   format(f10.2,5x,E13.6,5x,E13.6,5x,E13.6,5x,E13.6)
enddo

write(206-k,*)
write(206-k,*)
write(206-k,*) 'The average gas flux Variables'
c2345678901234567890123456789012345678901234567890123456789012
write(206-k,*) 'Time (yr), water vapor flux(kg/yr/m of drift),
@air flux (kg/yr/m of drift)'

do j = 1,npts
write(206-k,909) timeyr(j), qw_dw1a(j), qa_dw2a(j)

909   format(f10.2,5x,E13.6,5x,E13.6)
enddo

write(206-k,*)
write(206-k,*)
write(206-k,*) 'The average evaporation rate Variables'

```

```

c23456789012345678901234567890123456789012345678901234567890123456789012
  write(206-k,*) 'Time (yr), Evaporation rate Dshield top (m3/yr),
    @Evaporation rate Dshield top perimeter (m3/yr), Evaporation rate
    @backfill pk (m3/yr), Evaporation rate invert (m3/yr)'

910   format(f10.2,5x,E13.6,5x,E13.6,5x,E13.6,5x,E13.6)

      do j = 1,npts

        write(206-k,910) timeyr(j), qvpdsT1a(j)/rho,
          @ qvpdsP2a(j)/rho, qvpbfp3a(j)/rho,
          @ qvpinv4a(j)/rho

        enddo

        write(206-k,*)
        write(206-k,*)
        write(206-k,*) 'The average Pillar Temperatures'
c23456789012345678901234567890123456789012345678901234567890123456789012
        write(206-k,*) 'Time (yr), Tx=2.99m (C), Tx=3.69m (C), Tx=4.89m
          @ (C), Tx=6.89 m (C), Tx=10.14m (C), Tx=15.14m (C), Tx=22.64 (C),
          @Tx=33.82m (C)'

        do j = 1,npts
          write(206-k,911) timeyr(j),Tpl12991a(j), Tpl13692a(j),
            @ Tpl14893a(j), Tpl16894a(j), Tpl110145a(j), Tpl115146a(j),
            @ Tpl122647a(j), Tpl133828a(j)

911   format(f10.2,5x,E13.6,5x,E13.6,5x,E13.6,5x,E13.6,
          @ 5x, E13.6, 5x, E13.6, 5x, E13.6, 5x, E13.6)
        enddo

998   close(206-k)
      close(306-k)

c
c.....read the next infiltration bin and start process over--
c.....The portion of the routine from this point on up to the beginning
c      of the routine is completely general for any number of infiltration
c      bins specified in the parameter statement listed near the top of the
c      routine
c      **end the k loop**

      end do

c.....Now--write the average results to individual files for RIP
c
c
c
c23456789012345678901234567890123456789012345678901234567890123456789012
7   format(';', a70)
8   format(';', 'The Average Waste Package Surface Temp (C)')
9   format(';', 'The Average Invert Liquid Saturation')
12  format(';', 'The Average Liquid Flux at 5 m (mm/yr)')
27  format(';', 'The Maximum Waste Package Surface Temp (C)')
74  format(';', 'The Minimum Waste Package Surface Temp (C)')
75  format(';', 'The Average Invert Temp (C)')
76  format(';', 'The Average Invert Rel. Humidity')
77  format(';', 'The Average Invert Evaporation rate (m3/yr)')
13  format(';', 'Time(yr)',',', ' Bin Weight= ', E13.6)
14  format(';', a80)
80  format(';', 'The Average Top Dripshield Temp (C)')
91  format(';', 'The Average Invert Percolation Flux (m3/yr)')
92  format(';', 'The Absolute Average Invert Percolation Flux
    @ (m3/yr)')
928  format(f10.2, ', ', E13.6)

```

```
c.....Begin building the RIP column files for averages, maximum, minimum Ts
c      invert, etc
```

```
      do k = 1, ninf
```

```
c
```

```
c.....Average Temperature
```

```
      write(*,*) 'Writing T average value file for RIP'
      read(3,'(a)') resultsbinfile3(k)
      open(406-k,file=resultsbinfile3(k),status='new')
      write(406-k,8)
      write(406-k,7) resultsbinfile3(k)
      write(406-k,13) facttb(k)
      write(406-k,14) outfile(k)
```

```
      if (noent(k) .ne. 0) then
        write(406-k,*) 'No Entries for this Bin'
      else
```

```
        do j = 1,npts
          if ( j .eq. 1 ) then
            write(406-k,928) timeyr(j), TavgrIP(k,j)
            jtag = j
          else if (j .eq. npts) then
            write(406-k,928) timeyr(j), TavgrIP(k,j)
          else
            crate= ( (TavgrIP(k,j)-TavgrIP(k,jtag))/TavgrIP(k,jtag) )
@      *100.
```

```
            if(abs(crate) .ge. prntfac) then
              write(406-k,928) timeyr(j), TavgrIP(k,j)
              jtag = j
            end if
```

```
          end if
```

```
        end do
      end if
```

```
      close(406-k)
```

```
c.....Average Liquid Saturation
```

```
      write(*,*) 'Writing S_L average value file for RIP'
      read(3,'(a)') resultsbinfile3a(k)
      open(406+k,file=resultsbinfile3a(k),status='new')
      write(406+k,9)
      write(406+k,7) resultsbinfile3a(k)
      write(406+k,13) facttb(k)
      write(406+k,14) outfile(k)
```

```
      if (noent(k) .ne. 0) then
        write(406+k,*) 'No Entries for this Bin'
      else
```

```
        do j = 1,npts
          if ( j .eq. 1 ) then
            write(406+k,928) timeyr(j), S_lavgrIP(k,j)
            jtag = j
          else if (j .eq. npts) then
            write(406+k,928) timeyr(j), S_lavgrIP(k,j)
          else
```

```
            if (S_lavgrIP(k,j) .eq. 0.) then
              write(406+k,928) timeyr(j), S_lavgrIP(k,j)
              imark0=j
            else
```

```

        chl = S_lavgRIP(k,jtag)
        if(chl .eq. 0.) then
            write(406+k,928) timeyr(j), S_lavgRIP(k,j)
            jtag=j
            goto 88
        endif
        crate= ( (S_lavgRIP(k,j)-S_lavgRIP(k,jtag))/S_lavgRIP(k,jtag)
@         ) *100.

        if(abs(crate) .ge. prntfac .or.
@         j-1 .eq. imark0) then
            write(406+k,928) timeyr(j), S_lavgRIP(k,j)
            jtag = j
        end if
88      endif
        end if

        end do
        end if
        close(406+k)

c23456789012345678901234567890123456789012345678901234567890123456789012
c.....Average liquid flux at 5 m

        write (*,*) 'Writing Q_perc average value file for RIP'
        read(3,'(a)') resultsbinfile3b(k)
        open(506-k,file=resultsbinfile3b(k),status='new')

        write(506-k,12)
        write(506-k,7) resultsbinfile3b(k)
        write(506-k,13) facttb(k)
        write(506-k,14) outfile(k)

        if (noent(k) .ne. 0) then
            write(506-k,*) 'No Entries for this Bin'
        else
            do j = 1,npts
                if ( j .eq. 1 ) then
                    write(506-k,928) timeyr(j), ql_5mavgRIP(k,j)
                    jtag = j
                else if (j .eq. npts) then
                    write(506-k,928) timeyr(j), ql_5mavgRIP(k,j)
                else
                    if (ql_5mavgRIP(k,j) .eq. 0.) then
                        write(506-k,928) timeyr(j), ql_5mavgRIP(k,j)
                        imark0 = j
                    else
                        chl = ql_5mavgRIP(k,jtag)
                        if(chl .eq. 0.) then
                            write(506-k,928) timeyr(j), ql_5mavgRIP(k,j)
                            jtag=j
                            goto 87
                        endif
                    end if

                    crate= ( (ql_5mavgRIP(k,j)-ql_5mavgRIP(k,jtag))
@                     /ql_5mavgRIP(k,jtag) ) *100.

                    if(abs(crate) .ge. prntfac .or. j-1 .eq.
@                     imark0) then
                        write(506-k,928) timeyr(j), ql_5mavgRIP(k,j)
                        jtag = j
                    end if

```

```

87         endif
        end if

        end do
        end if

        close(506-k)

c.....Maximum Temperature

        write (*,*) 'Writing Tmax value file for RIP'
        read(3,'(a)') resultsbinfile4(k)
        open(506+k,file=resultsbinfile4(k),status='new')

        write(506+k,27)
        write(506+k,7) resultsbinfile4(k)
        write(506+k,13) facttb(k)
        write(506+k,14) outfile(k)

        if (noent(k) .ne. 0) then
            write(506+k,*) 'No Entries for this Bin'
        else

            do j = 1,npts
                if ( j .eq. 1 ) then
                    write(506+k,928) timeyr(j), Tmaxrip(k,j)
                    jtag = j
                else if (j .eq. npts) then
                    write(506+k,928) timeyr(j), Tmaxrip(k,j)
                else
                    crate= ( (Tmaxrip(k,j)-Tmaxrip(k,jtag))
@ /Tmaxrip(k,jtag) ) *100.

                    if(abs(crate) .ge. prntfac) then
                        write(506+k,928) timeyr(j), Tmaxrip(k,j)
                        jtag = j
                    end if
                end if
            end do
        end if

        close(506+k)

c.....Minimum Temperature

        write (*,*) 'Writing Tmin value file for RIP'
        read(3,'(a)') resultsbinfile5(k)
        open(606-k,file=resultsbinfile5(k),status='new')

        write(606-k,74)
        write(606-k,7) resultsbinfile5(k)
        write(606-k,13) facttb(k)
        write(606-k,14) outfile(k)

        if (noent(k) .ne. 0) then
            write(606-k,*) 'No Entries for this Bin'
        else

            do j = 1,npts
                if ( j .eq. 1 ) then
                    write(606-k,928) timeyr(j), Tminrip(k,j)
                    jtag = j
                else if (j .eq. npts) then
                    write(606-k,928) timeyr(j), Tminrip(k,j)
                end if
            end do
        end if

```



```

else
  crate= ( (Tminrip(k,j)-Tminrip(k,jtag))
@   /Tminrip(k,jtag) ) *100.

  if(abs(crate) .ge. prntfac) then
    write(606-k,928) timeyr(j), Tminrip(k,j)
    jtag = j
  end if

end if

end do
end if
close(606-k)

```

c.....Average Invert T

```

  write (*,*) 'Writing Tinvert value file for RIP'

  read(3,'(a)') resultsbinfile6(k)

  open(606+k,file=resultsbinfile6(k),status='new')

  write(606+k,75)
  write(606+k,7) resultsbinfile6(k)
  write(606+k,13) facttb(k)
  write(606+k,14) outfile(k)

  if (noent(k) .ne. 0) then
    write(606+k,*) 'No Entries for this Bin'
  else

    do j = 1,npts
      if ( j .eq. 1 ) then
        write(606+k,928) timeyr(j), TavGRIPinv(k,j)
        jtag = j
      else if (j .eq. npts) then
        write(606+k,928) timeyr(j), TavGRIPinv(k,j)
      else
        crate= ( (TavGRIPinv(k,j)-TavGRIPinv(k,jtag))
@       /TavGRIPinv(k,jtag) ) *100.

        if(abs(crate) .ge. prntfac) then
          write(606+k,928) timeyr(j), TavGRIPinv(k,j)
          jtag = j
        end if

      end if

    end do
  end if
  close(606+k)

```

c.....Average Invert RH

```

  write (*,*) 'Writing RHinvert value file for RIP'

  read(3,'(a)') resultsbinfile7(k)

  open(706-k,file=resultsbinfile7(k),status='new')

  write(706-k,76)
  write(706-k,7) resultsbinfile7(k)
  write(706-k,13) facttb(k)
  write(706-k,14) outfile(k)

```

```

if (noent(k) .ne. 0) then
  write(706-k,*) 'No Entries for this Bin'
else
  do j = 1,npts
  if ( j .eq. 1 ) then
    write(706-k,928) timeyr(j), RHavgRIPin(k,j)
    jtag = j
  else if (j .eq. npts) then
    write(706-k,928) timeyr(j), RHavgRIPin(k,j)
  else
    crate= ( (RHavgRIPin(k,j)-RHavgRIPin(k,jtag))
@    /RHavgRIPin(k,jtag) ) *100.

    if(abs(crate) .ge. prntfac) then
      write(706-k,928) timeyr(j), RHavgRIPin(k,j)
      jtag = j
    end if
  end if
end do
end if
close(706-k)

```

c.....Average Invert evaporation rate

```

write (*,*) 'Writing Q_evapinvert value file for RIP'
read(3,'(a)') resultsbinfile8(k)
open(706+k,file=resultsbinfile8(k),status='new')
write(706+k,77)
write(706+k,7) resultsbinfile8(k)
write(706+k,13) facttb(k)
write(706+k,14) outfile(k)

if (noent(k) .ne. 0) then
  write(706+k,*) 'No Entries for this Bin'
else
  do j = 1,npts
  if ( j .eq. 1 ) then
    qvpavgRIPinv(k,j)=-99.9

    write(706+k,928) timeyr(j), qvpavgRIPinv(k,j)
    jtag = j

  else if (j .eq. npts) then
    write(706+k,928) timeyr(j), qvpavgRIPinv(k,j)/rho
  else
    if (qvpavgRIPinv(k,j)/rho .eq. 0.) then
      if ( qvpavgRIPinv(k,j) .eq. -99.9) then
        write(706+k,928) timeyr(j), qvpavgRIPinv(k,j)
        imark0 = j
      else
        write(706+k,928) timeyr(j), qvpavgRIPinv(k,j)/rho
        imark0 = j
      endif
    endif
  end if
end do

```

```

else
    chl = (qvpavgRIPinv(k,jtag)/rho)
    if(chl .eq. 0.) then
        if ( qvpavgRIPinv(k,j) .eq. -99.9) then
            write(706+k,928) timeyr(j),qvpavgRIPinv(k,j)
            jtag=j
            goto 83
        else
            write(706+k,928) timeyr(j),qvpavgRIPinv(k,j)/rho
            jtag=j
            goto 83
        endif
    endif

    crate= ( (qvpavgRIPinv(k,j)/rho-qvpavgRIPinv(k,jtag)/rho)
@    /((qvpavgRIPinv(k,jtag)/rho) ) *100.

    if(abs(crate) .ge. prntfac .or. j-1 .eq.
@    imark0) then
        if ( qvpavgRIPinv(k,j) .eq. -99.9) then
            write(706+k,928) timeyr(j), qvpavgRIPinv(k,j)
            jtag = j
        else
            write(706+k,928) timeyr(j), qvpavgRIPinv(k,j)/rho
            jtag = j
        endif
    end if
83    endif
    end do
    end if

    close(706+k)

c
c.....Average DS Temperature

    write (*,*) 'Writing T DS average value file for RIP'
    read(3,'(a)') resultsbinfile9(k)
    open(750-k,file=resultsbinfile9(k),status='new')
    write(750-k,80)
    write(750-k,7) resultsbinfile9(k)
    write(750-k,13) facttb(k)
    write(750-k,14) outfile(k)

    if (noent(k) .ne. 0) then
        write(750-k,*) 'No Entries for this Bin'
    else
        do j = 1,npts
            if ( j .eq. 1 ) then
                write(750-k,928) timeyr(j), TavgrIPdstop(k,j)
                jtag = j
            else if (j .eq. npts) then
                write(750-k,928) timeyr(j), TavgrIPdstop(k,j)
            else

```

```

        crate= ( (TavgRIPdstop(k,j)-TavgRIPdstop(k,jtag))
@ /TavgRIPdstop(k,jtag) ) *100.

        if(abs(crate) .ge. prntfac) then
            write(750-k,928) timeyr(j), TavgRIPdstop(k,j)
            jtag = j
            end if

    end if

    end do
    end if

    close(750-k)

c23456789012345678901234567890123456789012345678901234567890123456789012
c.....Average Qperc.liq in the invert

    write (*,*) 'Writing Qperc_inv average value file for RIP'
    read(3,'(a)') resultsbinfile10(k)
    open(750+k,file=resultsbinfile10(k),status='new')
    write(750+k,91)
    write(750+k,7) resultsbinfile10(k)
    write(750+k,13) facttb(k)
    write(750+k,14) outfile(k)

    if (noent(k) .ne. 0) then
        write(750+k,*) 'No Entries for this Bin'
    else

        do j = 1,npts
            if (j .eq. 1) then
                write(750+k,928) timeyr(j), ql_invavgRIP(k,j)*(a_inv/1000.)
                jtag = j
            else if (j .eq. npts) then
                write(750+k,928) timeyr(j), ql_invavgRIP(k,j)*(a_inv/1000.)
            else

                if (ql_invavgRIP(k,j) .eq. 0.) then
                    write(750+k,928) timeyr(j), ql_invavgRIP(k,j)
@                    *(a_inv/1000.)
                    imark0=j
                else

                    chl = ql_invavgRIP(k,jtag)
                    if(chl .eq. 0.) then
                        write(750+k,928) timeyr(j), ql_invavgRIP(k,j)
@                        *(a_inv/1000.)
                        jtag=j
                        goto 66
                    endif
c23456789012345678901234567890123456789012345678901234567890123456789012
                    crate= ( (ql_invavgRIP(k,j)-ql_invavgRIP(k,jtag))/
@ ql_invavgRIP(k,jtag) ) *100.

                    if(abs(crate) .ge. prntfac .or.
@                     j-1 .eq. imark0) then
                        write(750+k,928) timeyr(j), ql_invavgRIP(k,j)
@                     *(a_inv/1000.)
                        jtag = j
                        end if
66                endif
            end if

            end do
            end if
            close(750+k)

```

```

        end do
c
c
c....All averages have been computed for RIP
c
c
c      This is an averaged value that disregards the directionality
c      given in the raw data for the invert flux.  It has been requested
c      by the THC TSPA model
c

        do k = 1, ninf

c23456789012345678901234567890123456789012345678901234567890123456789012

c.....Average ABS(Qperc.liq) in the invert

        write (*,*) 'Writing ABS(Qperc_inv) average value file for RIP'
        read(3,'(a)') resultsbinfile11(k)
        open(850-k,file=resultsbinfile11(k),status='new')
        write(850-k,92)
        write(850-k,7) resultsbinfile11(k)
        write(850-k,13) facttb(k)
        write(850-k,14) outfile(k)

        if (noent(k) .ne. 0) then
            write(850-k,*) 'No Entries for this Bin'
        else

            do j = 1,npts
            if (j .eq. 1) then
                write(850-k,928) timeyr(j), ql_invavgabs(k,j)*(a_inv/1000.)
                jtag = j
            else if (j .eq. npts) then
                write(850-k,928) timeyr(j), ql_invavgabs(k,j)*(a_inv/1000.)
            else

                if (ql_invavgabs(k,j) .eq. 0.) then
                    write(850-k,928) timeyr(j), ql_invavgabs(k,j)
@                *(a_inv/1000.)
                    imark0=j
                else

                    chl = ql_invavgabs(k,jtag)
                    if(chl .eq. 0.) then
                        write(850-k,928) timeyr(j), ql_invavgabs(k,j)
@                *(a_inv/1000.)
                        jtag=j
                        goto 67
                    endif
c23456789012345678901234567890123456789012345678901234567890123456789012
                    crate= ( (ql_invavgabs(k,j)-ql_invavgabs(k,jtag))/
@ ql_invavgabs(k,jtag) ) *100.

                    if(abs(crate) .ge. prntfac .or.
@                j-1 .eq. imark0) then
                        write(850-k,928) timeyr(j), ql_invavgabs(k,j)
@                *(a_inv/1000.)
                        jtag = j
                        end if
67                endif
                end if

            end do
            end if
            close(850-k)

        enddo

        close(3)

```

stop  
end

## Test Case

The test case for this routine is described as the following. Using an older set of process-level multiscale TH model results, a test case was specified using a subset of the location dependent results. The test case for **TH-msmabs\_ver\_1** utilized a small subset of the process-level location dependent results with enough infiltration rate variability to fill a number of predefined infiltration rate bins. The five infiltration rate bins predefined for this test case were arbitrarily selected to be:

- 0-5 mm/yr
- 5-20 mm/yr
- 20-50 mm/yr
- 50-100 mm/yr
- > 100 mm/yr

So, with the number of bins ( $n_{inf}=5$ ) and their ranges now specified, the first general step, 1) described above, has been completed in this test case. Now, specifics regarding the input files must be provided to the routine so that it can perform its functions. The abstraction routine is tested using a precursor set of data. The precursor data set is not used in the TH abstraction described in this AMR; it is used to ensure that this abstraction routine (TH-msmabs\_ver\_1) identifies, sorts, reformats, and computes averages as intended for the eventual application to the working TH abstraction (input files names and DTNs given in Table 2 Section 4 of the AMR). The precursor data set is in the exact format as the actual data set used as input to the abstraction routine and can subsequently be used in this testing capacity. Since this data set is intended as test data and is not actually used for abstraction purposes, this data is not treated as controlled data and is used (and documented) herein to demonstrate the correct usage of this one-time use software routine. The 19 testing raw input file names are the following:

```
csnf_x11_y23_data
csnf_x10_y10_data
csnf_x10_y25_data
csnf_x11_y13_data
csnf_x11_y3_data
csnf_x11_y31_data
csnf_x12_y13_data
csnf_x14_y21_data
csnf_x14_y25_data
csnf_x16_y12_data
csnf_x23_y14_data
csnf_x23_y24_data
csnf_x23_y25_data
csnf_x24_y24_data
csnf_x25_y13_data
csnf_x25_y25_data
csnf_x6_y22_data
```

csnf\_x8\_y18\_data  
csnf\_x9\_y25\_data

These filenames provide the raw data for the TH abstraction routine. The general step 2) described above is now complete. The input files are specified and ready to be sorted by the routine into the predefined infiltration rate bins. Note that the infiltration rate given in the input files above corresponds to the infiltration rate for the glacial-transition infiltration flux map. These 19 files as well as the ranges of the infiltration bins were selected so that one bin (>100) would be empty and the others would contain several waste package locations. Computer generated results for this range of inputs is given in terms of excerpts of the header information (printed directly from the test case input files) as the following (note: excerpts only are shown due to the size of the input test files):

From the 19 input files:

**file: csnf\_x10\_y10\_data**

data file creation date: Fri Nov 12 03:15:23 1999  
MSTHM version: MSTHM\_rev\_6.0  
base EXTfile creation date: Fri Nov 12 02:30:06 1999

Type:  
average WP type: bwr1

Location:  
easting (NV central): 170794.14  
northing (NV central): 232027.50

Area:  
fraction of repository area  
represented by cell 10,10 = 0.002370

Infiltration:  
cell 10,10 infiltration: 38.281521 (mm/yr)

**file: csnf\_x10\_y25\_data**

data file creation date: Fri Nov 12 03:15:23 1999  
MSTHM version: MSTHM\_rev\_6.0  
base EXTfile creation date: Fri Nov 12 02:30:06 1999

Type:  
average WP type: bwr1

Location:  
easting (NV central): 173259.67  
northing (NV central): 232158.33

Area:  
fraction of repository area  
represented by cell 10,25 = 0.002370

Infiltration:  
cell 10,25 infiltration: 58.710880 (mm/yr)

**file: csnf\_x11\_y13\_data**

data file creation date: Fri Nov 12 03:15:23 1999  
MSTHM version: MSTHM\_rev\_6.0



base EXTfile creation date: Fri Nov 12 02:30:06 1999

Type:  
average WP type: bwr1  
  
Location:  
easting (NV central): 171284.59  
northing (NV central): 232103.59

Area:  
fraction of repository area  
represented by cell 11,13 = 0.001471

Infiltration:  
cell 11,13 infiltration: 45.176048 (mm/yr)

**file: csnf\_x11\_y23\_data**

data file creation date: Fri Nov 12 03:15:23 1999  
MSTHM version: MSTHM\_rev\_6.0  
base EXTfile creation date: Fri Nov 12 02:30:06 1999

Type:  
average WP type: bwr1

Location:  
easting (NV central): 172928.28  
northing (NV central): 232190.81

Area:  
fraction of repository area  
represented by cell 11,23 = 0.001471

Infiltration:  
cell 11,23 infiltration: 58.402111 (mm/yr)

**file: csnf\_x11\_y3\_data**

data file creation date: Fri Nov 12 03:15:23 1999  
MSTHM version: MSTHM\_rev\_6.0  
base EXTfile creation date: Fri Nov 12 02:30:06 1999

Type:  
average WP type: bwr1

Location:  
easting (NV central): 170074.80  
northing (NV central): 232039.39

Area:  
fraction of repository area  
represented by cell 11,3 = 0.000736

Infiltration:  
cell 11, 3 infiltration: 10.243590 (mm/yr)

**file: csnf\_x11\_y31\_data**

data file creation date: Fri Nov 12 03:15:23 1999  
MSTHM version: MSTHM\_rev\_6.0  
base EXTfile creation date: Fri Nov 12 02:30:06 1999

Type:  
average WP type: bwr1

Location:  
easting (NV central): 174094.34  
northing (NV central): 232252.69

Area:  
fraction of repository area  
represented by cell 11,31 = 0.000736

Infiltration:  
cell 11,31 infiltration: 23.503290 (mm/yr)

**file: csnf\_x12\_y13\_data**

data file creation date: Fri Nov 12 03:15:23 1999  
MSTHM version: MSTHM\_rev\_6.0  
base EXTfile creation date: Fri Nov 12 02:30:06 1999

Type:  
average WP type: pwr1

Location:  
easting (NV central): 171281.95  
northing (NV central): 232153.52

Area:  
fraction of repository area  
represented by cell 12,13 = 0.002370

Infiltration:  
cell 12,13 infiltration: 43.338348 (mm/yr)

**file: csnf\_x14\_y21\_data**

data file creation date: Fri Nov 12 03:15:23 1999  
MSTHM version: MSTHM\_rev\_6.0  
base EXTfile creation date: Fri Nov 12 02:30:06 1999

Type:  
average WP type: pwr1

Location:  
easting (NV central): 172591.59  
northing (NV central): 232323.16

Area:  
fraction of repository area  
represented by cell 14,21 = 0.002370

Infiltration:  
cell 14,21 infiltration: 18.467110 (mm/yr)

**file: csnf\_x14\_y25\_data**

data file creation date: Fri Nov 12 03:15:23 1999  
MSTHM version: MSTHM\_rev\_6.0  
base EXTfile creation date: Fri Nov 12 02:30:06 1999

Type:  
average WP type: bwr1

Location:  
easting (NV central): 173249.08  
northing (NV central): 232358.05

Area:  
fraction of repository area  
represented by cell 14,25 = 0.002370

Infiltration:  
cell 14,25 infiltration: 55.427521 (mm/yr)

**file: csnf\_x16\_y12\_data**

data file creation date: Fri Nov 12 03:15:23 1999  
MSTHM version: MSTHM\_rev\_6.0  
base EXTfile creation date: Fri Nov 12 02:30:06 1999

Type:

average WP type: pwr1

Location:  
easting (NV central): 171106.98  
northing (NV central): 232344.52

Area:  
fraction of repository area  
represented by cell 16,12 = 0.001802

Infiltration:  
cell 16,12 infiltration: 26.987841 (mm/yr)

**file: csnf\_x23\_y14\_data**

data file creation date: Fri Nov 12 03:15:23 1999  
MSTHM version: MSTHM\_rev\_6.0  
base EXTfile creation date: Fri Nov 12 02:30:06 1999

Type:  
average WP type: pwr1

Location:  
easting (NV central): 171410.23  
northing (NV central): 232842.34

Area:  
fraction of repository area  
represented by cell 23,14 = 0.001153

Infiltration:  
cell 23,14 infiltration: 5.818380 (mm/yr)

**file: csnf\_x23\_y24\_data**

data file creation date: Fri Nov 12 03:15:23 1999  
MSTHM version: MSTHM\_rev\_6.0  
base EXTfile creation date: Fri Nov 12 02:30:06 1999

Type:  
average WP type: pwr1

Location:  
easting (NV central): 173053.92  
northing (NV central): 232929.56

Area:  
fraction of repository area  
represented by cell 23,24 = 0.001153

Infiltration:  
cell 23,24 infiltration: 4.026520 (mm/yr)

**file: csnf\_x23\_y25\_data**

data file creation date: Fri Nov 12 03:15:23 1999  
MSTHM version: MSTHM\_rev\_6.0  
base EXTfile creation date: Fri Nov 12 02:30:06 1999

Type:  
average WP type: pwr1

Location:  
easting (NV central): 173218.28  
northing (NV central): 232938.28

Area:  
fraction of repository area  
represented by cell 23,25 = 0.001153

Infiltration:  
cell 23,25 infiltration: 4.168559 (mm/yr)

**file: csnf\_x24\_y24\_data**

data file creation date: Fri Nov 12 03:15:23 1999  
MSTHM version: MSTHM\_rev\_6.0  
base EXTfile creation date: Fri Nov 12 02:30:06 1999

Type:  
average WP type: pwr1

Location:  
easting (NV central): 173052.33  
northing (NV central): 232959.52

Area:  
fraction of repository area  
represented by cell 24,24 = 0.000960

Infiltration:  
cell 24,24 infiltration: 3.302886 (mm/yr)

**file: csnf\_x25\_y13\_data**

data file creation date: Fri Nov 12 03:15:23 1999  
MSTHM version: MSTHM\_rev\_6.0  
base EXTfile creation date: Fri Nov 12 02:30:06 1999

Type:  
average WP type: pwr1

Location:  
easting (NV central): 171242.81  
northing (NV central): 232891.03

Area:  
fraction of repository area  
represented by cell 25,13 = 0.000576

Infiltration:  
cell 25,13 infiltration: 4.223064 (mm/yr)

**file: csnf\_x25\_y25\_data**

data file creation date: Fri Nov 12 03:15:23 1999  
MSTHM version: MSTHM\_rev\_6.0  
base EXTfile creation date: Fri Nov 12 02:30:06 1999

Type:  
average WP type: pwr1

Location:  
easting (NV central): 173215.23  
northing (NV central): 232995.70

Area:  
fraction of repository area  
represented by cell 25,25 = 0.000576

Infiltration:  
cell 25,25 infiltration: 3.046576 (mm/yr)

**file: csnf\_x6\_y22\_data**

data file creation date: Fri Nov 12 03:15:23 1999  
MSTHM version: MSTHM\_rev\_6.0  
base EXTfile creation date: Fri Nov 12 02:30:06 1999

Type:  
average WP type: bwr1

Location:  
easting (NV central): 172771.86

```

northing (NV central):      232032.30

Area:
fraction of repository area
represented by cell 6,22 =      0.000576

Infiltration:
cell 6,22 infiltration:      59.383259      (mm/yr)

file:      csnf_x8_y18_data

data file creation date:      Fri Nov 12 03:15:23 1999
MSTHM version:      MSTHM_rev_6.0
base EXTfile creation date:      Fri Nov 12 02:30:06 1999

Type:
average WP type:      pwr1

Location:
easting (NV central):      172112.00
northing (NV central):      232042.34

Area:
fraction of repository area
represented by cell 8,18 =      0.000960

Infiltration:
cell 8,18 infiltration:      30.672880      (mm/yr)

file:      csnf_x9_y25_data

data file creation date:      Fri Nov 12 03:15:23 1999
MSTHM version:      MSTHM_rev_6.0
base EXTfile creation date:      Fri Nov 12 02:30:06 1999

Type:
average WP type:      bwr1

Location:
easting (NV central):      173261.34
northing (NV central):      232126.72

Area:
fraction of repository area
represented by cell 9,25 =      0.001471

Infiltration:
cell 9,25 infiltration:      58.489750      (mm/yr)

```

The infiltration bin constituents (sorted by the routine) resulted in the following bin specifications and can be easily verified by referring to the header information for the infiltration rate (last line in the header as shown above) for each of the 19 file names given above. The routine output results in the following infiltration bin sort within each of the 5 predefined infiltration bins as a basis.

Routine generated output that specifies where the input files (19 total for the test case) reside within a particular infiltration bin:

```

5.0 > qinf > 0.0 mm/yr
csnf_x23_y24_data
csnf_x23_y25_data
csnf_x24_y24_data
csnf_x25_y13_data
csnf_x25_y25_data

```

```

20.0 > qinf > 5.0 mm/yr
csnf_x11_y3_data
csnf_x14_y21_data
csnf_x23_y14_data

50.0 > qinf > 20.0 mm/yr
csnf_x10_y10_data
csnf_x11_y13_data
csnf_x11_y31_data
csnf_x12_y13_data
csnf_x16_y12_data
csnf_x8_y18_data

100.0 > qinf > 50.0 mm/yr
csnf_x10_y25_data
csnf_x11_y23_data
csnf_x14_y25_data
csnf_x6_y22_data
csnf_x9_y25_data

qinf > 100.0 mm/yr
no entries

```

Reference to the above header information excerpts and the bin sort information from the routine indicates that the routine performed a correct infiltration bin sort. To verify that the routine was averaging the files correctly, the contents of the 5-20 mm/yr bin were analyzed since it contained only three entries.

Computer generated results for this range of testing inputs is given in terms of excerpts of input information (printed directly from the test case input files) as the following (note: excerpts only are shown due to the size of the input test files).

Step 3) of the general steps listed above is tested using the following computer generated inputs/outputs along with the sample hand calculations. The maximum and minimum peak waste package temperatures for an infiltration bin have been determined by the abstraction routine. The raw input file excerpts (from csnf\_x11\_y3\_data, csnf\_x14\_y21\_data, and csnf\_x23\_y14\_data) are the following where the waste package temperature is the seventh entry on each line of data.

Excerpt from the input file named: csnf\_x11\_y3\_data

time	T_dw	T_5m	T_bfpeak	T_ds	T_ds_top	T_wp	T_invert	T_dw_lower
5.020000e+01	1.079079e+02	5.946280e+01	9.495312e+01	1.933456e+02	2.100566e+02			
	1.990075e+02	1.865332e+02	1.305814e+02					
5.100000e+01	1.265991e+02	6.663611e+01	1.076963e+02	2.263057e+02	2.508282e+02			
	2.309583e+02	2.247124e+02	1.656196e+02					
5.200000e+01	1.374631e+02	7.230843e+01	1.144087e+02	2.375682e+02	2.604502e+02			
	2.419210e+02	2.363690e+02	1.792419e+02					
5.300000e+01	1.429321e+02	7.630112e+01	1.180446e+02	2.422036e+02	2.630546e+02			
	2.463977e+02	2.403818e+02	1.851753e+02					
5.500000e+01	1.481243e+02	8.066521e+01	1.214946e+02	2.450592e+02	2.642318e+02			
	<b>2.490645e+02</b>	2.430757e+02	1.901798e+02					
6.000000e+01	1.473233e+02	8.753497e+01	1.275821e+02	2.383133e+02	2.361833e+02			
	2.420897e+02	2.198097e+02	1.792415e+02					
6.500000e+01	1.362480e+02	8.510767e+01	1.199244e+02	2.216802e+02	2.106310e+02			
	2.253286e+02	1.968262e+02	1.628184e+02					
7.000000e+01	1.231383e+02	8.088477e+01	1.095362e+02	2.036236e+02	1.850576e+02			
	<b>2.071774e+02</b>	1.735592e+02						

Excerpt from the input file named: csnf\_x14\_y21\_data

time	T_dw	T_5m	T_bfpeak	T_ds	T_ds_top	T_wp	T_invert	T_dw_lower
------	------	------	----------	------	----------	------	----------	------------

5.020000e+01	8.434234e+01	5.893561e+01	7.837916e+01	1.858008e+02	1.535886e+02
	1.927077e+02	1.344603e+02	9.657288e+01		
5.100000e+01	1.079077e+02	6.157022e+01	9.625459e+01	2.218336e+02	2.160703e+02
	2.275257e+02	1.903096e+02	1.333903e+02		
5.200000e+01	1.227583e+02	6.590492e+01	1.054143e+02	2.365033e+02	2.444548e+02
	2.418567e+02	2.180495e+02	1.587123e+02		
5.300000e+01	1.313680e+02	6.975902e+01	1.106904e+02	2.439642e+02	2.562992e+02
	2.491412e+02	2.306773e+02	1.718645e+02		
5.500000e+01	1.413509e+02	7.548883e+01	1.169717e+02	2.512053e+02	2.643777e+02
	2.561747e+02	2.408007e+02	1.840303e+02		
6.000000e+01	1.521632e+02	8.360072e+01	1.255995e+02	2.554626e+02	2.680487e+02
	<b>2.601839e+02</b>	2.470273e+02	1.943517e+02		
6.500000e+01	1.568559e+02	8.838988e+01	1.322779e+02	2.541520e+02	2.648200e+02
	2.587371e+02	2.452089e+02	1.961259e+02		
7.000000e+01	1.586102e+02	9.053515e+01	1.345224e+02	2.506727e+02	2.599013e+02
	<b>2.551649e+02</b>	2.413101e+02	1.948222e+02		

Excerpt from the input file named: csnf\_x23\_y14\_data

time	T_dw	T_5m	T_bfpeak	T_ds	T_ds_top	T_wp	T_invert	T_dw_lower
5.020000e+01	1.115959e+02	6.142118e+01	9.766385e+01	2.130544e+02	2.225866e+02			
	2.199612e+02	1.958969e+02	1.386458e+02					
5.100000e+01	1.247149e+02	6.767982e+01	1.061320e+02	2.386408e+02	2.460411e+02			
	2.443329e+02	2.181769e+02	1.609650e+02					
5.200000e+01	1.342640e+02	7.332985e+01	1.125285e+02	2.480090e+02	2.538714e+02			
	2.533624e+02	2.282049e+02	1.734821e+02					
5.300000e+01	1.392271e+02	7.740089e+01	1.162857e+02	2.518232e+02	2.551589e+02			
	2.570002e+02	2.309404e+02	1.783068e+02					
5.500000e+01	1.448649e+02	8.281490e+01	1.210741e+02	2.547192e+02	2.545706e+02			
	<b>2.596887e+02</b>	2.323590e+02	1.829909e+02					
6.000000e+01	1.460401e+02	8.458882e+01	1.224996e+02	2.493394e+02	2.527710e+02			
	2.540608e+02	2.312749e+02	1.833191e+02					
6.500000e+01	1.410488e+02	9.031780e+01	1.239312e+02	2.383449e+02	2.209467e+02			
	2.429300e+02	2.046711e+02	1.686650e+02					
7.000000e+01	1.343912e+02	9.113138e+01	1.204031e+02	2.264538e+02	2.007162e+02			
	<b>2.309459e+02</b>	1.871023e+02	1.571478e+02					

The numbers in regular bold above are checked against excerpts from the software routine as generated evidence of the programmed algorithms for data from max and min waste package surface temperature in bold below for the same selected time:

The excerpt from the routine generated bin maximum temperature file is:

```

50.20, 0.192708E+03
51.00, 0.227526E+03
52.00, 0.241857E+03
53.00, 0.249141E+03
55.00, 0.256175E+03
60.00, 0.260184E+03
65.00, 0.258737E+03
70.00, 0.255165E+03

```

The excerpt from the routine generated bin minimum temperature file is:

```

50.20, 0.199007E+03
51.00, 0.230958E+03
52.00, 0.241921E+03
53.00, 0.246398E+03
55.00, 0.249065E+03
60.00, 0.242090E+03
65.00, 0.225329E+03
70.00, 0.207177E+03

```

The routine is making the correct evaluation of the maximum and minimum peak waste package

surface temperature as shown in the test case. The averaging process is also checked for each of the variables passed to the TSPA model. For convenience (refer to values in bold italics above), the average calculated value of the waste package surface temperature at 70 years was checked. The fraction of repository area corresponding to each waste package location file can be found in the header of the data file given above. The average is calculated as (refer to equation 2):

$$T_{avg} = \frac{0.000736}{0.004259}(207.1774) + \frac{0.00237}{0.004259}(255.1649) + \frac{0.001153}{0.004259}(230.9459) = 240.316$$

It is compared to the routine average value for the temperature of the waste package:

```
50.20, 0.201174E+03
51.00, 0.232669E+03
52.00, 0.244983E+03
53.00, 0.250795E+03
55.00, 0.255897E+03
60.00, 0.255399E+03
65.00, 0.248684E+03
70.00, 0.240316E+03
```

Again, the TH abstraction routine correctly performs its task. Although not shown here, each of the remaining TSPA averaged values given in Table 4 (in Section 6.1) have been spot checked at different times for this arbitrary infiltration bin. All of the averages have been calculated correctly by the TH abstraction routine. Additionally, the raw value files used in the TSPA model have also been spot checked at different times for every variable passed (see Table 3 in Section 6.1) and have been found to be completely correct.

## Ranges of Validity

The range of input parameter values for which this software routine is valid is dictated by the parameter statement given in the routine itself. Version 1.0 parameter statement is the following:

```
parameter(npts=352, ninf=5, nbinm=650) ---for the mean flux case or,
parameter(npts=442, ninf=5, nbinm=650) ---for the low flux case or,
parameter(npts=457, ninf=5, nbinm=650) ---for the high flux case.
```

This statement in the TH abstraction routine indicates that (ninf=5) bins are processed for (npts=352, 442, or 457) different time entries for each large block of data (refer to an input file). The maximum total number of location dependent (input) files that can be read in by this routine is (nbinm=650). The process model gives 623 location dependent result files (which is less than 650) so this statement is valid as specified. Although this routine uses one of the statements indicated above, the software routine is completely flexible. The parameter statement numbers (npts, ninf, and nbinm) can all be changed to any value needed and re-compiled (in SUN OS FORTRAN 77) for complete software routine flexibility. Changes to the parameter statement do not require any changes to lines of code within the routine. However, if the parameter value for ninf changes, the input file required by the abstraction routine to read in the file names for the abstraction output must be modified by



the user. If *ninf* is either increased or decreased, the total number of filenames (provided by the user in the input file called: THabstraction.fil) needed to write the output data for TSPA will change according to the following line in the abstraction routine:

$$\text{ifiles} = \text{ninf} + 1 + 3 * \text{ninf} + 11 * \text{ninf}$$

where *ifiles* are the total number of filenames required in the first input file (THabstraction.fil) used to run the TH abstraction routine. A second input file required to run the TH abstraction routine contains the names of the location dependent results from the process model. As indicated for the no backfill repository design, this routine required input file contains the individual filenames for 623 different location dependent result files. The input file format for the routine must have a portion of the name of the input file (e.g., *csnfmean*) on the first line and the word *end* on the last line (with 623 location dependent filenames in-between). Finally, 623 location dependent files must be available for input to the routine. Each file contains the process model raw data given in blocks of specific data (e.g., a temperature block containing the temperature results of different repository components).

## Attachment II TH Abstraction Routine (pillart)

This attachment contains documentation of the hand-check to demonstrate that the Routine **pillart** versions 1.00 through 1.04 work correctly. This routine was written in Fortran 77 and reads all 600+ waste package files and searches for the peak pillar temperature at two locations that are closest to the quarter pillar locations. Quarter-pillar temperatures that are lower than the local boiling temperature implies that over half of the pillar remains sub-boiling and therefore will always allow, if available, liquid to drain through fractures in the pillars. The output file contains the following variables: the waste package name, the easting (m) location, the northing (m) location, the time for peak temperature at 15.14 m (years), the peak pillar temperature (°C) at X = 15.14 m, the time for peak temperature at 22.64 m (years), and the peak pillar temperature (°C) at X = 22.64 m. The four versions of this routine were written for use on the low infiltration flux backfill case (version 1.00), the mean infiltration flux no-backfill case (version 1.02), the low infiltration flux no-backfill case (version 1.03), and the high infiltration no-backfill flux case (version 1.04).

For version 1.00 of this subroutine to function correctly, the routine must have a file named "csnflow" that contains the locations of all of the 623 waste package files. The name of the output file is "output."

A copy of version 1.00 of this routine can be found in DTN: SN0001T0872799.006 in the Zip file called source\_routines.ZIP. The output file for the CSNF low infiltration flux case can be found in the same DTN in the file called: wptemp\_pillert\_out.ZIP.

A copy of versions 1.02, 1.03, and 1.04 of this routine can be found in DTN: SN0007T0872799.014 in the Zip file called pillart.ZIP. The output file for the CSNF low infiltration flux case can be found in the same DTN in the file called: pillart.ZIP.

```

c2345678901234567890123456789012345678901234567890123456789012
c....This routine pulls the maximum temperature from the pillars
c   from the output files.
c
c   MT Itamura 1/10/00
c
c   pillart version 1.00 for low infiltration rate files
c
c....Nomenclature for this processor
c   timeyr --time in years as taken from the multiscale results
c   temp(8)--eight pillar 3emps going from 2.99m, 3.69m, 4.89m,
c           6.89 m, 10.14m, 15.14m, 22.64, 33.82m.
c   time15 --time in years for the max temp at 15.14 meters
c   time23 --time in years for the max temp at 22.14 meters
c
c   implicit double precision (a-h,l,o-z)
c   character*4 name
c   character*10 text10
c   character*80 infile1
c
c2345678901234567890123456789012345678901234567890123456789012
c
c       real *8 temp(8)
c
c
c..... open the file containing the THSM file names and the
c       output files
c

```

```

        open(3,file='csnflow', status='old')
        read(3,*)
        open(4,file='output',status='new')
c
c..... start main loop
c
50      read(3,'(a)') infile1
        if (infile1 .eq. 'end') goto 100
        open(5,file=infile1,status='old')
40      read(5,10) name
c
c..... isolate coordinate locations
c
10      format (a4)
        if(name .ne. 'Loca') goto 40
        read(5,20) coord1
        read(5,20) coord2
20      format(23x,f9.2)
c
c..... Search files for Pillar Temps
c
60      read(5,30) text10
        if(text10 .ne. 'T_pillar_x') goto 60
30      format(5x,A10)
c
c..... Loop to find the maximum pillar temps.
c
        tmax15 = 0.
        tmax23 = 0.
        do I = 1,442
            read(5,*) timeyr, (temp(J),J=1,8)
            if (temp(6) .ge. tmax15) then
                tmax15 = temp(6)
                time15 = timeyr
            endif
            if (temp(7) .ge. tmax23) then
                tmax23 = temp(7)
                time23 = timeyr
            endif
        end do
        close (5)
c
c..... print out the name/location of WP and Pill Temps
c
        if(infile1(11:12) .eq. '_d') infile1(11:12)=' '
        if(infile1(12:12) .eq. '_') infile1(12:12)=' '
        write (4,80) infile1(6:12),coord1,coord2,time15,
&          tmax15,time23,tmax23
80      format(A7,3x,6F12.3)
        goto 50
100     continue
        close (4)
        stop
        end

```

To verify that the **pillart** v 1.00 was working properly, the maximum temperature in several files were checked against the contents of the output files. Due to the length of the thermal hydrology multi-scale files, only a few lines out of a one output file will be presented here. The routine works by first searching for the section that contains the pillar temperatures by searching for the data header line that contains the string "T\_pillar\_x." The routine then loops through the data to find the maximum values at the pillar locations X = 15.14 and 22.64 meters for all of the waste packages.

The following five entries were taken from the pillar section of the file `csnf_x1_y20_data` using the mean infiltration flux map. The first entry is the time in years and the next eight entries correspond to pillar temperatures at eight different locations. The sixth and seventh temperatures correspond

to the locations X = 15.14 and 22.64 meters and the maximum temperatures are highlighted in bold type.

```

5.300000e+01  1.423711e+02  1.351577e+02  1.232342e+02  1.067540e+02  9.005058e+01
7.398631e+01  5.757977e+01  5.576180e+01
5.500000e+01  1.439366e+02  1.372549e+02  1.261465e+02  1.105013e+02  9.341956e+01
7.862854e+01  6.248182e+01  6.050611e+01
6.000000e+01  1.360688e+02  1.308228e+02  1.220843e+02  1.096992e+02  9.490884e+01
8.151456e+01  6.825842e+01  6.646258e+01
6.500000e+01  1.269969e+02  1.226202e+02  1.153304e+02  1.049925e+02  9.254220e+01
8.063892e+01  6.947131e+01  6.795477e+01
7.000000e+01  1.083797e+02  1.053895e+02  1.004097e+02  9.335429e+01  8.481591e+01
7.618452e+01  6.836872e+01  6.734280e+01
8.000000e+01  9.532781e+01  9.326108e+01  8.982748e+01  8.497298e+01  7.909160e+01
7.300096e+01  6.749231e+01  6.681044e+01
9.000000e+01  9.172752e+01  8.993189e+01  8.694819e+01  8.272629e+01  7.760643e+01
7.227520e+01  6.741820e+01  6.682641e+01

```

An excerpt from routine of output file for the waste package location are presented here to check if the routine is working properly.

```

x1_y20      170208.780  234316.700      60.000      81.515      65.000      69.471

```

Both the time printouts and the maximum pillar temperatures match. Another excerpt from the output file from csnf\_x13\_y31 show that maximum pillar temperatures at 15.14 and 22.64 meters occur at 70 and 120 years, respectively.

```

5.200000e+01  1.213061e+02  1.144523e+02  1.039011e+02  9.307321e+01  7.870619e+01
6.307616e+01  4.973679e+01  4.849637e+01
5.300000e+01  1.272037e+02  1.200079e+02  1.085175e+02  9.624622e+01  8.339574e+01
6.748940e+01  5.299600e+01  5.153705e+01
5.500000e+01  1.321354e+02  1.252082e+02  1.137900e+02  9.939754e+01  8.809335e+01
7.267431e+01  5.774720e+01  5.609202e+01
6.000000e+01  1.331451e+02  1.272544e+02  1.174956e+02  1.039785e+02  9.123426e+01
7.812762e+01  6.472215e+01  6.309930e+01
6.500000e+01  1.255228e+02  1.208164e+02  1.130022e+02  1.020672e+02  9.063167e+01
7.980171e+01  6.899314e+01  6.766010e+01
7.000000e+01  1.151501e+02  1.115701e+02  1.056237e+02  9.730519e+01  8.832446e+01
7.981609e+01  7.160784e+01  7.060218e+01
8.000000e+01  1.005094e+02  9.831336e+01  9.467903e+01  8.972212e+01  8.427147e+01
7.889580e+01  7.391724e+01  7.332684e+01
9.000000e+01  9.728370e+01  9.541467e+01  9.233379e+01  8.818055e+01  8.357285e+01
7.895582e+01  7.468965e+01  7.418692e+01
1.000000e+02  9.559982e+01  9.389543e+01  9.109969e+01  8.734933e+01  8.315911e+01
7.892779e+01  7.501669e+01  7.455741e+01
1.200000e+02  8.990249e+01  8.873103e+01  8.682445e+01  8.425212e+01  8.126514e+01
7.820049e+01  7.535120e+01  7.502020e+01
1.400000e+02  8.769317e+01  8.669902e+01  8.506699e+01  8.286695e+01  8.027061e+01
7.759660e+01  7.510276e+01  7.481392e+01
1.500000e+02  8.534691e+01  8.455280e+01  8.324000e+01  8.138216e+01  7.913449e+01
7.681091e+01  7.463757e+01  7.438668e+01
1.600000e+02  8.475370e+01  8.397767e+01  8.269715e+01  8.091068e+01  7.876307e+01
7.654623e+01  7.447131e+01  7.423197e+01

```

The entry in the output file reflects that both the time and the temperature are being correctly identified by the software routine.

```

x13_y31      170700.530  235815.300      70.000      79.816      120.000      75.351

```

The number of time entries in the output file was checked to verify that there was one entry for each of the 623 waste packages in the output file.

## Routine pillart version 1.02.

This routine is a modification of routine pillart version 1.00. Modifications to the routine were made for use with the no-backfill SR base case mean infiltration flux case thermal-hydrologic simulation results. Pertinent changes were that the location in the pillars where the temperatures are printed out as well as fewer time print statements in the waste package data files. This routine was written in Fortran 77 and reads in the 610 files whose names are listed in the file "csnfmean" and searches for the peak pillar temperature at the same two locations that were printed out in version 1.00 of pillart. The output file contains the following variables: the waste package name, the easting (m) location, the northing (m) location, the time for peak temperature at 15.14 m (years), the peak pillar temperature (°C) at X = 15.14 m, the time for peak temperature at 22.64 m (years), and the peak pillar temperature (°C) at X = 22.64 m.

For this subroutine to function correctly, the routine must have a file named "csnfmean" that contains the locations of all of the 610 waste package files. The name of the output file is "output."

```
c2345678901234567890123456789012345678901234567890123456789012
c....This routine pulls the maximum temperature from the pillars
c   from the output files.
c
c   pillart version 1.02 To be used for TSPA-SR base case without
c   backfill TH simulations. Mean Infiltration Flux case
c
c   MT Itamura 5/4/00
c
c.....Nomenclature for this processor
c   timeyr --time in years as taken from the multiscale results
c   temp(11)--eight pillar temps going from 2.99 m, 3.69 m,
c   4.89 m, 6.89 m, 10.14 m, 10.39 m, 15.14 m, 16.64 m,
c   22.64 m, 24.14 m, 27.68 m
c   time15 --time in years for the max temp at 15.14 meters
c   time23 --time in years for the max temp at 22.64 meters
c
c   implicit double precision (a-h,l,o-z)
c   character*4 name
c   character*10 text10
c   character*80 infile1
c
c2345678901234567890123456789012345678901234567890123456789012
c
c   real *8 temp(11)
c
c..... open the file containing the THSM file names and the
c   output files
c
c   open(3,file='csnfmean', status='old')
c   read(3,*)
c   open(4,file='output',status='new')
c
c..... start main loop
c
c   50   read(3,'(a)') infile1
c       if (infile1 .eq. 'end') goto 100
c       open(5,file=infile1,status='old')
c       40   read(5,10) name
c
c..... isolate coordinate locations
c
c   10   format (a4)
```

```

        if(name .ne. 'Loca') goto 40
        read(5,20) coord1
        read(5,20) coord2
20      format(23x,f9.2)
c
c..... Search files for Pillar Temps
c
60      read(5,30) text10
        if(text10 .ne. 'T_pillar_x') goto 60
30      format(5x,A10)
c
c..... Loop to find the maximum pillar temps.
c
        tmax15 = 0.
        tmax23 = 0.
        do I = 1,90
            read(5,*) timeyr, (temp(J),J=1,11)
            if (temp(7) .ge. tmax15) then
                tmax15 = temp(7)
                time15 = timeyr
            endif
            if (temp(9) .ge. tmax23) then
                tmax23 = temp(9)
                time23 = timeyr
            endif
        end do
        close (5)
c
c..... print out the name/location of WP and Pill Temps
c
        if(infile1(11:12) .eq. '_d') infile1(11:12)=' '
        if(infile1(12:12) .eq. '_') infile1(12:12)=' '
        write (4,80) infile1(6:12),coord1,coord2,time15,
&      tmax15,time23,tmax23
80      format(A7,3x,6F12.3)
        goto 50
100     continue
        close (4)
        stop
        end

```

The data from two waste package locations were extracted from the output file to verify that the routine was working properly. The seven columns of data for the two locations listed below contain, waste package name, easting (m), northing (m), maximum temperature time for 15.14 meter location (year), maximum temperature at 15.14 meters (°C), maximum temperature time for 22.64 meter location (year), and maximum temperature at 22.64 meters (°C).

x1_y20	<b>170208.780</b>	<b>234316.700</b>	<b>65.000</b>	<b>72.645</b>	<b>65.000</b>	<b>63.366</b>
x5_y7	<b>170206.880</b>	<b>232174.000</b>	<b>120.000</b>	<b>81.311</b>	<b>180.000</b>	<b>78.589</b>

The relevant output from mean file for *csnf\_x1\_y20\_data* file is printed out below. The format of the input files changed from those used with version 1.00. Both the number as well as the location of some of the pillar temperatures were changed in the input files. The first column of the no backfill thermal-hydrology results contain the time (years) and the other eleven columns contain the pillar temperatures from closest to farthest from the drift. The seventh and the ninth temperatures listed on each line from the file correspond to those at 15.14 meters and 22.64 meters. The location of the waste package, the peak temperatures, and the time of the peak temperatures are highlighted in bold. For this waste package location, the peak temperatures at both locations occurred at 65 years.

```

easting (NV central):      170208.78
northing (NV central):    234316.72

```

...

```
6.000000e+01  1.284488e+02  1.192540e+02  1.070799e+02  9.443495e+01  8.438648e+01
8.379230e+01  7.250266e+01  7.022507e+01  6.111471e+01  5.926271e+01  5.620727e+01
6.500000e+01  1.171960e+02  1.098333e+02  1.002500e+02  9.103469e+01  8.224245e+01
8.176257e+01  7.264503e+01  7.078925e+01  6.336620e+01  6.185315e+01  5.929710e+01
7.000000e+01  9.364296e+01  8.981226e+01  8.523154e+01  8.025027e+01  7.438319e+01
7.408407e+01  6.840086e+01  6.723656e+01  6.257932e+01  6.162888e+01  6.000687e+01
```

The relevant output from mean file for *csnf\_x5\_y7\_data* file. For this waste package location, the peak temperature at 15.14 meters happened at 120 years and the peak temperature occurred at 22.64 meters at 180 years.

```
easting (NV central):      170206.88
northing (NV central):    232174.02
```

...

```
1.000000e+02  1.022586e+02  9.865234e+01  9.414485e+01  8.998539e+01  8.542740e+01
8.519718e+01  8.082329e+01  7.995560e+01  7.648478e+01  7.599567e+01  7.484426e+01
1.200000e+02  9.607705e+01  9.374869e+01  9.116217e+01  8.813738e+01  8.473774e+01
8.456639e+01  8.131070e+01  8.066432e+01  7.807879e+01  7.771458e+01  7.685720e+01
1.400000e+02  9.278651e+01  9.122458e+01  8.914347e+01  8.665068e+01  8.391667e+01
8.377935e+01  8.117038e+01  8.065275e+01  7.858231e+01  7.829086e+01  7.760480e+01
1.600000e+02  9.203992e+01  9.056227e+01  8.859185e+01  8.622839e+01  8.363226e+01
8.350233e+01  8.103382e+01  8.054396e+01  7.858454e+01  7.830872e+01  7.765939e+01
1.800000e+02  9.223432e+01  9.073529e+01  8.873683e+01  8.634026e+01  8.370890e+01
8.357711e+01  8.107341e+01  8.057657e+01  7.858922e+01  7.830945e+01  7.765085e+01
2.000000e+02  9.061768e+01  8.929012e+01  8.751414e+01  8.537905e+01  8.302695e+01
8.290932e+01  8.067424e+01  8.023141e+01  7.846005e+01  7.821069e+01  7.762370e+01
```

A comparison of the input and output files verified that the routine ran correctly. It was also verified that there were 610 waste package entries in the output file.

### Routine pillart version 1.03.

This routine is a modification of routine pillart version 1.02. Modifications to the routine were made for use with the no-backfill SR base case low infiltration flux thermal-hydrologic simulation results. The only difference between version 1.02 and 1.03 is that the input file that contains the list of waste packages has been changed from "csnfmean" to "csnflow." This routine was written in Fortran 77 and reads in the 610 files whose names are in the file "csnflow" and searches for the peak pillar temperature at the same two locations that were printed out in version 1.00 of pillart. The output file contains the following variables: the waste package name, the easting (m) location, the northing (m) location, the time for peak temperature at 15.14 m (years), the peak pillar temperature (°C) at X = 15.14 m, the time for peak temperature at 22.64 m (years), and the peak pillar temperature (°C) at X = 22.64 m.

For this subroutine to function correctly, the routine must have a file named "csnflow" that contains the locations of all of the 610 waste package files. The name of the output file is "output."

```
c2345678901234567890123456789012345678901234567890123456789012
c....This routine pulls the maximum temperature from the pillars
c   from the output files.
c
c   pillart version 1.03 To be used for TSPA-SR base case without
c   backfill TH simulations. Low Infiltration Flux case
c
c   MT Itamura 5/4/00
c
c....Nomenclature for this processor
c   timeyr --time in years as taken from the multiscale results
c   temp(11)--eight pillar temps going from 2.99 m, 3.69 m,
c   4.89 m, 6.89 m, 10.14 m, 10.39 m, 15.14 m, 16.64 m,
c   22.64 m, 24.14 m, 27.68 m
c   time15 --time in years for the max temp at 15.14 meters
c   time23 --time in years for the max temp at 22.64 meters
c
c   implicit double precision (a-h,i,o-z)
c   character*4 name
c   character*10 text10
c   character*80 infile1
c
c2345678901234567890123456789012345678901234567890123456789012
c
c   real *8 temp(11)
c
c..... open the file containing the THSM file names and the
c   output files
c
c   open(3,file='csnflow', status='old')
c   read(3,*)
c   open(4,file='output',status='new')
c
c..... start main loop
c
c   50   read(3,'(a)') infile1
c       if (infile1 .eq. 'end') goto 100
c       open(5,file=infile1,status='old')
c       40   read(5,10) name
c
c..... isolate coordinate locations
c
c   10   format (a4)
c       if(name .ne. 'Loca') goto 40
c       read(5,20) coord1
c       read(5,20) coord2
c       20   format(23x,f9.2)
c
```



```

c..... Search files for Pillar Temps
c
60      read(5,30) text10
      if(text10 .ne. 'T_pillar_x') goto 60
30      format(5x,A10)
c
c..... Loop to find the maximum pillar temps.
c
      tmax15 = 0.
      tmax23 = 0.
      do I = 1,90
        read(5,*) timeyr,(temp(J),J=1,11)
        if (temp(7) .ge. tmax15) then
          tmax15 = temp(7)
          time15 = timeyr
        endif
        if (temp(9).ge. tmax23) then
          tmax23 = temp(9)
          time23 = timeyr
        endif
      end do
      close (5)
c
c..... print out the name/location of WP and Pill Temps
c
      if(infile1(11:12) .eq. '_d') infile1(11:12)=' '
      if(infile1(12:12) .eq. '_') infile1(12:12)=' '
      write (4,80) infile1(6:12),coord1,coord2,time15,
&      tmax15,time23,tmax23
80      format (A7,3x,6F12.3)
      goto 50
100     continue
      close (4)
      stop
      end

```

Sample output from the output file. The seven data columns for the two locations listed below contain, waste package name, easting (m), northing (m), maximum temperature time for 15.14 meter location (year), maximum temperature at 15.14 meters (°C), maximum temperature time for 22.64 meter location (year), and maximum temperature at 22.64 meters (°C).

x1_y20	170208.780	234316.700	65.000	80.525	65.000	70.369
x5_y7	170206.880	232174.000	120.000	87.297	160.000	84.054

Relevant output from mean file for *csnf\_x1\_y20\_data* file. As was the case for version 1.02, the peak temperatures at 15.14 and 22.64 meters happened at 65 years.

```

easting (NV central):      170208.78
northing (NV central):    234316.72

6.000000e+01  1.440321e+02  1.350913e+02  1.231830e+02  1.088901e+02  9.354680e+01
9.289317e+01  8.047438e+01  7.798280e+01  6.801651e+01  6.595377e+01  6.245416e+01
6.500000e+01  1.329328e+02  1.257123e+02  1.160890e+02  1.045214e+02  9.193641e+01
9.136585e+01  8.052527e+01  7.849394e+01  7.036867e+01  6.868716e+01  6.578288e+01
7.000000e+01  1.095526e+02  1.050044e+02  9.894300e+01  9.166425e+01  8.371171e+01
8.332819e+01  7.604133e+01  7.471141e+01  6.939172e+01  6.832220e+01  6.649298e+01

```

Relevant output from mean file for *csnf\_x5\_y7\_data* file. For this waste package location, the peak temperature at 15.14 meters happened at 120 years and the peak temperature occurred at 22.64 meters at 160 years.

```

easting (NV central):      170206.88
northing (NV central):    232174.02

1.000000e+02  1.125631e+02  1.089888e+02  1.042300e+02  9.853561e+01  9.232269e+01
9.202274e+01  8.632367e+01  8.533723e+01  8.139140e+01  8.087196e+01  7.964918e+01

```

1.200000e+02	1.069188e+02	1.042617e+02	1.007259e+02	9.647899e+01	9.183324e+01
9.160644e+01	8.729730e+01	8.651296e+01	8.337556e+01	8.298386e+01	8.206183e+01
1.400000e+02	1.029511e+02	1.008366e+02	9.801431e+01	9.462112e+01	9.090598e+01
9.072381e+01	8.726270e+01	8.661330e+01	8.401566e+01	8.369394e+01	8.293656e+01
1.600000e+02	1.019998e+02	9.999846e+01	9.732713e+01	9.411515e+01	9.059760e+01
9.042501e+01	8.714551e+01	8.652723e+01	8.405412e+01	8.374662e+01	8.302274e+01
1.800000e+02	1.022442e+02	1.002145e+02	9.750521e+01	9.424767e+01	9.068049e+01
9.050549e+01	8.718028e+01	8.655408e+01	8.404935e+01	8.373827e+01	8.300599e+01

A comparison of the input and output files verified that the routine ran correctly. It was also verified that there were 610 waste package entries in the output file.

## Routine pillart version 1.04.

This routine is a modification of routine pillart version 1.02. Modifications to the routine were made for use with the no-backfill SR base case low infiltration flux thermal-hydrologic simulation results. The only difference between versions 1.02 and 1.04 is that the input file that contains the list of waste packages has been changed from "csnfmean" to "csnfhigh." This routine was written in Fortran 77 and reads in the 610 files whose names are in the file "csnfhigh" and searches for the peak pillar temperature at the same two locations that were printed out in version 1.00 of pillart. Quarter-pillar temperatures that are lower than the local boiling temperature implies that over half of the pillar remains sub-boiling and therefore will always allow, if available, liquid to drain through fractures in the pillars. The output file contains the following variables: the waste package name, the easting (m) location, the northing (m) location, the time for peak temperature at 15.14 m (years), the peak pillar temperature (°C) at X = 15.14 m, the time for peak temperature at 22.64 m (years), and the peak pillar temperature (°C) at X = 22.64 m.

For this subroutine to function correctly, the routine must have a file named "csnfhigh" that contains the locations of all of the 610 waste package files. The name of the output file is "output."

```
c23456789012345678901234567890123456789012345678901234567890123456789012
c.....This routine pulls the maximum temperature from the pillars
c      from the output files.
c
c      pillart version 1.04 To be used for TSPA-SR base case without
c      backfill TH simulations. High Infiltration Flux case
c
c      MT Itamura 5/4/00
c
c.....Nomenclature for this processor
c      timeyr --time in years as taken from the multiscale results
c      temp(11)--eight pillar temps going from 2.99 m, 3.69 m,
c      4.89 m, 6.89 m, 10.14 m, 10.39 m, 15.14 m, 16.64 m,
c      22.64 m, 24.14 m, 27.68 m
c      time15 --time in years for the max temp at 15.14 meters
c      time23 --time in years for the max temp at 22.64 meters
c
c      implicit double precision (a-h,l,o-z)
c      character*4 name
c      character*10 text10
c      character*80 infile1
c
c23456789012345678901234567890123456789012345678901234567890123456789012
c
c      real *8 temp(11)
c
c..... open the file containing the THSM file names and the
c      output files
c
c      open(3,file='csnfhigh', status='old')
c      read(3,*)
c      open(4,file='output',status='new')
c
c..... start main loop
c
c      50      read(3,'(a)') infile1
c              if (infile1 .eq. 'end') goto 100
c              open(5,file=infile1,status='old')
c      40      read(5,10) name
c
c..... isolate coordinate locations
c
c      10      format (a4)
c              if(name .ne. 'Loca') goto 40
c              read(5,20) coord1
```

```

        read(5,20) coord2
20      format(23x,f9.2)
c
c..... Search files for Pillar Temps
c
60      read(5,30) text10
        if(text10 .ne. 'T_pillar_x') goto 60
30      format(5x,A10)
c
c..... Loop to find the maximum pillar temps.
c
        tmax15 = 0.
        tmax23 = 0.
        do I = 1,90
          read(5,*) timeyr, (temp(J),J=1,11)
          if (temp(7) .ge. tmax15) then
            tmax15 = temp(7)
            time15 = timeyr
          endif
          if (temp(9) .ge. tmax23) then
            tmax23 = temp(9)
            time23 = timeyr
          endif
        end do
        close (5)
c
c..... print out the name/location of WP and Pill Temps
c
        if(infile1(11:12) .eq. '_d') infile1(11:12)=' '
        if(infile1(12:12) .eq. '_') infile1(12:12)=' '
        write (4,80) infile1(6:12),coord1,coord2,time15,
&      tmax15,time23,tmax23
80      format(A7,3x,6F12.3)
        goto 50
100     continue
        close (4)
        stop
        end

```

Sample output from the output file. The seven data columns for the two locations listed below contain, waste package name, easting (m), northing (m), peak temperature time for 15.14 meter location (year), peak temperature at 15.14 meters (°C), peak temperature time for 22.64 meter location (year), and peak temperature at 22.64 meters (°C).

x1_y20	170208.780	234316.700	65.000	70.124	65.000	60.960
x5_y7	170206.880	232174.000	120.000	81.006	160.000	78.367

The relevant output from mean file for *csnf\_x1\_y20\_data* file are listed below. The peak temperatures at both 15.14 and 22.64 meters happened at 65 years.

```

easting (NV central):      170208.78
northing (NV central):    234316.72

6.000000e+01  1.217521e+02  1.128836e+02  1.013508e+02  9.197677e+01  8.154805e+01
8.097211e+01  7.002953e+01  6.778462e+01  5.880506e+01  5.697462e+01  5.393250e+01
6.500000e+01  1.109364e+02  1.039876e+02  9.589998e+01  8.849369e+01  7.952020e+01
7.905036e+01  7.012354e+01  6.829093e+01  6.096046e+01  5.946243e+01  5.692342e+01
7.000000e+01  9.012860e+01  8.672684e+01  8.286224e+01  7.765278e+01  7.179035e+01
7.149235e+01  6.583021e+01  6.467090e+01  6.003366e+01  5.908672e+01  5.747176e+01

```

Relevant output from mean file for *csnf\_x5\_y7\_data* file. For this waste package location, the peak temperature at 15.14 meters happened at 120 years and the peak temperature occurred at 22.64 meters at 160 years.

easting (NV central):           **170206.88**  
northing (NV central):       **232174.02**

1.000000e+02	1.017222e+02	9.821016e+01	9.379375e+01	8.952999e+01	8.499046e+01
	8.476243e+01	8.042970e+01	7.957271e+01	7.614481e+01	7.566116e+01
1.200000e+02	9.575394e+01	9.343166e+01	9.080788e+01	8.778442e+01	8.440197e+01
	8.423215e+01	<b>8.100555e+01</b>	8.036589e+01	7.780721e+01	7.744653e+01
1.400000e+02	9.217081e+01	9.072308e+01	8.874005e+01	8.631538e+01	8.361820e+01
	8.348244e+01	8.090252e+01	8.039044e+01	7.834209e+01	7.805350e+01
1.600000e+02	9.150115e+01	9.011586e+01	8.822916e+01	8.592764e+01	8.336907e+01
	8.324033e+01	8.079433e+01	8.030895e+01	<b>7.836745e+01</b>	7.809393e+01
1.800000e+02	9.167445e+01	9.027296e+01	8.836181e+01	8.602914e+01	8.343579e+01
	8.330528e+01	8.082556e+01	8.033345e+01	7.836503e+01	7.808769e+01

A comparison of the input and output files verified that the routine ran correctly. It was also verified that there were 610 waste package entries in the output file.