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Infiltration Time Profiles for E-Area LLWF Intact and Subsidence Scenarios

J. A. Dyer

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July 2018

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EXECUTIVE SUMMARY

To support future Unreviewed Disposal Question Evaluations (UDQEs), Special Analyses (SAs) and/or Performance Assessments (PAs) for the E-Area Low-Level Waste Facility (LLWF) at the Savannah River Site (SRS), the Hydrologic Evaluation of Landfill Performance (HELP) model and a newly developed, Python-based, probabilistic model employing a Monte Carlo sampling technique were used together to generate infiltration degradation curves over a 10,000-year simulation period for both intact and subsided slit- and engineered-trench closure-cap scenarios. The results will be used in PORFLOW transport model simulations of the E-Area LLWF trench units.

Previous HELP-model-based infiltration studies (Shipmon and Dyer, 2017; Dyer, 2018a) found that the F-Area Tank Farm (FTF) Bahia grass case (Phifer et al., 2007) with 2% slope and 585-foot slope length represents a reasonable upper bound on intact infiltration rates for the proposed E-Area LLWF final closure cap design (Dyer, 2017). Use of a single intact infiltration case will reduce the number of more computationally intensive vadose- and aquifer-zone PORFLOW simulations.

The probabilistic subsidence infiltration model calculates a spatially averaged infiltration rate for each percent-subsidence case using HELP-model-generated infiltration rates for an intact case. The spatial averaging occurs over the user-specified, sloped-length of the cap surface. Input parameters include compartment size, total number of compartments, percent subsidence (0% to 100%), average annual rainfall minus average evapotranspiration rate from HELP, and intact infiltration rate from HELP.

Table 0-1 presents spatially averaged infiltration rates as a function of relative time for intact and 2%, 0.6%, and 0.04% subsidence cases for the E-Area LLWF closure cap design. The reported infiltration rates for the three subsidence cases are slope-length-weighted spatial averages for slope lengths of 545 feet and 110 feet. While the modeling approach described in this report applies at any percent subsidence, the infiltration data presented herein apply specifically to low-percent-subsidence (< 2%) trench units of interest in the upcoming E-Area UDQE.

Table 0-1. Spatially Averaged Infiltration Rates for E-Area LLWF Intact and Subsidence Cases (Intact Case: 2% slope, 585-foot slope length).

Relative Year	Intact Infiltration Rate (in/yr)	Slope-Length-Weighted, Spatially Averaged Infiltration Rate (in/yr)		
		2.0% Subsidence (ST6, ST15-21)	0.6% Subsidence (ST5, ST7, ST14)	0.04% Subsidence (ET2)
0	0.1	N/A	N/A	N/A
100	0.00088	5.858	2.166	0.157
180	0.00791	5.824	2.188	0.165
290	0.18881	5.938	2.336	0.348
300	0.20409	5.972	2.353	0.361
340	0.32167	6.020	2.462	0.477
380	0.40513	6.092	2.514	0.568
480	1.45728	6.771	3.465	1.600
660	3.23003	7.928	4.982	3.358
1100	7.01494	10.380	8.274	7.102
1900	10.64990	12.719	11.416	10.708
2723	11.47210	13.255	12.129	11.520
3300	11.53200	13.302	12.195	11.582
5700	11.63140	13.346	12.271	11.678
10100	11.67340	13.373	12.304	11.720

Year 0: Beginning of institutional control period. Interim runoff cover is installed and maintained for next 100 years (i.e., any subsidence is repaired). Infiltration rate for interim cover is assumed to equal 0.1 inches/year.

Year 100: End of institutional control period; installation date of final closure cap.

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LIST OF ABBREVIATIONS

CLM	Central Climatology site
CN	Curve number
FTF	F-Area Tank Farm
GCL	Geosynthetic clay liner
HDPE	High-density polyethylene
HELP	Hydrologic Evaluation of Landfill Performance
LAI	Leaf area index
LLWF	Low-Level Waste Facility
PA	Performance Assessment
SA	Special Analysis
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
UDQE	Unreviewed Disposal Question Evaluation
USACE	United States Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency

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1.0 Introduction

To support future Unreviewed Disposal Question Evaluations (UDQEs), Special Analyses (SAs) and/or Performance Assessments (PAs) for the E-Area Low-Level Waste Facility (LLWF) at the Savannah River Site (SRS), the Hydrologic Evaluation of Landfill Performance (HELP) model and a newly-developed, Python-based, probabilistic model employing a Monte Carlo sampling technique were used to generate infiltration degradation curves for both intact and subsidence closure-cap scenarios for a 10,000-year simulation period.

1.1 Intact Infiltration Scenario

Previous HELP-model-based infiltration studies (Shipmon and Dyer, 2017; Dyer, 2018a) found that the F-Area Tank Farm (FTF) Bahia grass case (Phifer et al., 2007) with 2% slope and 585-foot slope length represents a reasonable upper bound on intact infiltration rates for the planned E-Area LLWF final closure cap design (Dyer, 2017; Figure 1-1). The use of a single intact infiltration case will reduce the number of more computationally intensive vadose- and aquifer-zone PORFLOW simulations for both the intact- and subsided-cap scenarios. Version 4.0 of the HELP model (Dixon, 2017) was used to generate the desired intact infiltration-rate time profile (degradation curve) based on the same (or slight modifications thereof) cap design and degradation parameters employed for the FTF infiltration calculations. The simulation period of interest for the E-Area LLWF is 100 to 10,100 years, where Year 100 is the installation date of the final closure cap.

- Layer 1 - Topsoil
- Layer 2 - Upper Backfill
- Layer 3 - Erosion Barrier
- Layer 4 - Middle Backfill
- Layer 5 - Lateral Drainage Layer
- Layer 6 - Combined Geomembrane
- Layer 7 - Geotextile Clay Liner
- Layer 8 - Upper Foundation Layer
- Layer 9 - Lower Foundation Layer

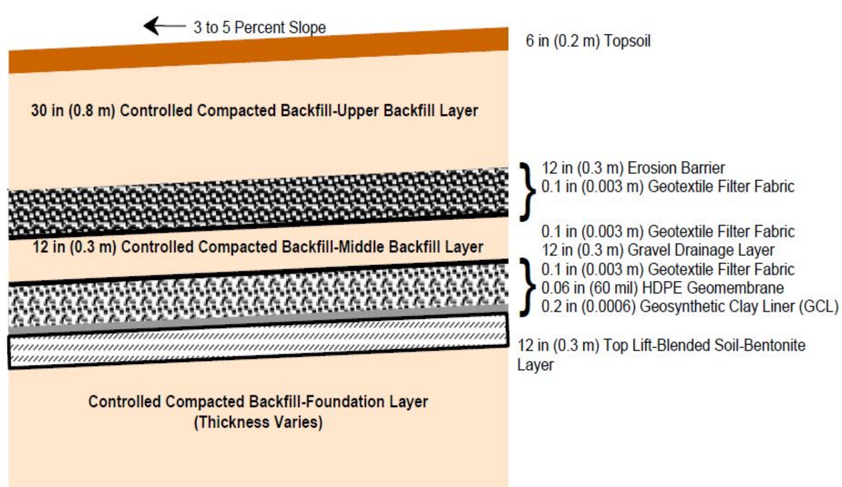

Figure 1-1. Planned Final Closure Cap Design for E-Area LLWF.

1.2 Subsidence Infiltration Scenarios

Subsidence is assumed to occur when "non-crushable" containers and equipment (i.e., items that do not collapse during previous waste stabilization measures, including dynamic compaction) fail immediately upon installation of the final multilayer closure cap. The sudden collapse is assumed to result in catastrophic, localized failures that create holes (or subsided "compartments") in the closure cap surface. Dyer and Flach (2017) describe a Python-based probabilistic model employing Monte Carlo sampling that generates statistical distributions of the upslope-intact-area to subsided-area ratio ($Area_{UAi}/Area_{SAi}$) for E-Area LLWF closure-cap subsidence scenarios that vary in percent subsidence and the total number of uniformly sized compartments (see Section 2.2.1, Model Assumptions). The two main input parameters in the first version of the probabilistic model are the integer number of subsided compartments and the total integer number of compartments (intact plus subsided). As a result, percent subsidence is implicit in the assumed integer-number of subsided compartments, which leads to computational limitations for low-percent-subsidence cases (≤ 1 percent).

The revised version of the probabilistic model provides greater flexibility in case definition by allowing rational numbers to be used for all input parameters except the total number of compartments. In addition, the revised model calculates a spatially averaged infiltration rate for each subsidence case using HELP-model-generated infiltration rates for an intact case. The spatial averaging occurs over the user-specified, sloped-length of the cap surface. Revised input parameters include compartment size (feet, rational), total number of compartments (integer), percent subsidence (rational), average annual rainfall minus average evapotranspiration rate from HELP (inches/year, rational), and intact infiltration rate from HELP (inches/year, rational). The benefit of the revised model is that any percent-subsidence case from 0% to 100% can be simulated.

2.0 Model Formulation and Assumptions

2.1 HELP Intact Infiltration Model

The HELP model is a quasi-two-dimensional hydrologic model for conducting landfill water balance calculations. The model requires the input of weather, soil, and closure cap design data, and provides quantitative estimates of surface runoff, evapotranspiration, lateral drainage, vertical percolation (i.e., infiltration), hydraulic head build-up, and water storage for the evaluation of different landfill designs.

United States Army Corps of Engineers (USACE) personnel at the Waterways Experiment Station in Vicksburg, MS developed the HELP model under an interagency agreement (DW21931425) with the U.S. Environmental Protection Agency (USEPA). As such, the HELP model is a USEPA-approved model for conducting water balance analyses of landfills and other land disposal systems. HELP model version 3.07 (released November 1, 1997) is the most recent official-release public-domain version of the model available for download at https://www.epa.gov/land-research/hydrologic-evaluation-landfill-performance-help-model. The graphical user interface for HELP v3.07, however, is not compatible with Windows 7 or later; therefore, the user must execute the program using Windows XP or from within a virtual Windows XP environment.

USEPA and the USACE provide the following documentation for the HELP model:

- A user's guide (Schroeder et al. 1994a) that gives instructions on setting up and executing the HELP model.
- Engineering documentation (Schroeder et al. 1994b) that provides information on the FORTRAN source code, hardware necessary to operate the code, data generation methodologies available for use, and methods of solution.
- Verification test reports comparing the model's drainage layer estimates to the results of large-scale physical models (Schroeder et al. 1987a) and water balance estimates to "field data from a total of 20 landfill cells at 7 sites in the United States" (Schroeder et al. 1987b).

HELP v4.0 (Dixon, 2017), which was used in this study, is an SRNL-recompiled version of HELP v3.07 that is compatible with 64-bit Windows 7/10 operating systems. HELP v3.07 was recompiled using the open source compiler GFORTRAN (GNU Compiler Collection, GNU Project). Dixon (2017) documents the successful completion of verification testing of the recompiled code in accordance with Q-SQA-A-00005, Rev. 1.

2.1.1 FTF and E-Area HELP Model Comparisons

Appendix J by Phifer et al. (2007) contains the HELP Model input datasheets for the FTF design case that parallels the E-Area Bahia grass design case (for example, FTF Year 0 corresponds to \ST00 or Year 100 for the E-Area timeline). Because the timeline for the E-Area LLWF final closure cap commences 100 years later than the timeline for the FTF case, topsoil thickness, total porosity, field capacity, wilting point, saturated hydraulic conductivity, and the number of geomembrane defects assumed for the FTF case were modified, as necessary, for the impacted timesteps via linear interpolation of the input parameter values reported by Phifer et al. (2007).

A Microsoft Excel spreadsheet HELPModel_Interpolation_Tool.xlsx (Appendix A) was developed for interpolating input parameter values for topsoil thickness, total porosity, field capacity, wilting point, and saturated hydraulic conductivity for the E-Area Bahia grass design case using FTF design case values reported in Appendix J by Phifer et al. (2007). Dyer (2018a) describes in greater detail the basis for revised geomembrane defect assumptions for the E-Area Bahia grass design case; the revised assumptions are shown in Table 2-1 under the column heading "E-Area Phifer/Nelson Grass Only." Appendix B contains the final revised HELP model input datasheets for the fourteen timesteps in E-Area LLWF Bahia Grass intact infiltration case.

2.1.2 HELP Model Execution

HELP v4.0 model files for the E-Area LLWF intact case of interest in this report (2% slope, 585-foot slope length, 100 to 10,100 years, Phifer/Nelson Bahia grass) were stored in the parent directory C:\Help4.0 in three separate subdirectories:

- C:\Help4.0\Hweather stores input parameters for evapotranspiration calculations (FEVAP.D11) as well as HELP-model-generated weather input files containing 100 years of daily precipitation data (FPREC.D4), daily temperature data (FTEMP.D7), and daily solar radiation data (FSOLAR.D13). Appendix C provides additional background information on weather data input for the HELP model.
- C:\Help4.0\PNGRASS contained the input and output files for each intact-infiltration time step (stored in separate subdirectories labeled C:\Help4.0\PNGRASS\ST00 for Year 100 through C:\Help4.0\PNGRASS\ST13 for Year 10,100).
- C:\Help4.0\Source contains the executable Fortran files for the HELP model.

All 14 intact infiltration timesteps were executed at once by double-clicking the HELP.bat Windows batch file stored in the subdirectory C:\Help4.0\PNGRASS. Overall summary files labeled ST.OUT, ST_DRAINAGE.OUT, ST_PERC.OUT, and ST_RUNOFF.OUT were created by double-clicking the Python-based model cat_FC.py stored in the subdirectory C:\Help4.0\PNGRASS. Output files for each individual time-step case were stored in C:\Help4.0\PNGRASS\STxx\Output, where xx ranges from 00 to 13.

Table 2-1. Defect Assumptions for use in HELP Model Simulations for Slit and Engineered Trenches – Next Revision of the E-Area LLWF Performance Assessment.

Facility Event	Number of 1 cm^2 holes in geomembrane layer									
	Relative Year (yr)	F-Area Tank Farm (# defects)	Relative Year (yr)	E-Area Phifer/Nelson Grass Only (# defects)	Relative Year (yr)	E-Area Skibo Grass Only (# defects)	Relative Year (yr)	E-Area Skibo Bamboo Unmanaged (#defects)	Relative Year (yr)	E-Area Skibo Bamboo Managed (# defects)
Start of Institutional Control	0	4	0		0		0		0	
Interim Cap Installed	NA		0		0		0		0	
Establish 600-foot Bahiagrass Buffer	0		0		0		0		0	
Final Cap Installed	0		100	4	100	4	100	4	100	4
Bamboo Planted as Final Vegetative Cover	NA		NA		NA		100		100	
End of Active Cap Maintenance	100	50	100		100		100		135	17
	180	90	180	40						
Initial Pine Tree Encroachment	260	131	260	80	110	6	120	9	185	42
Tap Roots Reach Geomembrane	290	146	290	96	160		180		270	85
Pine Trees Cover 1/3 Cap	300	170	300	101	130	14	140	19	220	60
Pine Trees Cover 2/3 Cap	340	334	340	121	160	29	180	40	300	101
Pine Trees Cover 100% Cap	380	479	380	141	175	37	225	63	360	131
Mature Pine Tree Stand with 100-year Turnover	380		380		187	43	275	88	450	373
			480	479	400	170	400	170		
	560	1115	660	1115	660	1115	660	1115	660	1115
	1000	2669	1100	2669	1100	2669	1100	2669	1100	2669
	1800	5496	1900	5496	1900	5496	1900	5496	1900	5496
Silting In of Lateral Drainage Layer Complete	2623	8403	2723	8403	2723	8403	2723	8403	2723	8403
	3200	10442	3300	10442	3300	10442	3300	10442	3300	10442
	5600	18921	5700	18921	5700	18921	5700	18921	5700	18921
	10000	34466	10100	34466	10100	34466	10100	34466	10100	34466

(Highlighted) Pine tree roots reach geomembrane or pine trees cover 1/3 cap, whichever comes later.

The number of defects for the F-Area Tank Farm case are given by Phifer et al. (2007) in WSRC-STI-2007-00184, Rev. 2, Appendix I, pg. 329, lower table.

The number of defects for the four E-Area cases are also derived from the F-Area Tank Farm case, but are adjusted to account for the four different E-Area grass and bamboo timelines shown in the table above. The time-adjusted defect numbers are calculated via linear interpolation of values reported by Phifer et al. (2007) in WSRC-STI-2007-00184, Rev. 2, Appendix I, tables on pp. 325 and 329.

Intact percolation (infiltration) rates for the 14 cases (timesteps) are reported in ST_PERC.OUT. Two percolation rates are given for each case: percolation through the geomembrane/geosynthetic clay liner (GCL) barrier layer and percolation through the lower foundation layer (bottom layer in cap design). Infiltration rates used in PA/UDQE PORFLOW simulations have been based historically on percolation through the geomembrane/GCL barrier layer. The barrier layer is Layer 7 for the first four timesteps (ST00 through ST03), Layer 6 for the next six timesteps (ST04 through ST09), and Layer 5 for the remaining four timesteps (ST10 through ST13). Figure 2-1 shows ST_PERC.OUT for the E-Area LLWF intact case; the percolation rates of interest in inches/year are in the third column in the rows highlighted in light purple.

2.2 Probabilistic Subsidence Infiltration Model

A probabilistic model employing Monte Carlo sampling was developed using the Python programming language to calculate average infiltration rates through the closure cap for cases where subsidence occurs due to the presence of randomly placed non-crushable items in the underlying waste zone. Non-crushable items include large structurally-robust metal storage boxes, tanks, and other equipment that contain significant void space.

2.2.1 Model Assumptions

2.2.1.1 General

- Reported infiltration rates at each time step on the infiltration-rate degradation curve are average values based on the portion of the total cap area that overlies the waste footprint (i.e., 40-foot overhangs are excluded). This is true for both the intact and subsidence cases. An intact infiltration rate will be applied for the 40-foot overhangs.

- Intact infiltration rates are not adjusted for location along the sloped length of the closure cap (i.e., increasing infiltration rate from crest to base).

- For the low-percent subsidence cases (typically < 2% non-crushable items), hole (or compartment) size is fixed at 10 feet in the infiltration model simulations. As discussed by Dyer and Flach (2017), a minimum hole size of 10 feet is considered “practical” or “realistic” based on typical non-crushable container dimensions. For higher-percent-subsidence cases (typically > 2% non-crushable items) that are not addressed in this report, a larger hole size may be more realistic and warranted. For example, six (6) percent subsidence over a 500-foot slope length equates to a total subsided length of 30 feet. In this case, the infiltration model could assume three 10-foot-long holes, two 15-foot-long holes, or one 30-foot-long hole.

- In PORFLOW simulations of the vadose zone, the spatially averaged infiltration rate for the subsided case-of-interest will be used to back-calculate the effective infiltration rate into the subsided “hole(s)” in PORFLOW, which in some cases may differ in number and size compared to the infiltration model.

- Except where impacted by a 100-year shift in the disposal-unit timeline (e.g., changes in the number of geomembrane defects due to differences in the age of the geomembrane when pine tree intrusion occurs), the E-Area LLWF HELP-model simulations assume the same cap layers and thicknesses as well as material and hydraulic property parameters as the F-Area Tank Farm cap design. A vegetative cover of Bahia grass is assumed.

PERCOLATION/LEAKAGE THROUGH LAYER	7	0.00088	0.00102	0.861	0.00180
PERCOLATION/LEAKAGE THROUGH LAYER	9	0.00095	0.00107	0.930	0.00194
PERCOLATION/LEAKAGE THROUGH LAYER	7	0.00791	0.01025	7.709	0.01609
PERCOLATION/LEAKAGE THROUGH LAYER	9	0.00827	0.00283	8.061	0.01682
PERCOLATION/LEAKAGE THROUGH LAYER	7	0.18881	0.23219	184.090	0.38420
PERCOLATION/LEAKAGE THROUGH LAYER	9	0.16789	0.12661	163.697	0.34164
PERCOLATION/LEAKAGE THROUGH LAYER	7	0.20409	0.24906	198.990	0.41530
PERCOLATION/LEAKAGE THROUGH LAYER	9	0.18228	0.13718	177.723	0.37091
PERCOLATION/LEAKAGE THROUGH LAYER	6	0.32167	0.24446	313.638	0.65457
PERCOLATION/LEAKAGE THROUGH LAYER	8	0.29459	0.17323	287.228	0.59946
PERCOLATION/LEAKAGE THROUGH LAYER	6	0.40513	0.30308	395.012	0.82441
PERCOLATION/LEAKAGE THROUGH LAYER	8	0.37645	0.21731	367.050	0.76605
PERCOLATION/LEAKAGE THROUGH LAYER	6	1.45728	1.01048	1420.874	2.96542
PERCOLATION/LEAKAGE THROUGH LAYER	8	1.41965	0.83445	1384.183	2.88884
PERCOLATION/LEAKAGE THROUGH LAYER	6	3.23003	1.61328	3149.335	6.57278
PERCOLATION/LEAKAGE THROUGH LAYER	8	3.18156	1.50584	3102.081	6.47416
PERCOLATION/LEAKAGE THROUGH LAYER	6	7.01494	2.02368	6839.695	14.27470
PERCOLATION/LEAKAGE THROUGH LAYER	8	6.95235	2.01104	6778.669	14.14734
PERCOLATION/LEAKAGE THROUGH LAYER	6	10.64993	1.75127	10383.872	21.67153
PERCOLATION/LEAKAGE THROUGH LAYER	8	10.57798	1.90916	10313.723	21.52512
PERCOLATION/LEAKAGE THROUGH LAYER	5	11.47205	1.39038	11185.459	23.34447
PERCOLATION/LEAKAGE THROUGH LAYER	7	11.39622	1.69522	11111.522	23.19016
PERCOLATION/LEAKAGE THROUGH LAYER	5	11.53200	1.35958	11243.908	23.46646
PERCOLATION/LEAKAGE THROUGH LAYER	7	11.45505	1.68162	11168.876	23.30986
PERCOLATION/LEAKAGE THROUGH LAYER	5	11.63143	1.29602	11340.857	23.66879
PERCOLATION/LEAKAGE THROUGH LAYER	7	11.55326	1.64748	11264.637	23.50972
PERCOLATION/LEAKAGE THROUGH LAYER	5	11.67340	1.27981	11381.774	23.75419
PERCOLATION/LEAKAGE THROUGH LAYER	7	11.59336	1.64957	11303.730	23.59131

Figure 2-1. HELP 4.0 Summary File ST_PERC.OUT for E-Area LLWF Intact Case.

2.2.1.2 Intact Case

- The new E-Area LLWF closure cap design contains numerous changes in slope, slope length, and direction across the E-Area footprint as detailed in the Design Engineering conceptual closure cap plot plan (C-CT-E-00083). Therefore, each individual trench footprint will have a unique set of slope characteristics relative to the overlying closure cap. To reduce the number of detailed PORFLOW flow and transport simulations, a single intact infiltration case based on 2% slope and 585-foot slope length is used for all E-Area disposal units. This case represents an upper bound on intact infiltration rate for the proposed E-Area final closure cap when considering variability in percent slope and slope length and other HELP model parameter uncertainties. Dyer (2018a, 2018b) provide the rationale and basis for choosing 2% slope and 585-foot slope length as an upper-bound case for all intact infiltration scenarios.

2.2.1.3 Subsidence Case

- For new and future trench units, 2% subsidence is assumed based on input from E-Area LLWF SW Engineering (verbal communication between K. L. Tempel and B. T. Butcher and G. P. Flach).

- For closed trench units, percent subsidence is based on reported non-crushable content (surficial area).

- Percent subsidence for partially filled trench units is based on the reported non-crushable surficial area linearly extrapolated to 100% full.

- For closed and partially filled open trench units, unit-by-unit total footprint area is reported in Table 2-2. Non-crushable content (surficial area) and percent-filled values are reported in Table 2-3.

- Percent subsidence for closed units is calculated using the equation $(non - crushable\ area)/(total\ footprint\ area) \times 100\%$.

- Percent subsidence for partially filled units is calculated using the equation $(non - crushable\ area)(100\%)/\big((total\ footprint\ area)(fraction\ filled)\big)$.

- Percent subsidence will be set at 2% for all future trench units including ST15, ST16, ST17, ST18, ST19, ST20, and ST21 (ST8, ST10, and ET4 are also in this category, but are not included in the upcoming E-Area UDQE).

- Closed trench units include ST5 and ET1 (ST1, ST2, ST3, and ST4 are also in this category, but are not included in the upcoming E-Area UDQE).

- Open trench units include ST6, ST7, ST14, and ET2 (ST9 and ET3 are also in this category, but are not included in the upcoming E-Area UDQE).

- Calculated percent subsidence values for closed and partially filled open trench units are:

  ST5: 0.54% (closed)
  ET1: 0.00% (closed)
  ST6: 2.00%
  ST7: 0.64%
  ST14: 0.56%
  ET2: 0.04%

Table 2-2. Calculated Areas for E-Area LLWF Disposal Units.

(\\godzilla-01\hpc_project\projwork50\QA\Data\ELLWF\DU_CoordDrawings\DisposalUnit_Coordinates-Areas-VolCapacity\Rev6-E-Area_LLWF_Coordinates_and_Areas_03-Jul-2017.xlsx)

			corner #1		corner #2		corner #3		corner #4		corner #5		
Low-Level Waste Facility	Area (m^2)	Calculated Area (m^2)	SRS N	SRS E	SRS N	SRS E	SRS N	SRS E	SRS N	SRS E	SRS N	SRS E	Source Document (Current Revision as of 7-3-17)
Slit Trench 1	9,568	9,581	N77434.5	E58157.1	N77318.4	E58263.6	N77757.8	E58750.0	N77874.2	E58644.9			C-CV-E-0070, Rev. 10
Slit Trench 2	9,568	9,586	N77307.1	E58273.7	N77190.1	E58379.2	N77630.4	E58865.8	N77746.9	E58760.6			C-CV-E-0070, Rev. 10
Slit Trench 3	9,568	9,569	N77179.9	E58389.5	N77063.7	E58495.1	N77503.4	E58981.9	N77619.6	E58876.3			C-CV-E-0070, Rev. 10
Slit Trench 4	9,568	9,566	N77052.6	E58505.1	N76936.4	E58610.7	N77375.8	E59097.2	N77492.3	E58991.9			C-CV-E-0070, Rev. 10
Slit Trench 5	9,568	9,564	N76674.9	E58856.7	N76558.4	E58961.9	N76998.1	E59448.8	N77114.5	E59343.6			C-CV-E-0206, Rev. 7
Slit Trench 6	9,568	9,568	N76548.4	E58971.0	N76431.8	E59076.2	N76871.5	E59563.0	N76988.0	E59457.8			C-CV-E-0206, Rev. 7
Slit Trench 7	9,568	9,570	N76419.6	E59087.3	N76303.1	E59192.5	N76742.7	E59679.4	N76859.3	E59574.1			C-CV-E-0206, Rev. 7
Slit Trench 8		9,567	N77804.0	E57809.6	N77877.7	E57671.0	N78456.9	E57979.0	N78383.2	E58117.6			C-CV-E-00207, Rev. 7
Slit Trench 9		9,567	N77797.4	E57822.0	N77723.7	E57960.6	N78376.6	E58130.0	N78302.9	E58268.6			C-CV-E-00207, Rev. 7
Slit Trench 10		8,692	N78278.6	E58271.6	N78204.9	E58410.2	N77752.4	E57991.7	N77678.7	E58130.3			C-CV-E-00207, Rev. 7
Slit Trench 11		7,455	N77622.1	E58085.5	N77503.1	E58188.0	N77955.7	E58472.6	N77836.8	E58575.1			C-CV-E-00207, Rev. 7
Slit Trench 14		9,568	N75830.9	E58944.8	N75673.9	E58944.8	N75673.9	E59600.8	N75830.9	E59600.8			C-CV-E-00209, Rev. 4
Slit Trench 15		9,564	N75659.6	E58945.4	N75502.6	E58945.9	N75502.6	E59601.4	N75659.6	E59601.4			C-CV-E-00209, Rev. 4
Slit Trench 16		8,726	N75315.0	E58941.5	N75170.0	E58941.5	N75170.0	E59589.3	N75315.0	E59589.3			C-CV-E-00209, Rev. 4
Slit Trench 17		8,726	N75155.0	E58941.5	N75010.0	E58941.5	N75010.0	E59589.3	N75155.0	E59589.3			C-CV-E-00209, Rev. 4
Slit Trench 18		8,726	N74995.0	E58941.5	N74850.0	E58941.5	N74850.0	E59589.3	N74995.0	E59589.3			C-CV-E-00209, Rev. 4
Slit Trench 19		8,726	N74835.0	E58941.5	N74690.0	E58941.5	N74690.0	E59589.3	N74835.0	E59589.3			C-CV-E-00209, Rev. 4
Slit Trench 20		8,726	N74675.0	E58941.5	N74530.0	E58941.5	N74530.0	E59589.3	N74675.0	E59589.3			C-CV-E-00209, Rev. 4
Slit Trench 21		15,677	N74515.0	E58941.5	N74140.0	E58941.5	N74140.0	E59391.5	N74515.0	E59391.5			C-CV-E-00209, Rev. 4
CIG Trench 1	9,568	9,569	N77362.3	E59110.0	N77246.1	E59215.6	N76805.0	E58730.0	N76921.2	E58624.4			C-A2-E-0001, Rev. 8
CIG Trench 2	9,568	9,566	N77125.7	E59333.5	N77242.2	E59228.3	N76686.0	E58846.7	N76802.5	E58741.5			SRNS Survey Drawing
Engineered Trench #1	9,568	8,913	N75995.2	E58944.7	N75845.2	E58943.8	N75845.1	E59590.3	N75992.1	E59590.3			C-CV-E-0130, Rev. 10
Engineered Trench #2	9,568	9,559	N76286.7	E58946.3	N76127.6	E58946.0	N76129.0	E59601.9	N76283.3	E59603.7			C-CV-E-0202, Rev. 5
Engineered Trench #3		7,511	N78727.8	E57528.3	N78522.9	E57934.5	N78443.2	E57899.4	N78378.9	E57817.6	N78564.7	E57448.6	C-CV-E-00207, Rev. 7
Engineered Trench #4		9,638	N77943.5	E57147.3	N77865.0	E57283.8	N78465.6	E57574.4	N78533.8	E57433.5			C-CV-E-00207, Rev. 7
LAW Vault	8,662	8,666	N75475.0	E59589.3	N75330.0	E59589.3	N75330.0	E58946.0	N75475.0	E58946.0			W2017810, Rev. 3
IL Vault	1,256	1,262	N77790.4	E57679.7	N77748.1	E57657.0	N77658.1	E57928.4	N77615.4	E57905.6			SE5-6-2003300, Rev. 4 & SRNS Survey Data
643-26E NRCDA	4,435	4,430	N78152.4	E57675.1	N78241.6	E57504.9	N78434.5	E57598.2	N78327.4	E57819.6			C-CV-E-00207, Rev. 7
643-7E NRCDA	1,226	546	N74311.6	E58333.3	N74310.5	E58425.0	N74418.9	E58426.6	N74424.0	E58396.4	N74347.9	E58370.6	DCF C-DCF-E-00367 to Drwg. C-CV-E-0072, Rev. 0

Notes

1 Highlighted cells represent changes made to table in response to updates/corrections by SW Engineering and SRNL.

2 The "Area" column represents area estimates provided by SW Engineering. The "Calculated Area" column contains areas calculated in Excel by SRNL using coordinates of the corners. Area calculation includes space between slit trench segments.

3 Corner coordinates for Engineered Trenches apply to the base of the trench (i.e., bottom of side slopes).

4 Disposal unit coordinates in table cross-checked with coordinates on drawings by N. Halverson on 7-3-17 resulting in change to one coordinate and update to some calculated areas. Also updated source documents to current revision as of 7-3-17.

Table 2-3. Non-Crushable Content and Percent-Filled Values for Closed and Partially Filled Open E-Area LLWF Trench Units.

Trench ID	Capacity Volume[1] (m^3)	Volume Status[1] (m^3) (1/31/18)	Percent Filled[1] (1/31/18)	Trench Area[2] (m^2)	Trench Area[2] (ft^2)	No. of Waste Packages[3]	Non-Crush Area[3] (ft^2)	Non-Crush Area[3] (%)	Non-Crush Sr90[4] Ci	Non-Crush Sr90[4] (ft^2)	Non-Crush Sr90[4] (%)	Trench ID
ET #1	35,660	35,660	100.0%	8,913	95,939	0	0	0.00%	0	0	0.00%	ET #1
ET #2	35,500	27,252	76.8%	9,559	102,892	3	34	0.03%	0	0	0.00%	ET #2
ET #3[5]	27,000	14,417	53.4%	7,511	80,848	0	0	0.00%	0	0	0.00%	ET #3[5]
SLIT1	14,264	14,264	100.0%	9,581	65,000	0	0	0.00%	0	0	0.00%	SLIT1
SLIT2	15,560	15,560	100.0%	9,586	65,000	9	2,046	3.15%	0	0	0.00%	SLIT2
SLIT3	16,953	16,953	100.0%	9,569	65,000	28	5,019	7.72%	1.17E-06	447	0.69%	SLIT3
SLIT4	19,193	19,193	100.0%	9,566	65,000	33	3,710	5.71%	5.37E-03	3152	4.85%	SLIT4
SLIT5	28,125	28,125	100.0%	9,564	65,000	18	557	0.86%	1.16E+00	141	0.22%	SLIT5
SLIT6	23,000	20,848	90.6%	9,568	65,000	49	1,866	2.87%	3.39E-02	968	1.49%	SLIT6
SLIT7	15,900	10,555	66.4%	9,570	65,000	12	435	0.67%	6.28E-02	329	0.51%	SLIT7
SLIT8	16,275	15,461	95.0%	9,567	65,000	1	13	0.02%	2.82E-04	13	0.02%	SLIT8
SLIT9	21,000	18,409	87.7%	9,567	65,000	0	0	0.00%	0	0	0.00%	SLIT9
SLIT14	19,500	12,852	65.9%	9,568	65,000	1	383	0.59%	1.60E-02	383	0.59%	SLIT14

[1] From SWE January 2018 LLW review memo (SRNS-N4222-2018-00002, Stewart to Mooneyhan, 2/1/2018)

[2] Calculated Engineered Trench areas based on as-built corner coordinates of trench base. Slit Trench areas based on nominal five trench segments each 20 feet wide by 650 feet long.

[3] From 2/1/2018 WITS report

[4] Non-crushable Sr90 package activity based on 1/19/2018 WITS query.

[5] No non-crushable containers permitted in ET #3.

Less than 1% of trench area filled with non-crushables

Less than 1% of trench area filled with non-crushables containing Sr90

- To reduce the number of PORFLOW simulation cases, the number of subsidence infiltration cases is reduced to only three for the upcoming E-Area UDQE.

ST6, ST15-ST21:	2% subsidence
ET2:	0.04% subsidence
ST5, ST7, ST14:	0.6% subsidence
ET1:	Intact case

2.2.2 Model Execution

For a PORFLOW closure-cap transect with two sides of unequal slope length (e.g., 545 feet and 110 feet), the probabilistic model is executed twice (once for each slope length) for each percent-subsidence case. The results of the two probabilistic simulations for each percent-subsidence case are then used to calculate a slope-length-weighted, spatially averaged infiltration rate curve. As discussed in the previous section, four (4) sets of infiltration rate vs. time data will be generated for the vadose-zone PORFLOW simulations: intact, 2% subsidence, 0.6% subsidence, and 0.04% subsidence.

The probabilistic infiltration model consists of two files: SubsideAverage_rev6.py (Python source code, Appendix D) and runPython_rev6.bat (Windows batch file, Appendix E). The Windows batch file contains the required input parameters and model/output filenames for each simulation case and can be set up to generate multiple infiltration-rate time profiles in one model execution step. For example, Appendix E includes six profiles encompassing 2%, 0.6%, and 0.04% subsidence at slope lengths of 545 feet and 110 feet each. These lengths represent the slope on either side of the crest of the cap minus the 40 feet of overhang past the end of the trenches as described in Scenario 1 of Dyer (2017). Fourteen timesteps are included for each infiltration-rate time profile; however, the number of timesteps can be increased or decreased as desired. Column 1 in runPython_rev6.bat contains the filename for the Python source code (SubsideAverage_rev6.py), while columns 2 through 10 are defined in Figure 2-2. Note that the model cases designated “545-foot slope length” are based on 550 feet in the Python model simulations because the total number of compartments must be an integer number (55 compartments times 10.0-foot compartment size). This model constraint introduces only a small error in the slope-length-weighted infiltration rates.

```
### Read filenames
prefixFile            = sys.argv[1]  # prefix for output files
compartmentsSize = float(sys.argv[2]) # size of compartment (feet)
compartmentsTotal  = int(sys.argv[3]) # total number of compartments
percentSubsided  = float(sys.argv[4]) # percent subsidence
F_notET          = float(sys.argv[5]) # annual average rainfall minus evapotranspiration
F_intact         = float(sys.argv[6]) # intact infiltration rate
realizations       = int(sys.argv[7]) # (number of Monte Carlo realizations)
debugArg              = sys.argv[8]  # debug flag (true or false)
graphicArg            = sys.argv[9]  # graphic flag for .out file (>>>>>>0>>>>>>)
appendFlag           = sys.argv[10]  # append flag for summary file (w for overwrite or a for append)
```

Figure 2-2. Definition of Arguments in Windows Batch File.

The probabilistic model is executed by double-clicking the runPython_rev6.bat file. Upon execution, the batch file will generate three output files for each percent-subsidence case: detailed output file (*.out), summary file (*.sum), and tabulated results file for import into Microsoft Excel (*.tab). Figure 2-3, Figure 2-4, and Figure 2-5 display examples of the three output files for the simulation case: 2% subsidence, 550-foot slope length, and 10-foot hole size. In Figure 2-3, each row of 55 randomly located > and O characters represents one Monte Carlo realization where “>” is an intact compartment and “O” is a subsided compartment. Over 100,000 realizations, the average number of “O” compartments in each row will equal 1.1 (2% subsidence x 55 total compartments).

2.2.3 Slope-Length-Weighted Infiltration Rate

For PORFLOW vadose-zone simulations of closure-cap transects with two sides of unequal slope length, the probabilistic model is executed twice (once for each slope length) at each percent subsidence of interest. A single slope-length-weighted, spatially averaged infiltration-rate time profile for each percent-subsidence case is then calculated using the model output for the two different slope lengths. A Microsoft Excel spreadsheet was used for slope-length averaging.

2.3 Quality Assurance

The software quality assurance plan for the HELP v4.0 model was performed by Dixon (2017). Design checks were completed for both the HELP model simulations of the intact case (Dyer, 2018c) and the probabilistic subsidence infiltration model (Dyer, 2018d). A technical review of this report was performed consistent with the E7 Manual, procedure 2.60 as outlined in SRNL Technical Report Design Checklist contained in WSRC-IM-2002-00011, Rev. 2.

```
                Compartment size: 10.000000
    Total number of compartments: 55
                    Slope length: 550.000000
   Percent subsided compartments: 2.000000
              Flux, intact cover: 0.000880
            Flux, subsided cover: 16.500000
                    Realizations: 100000
=========================================================
Subsided compartments
>>O>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>O>>>>>>>>>>>>>>O>>>>>>>>>
>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
>>>>>>>>>>O>>>>>>>>>>>>>>>>>>>>O>>>>>>>>>>>>>>>>>>>>>>>
>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>O>>>>>>>>>>>>>>
>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
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>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>O>>>>>>>>>>>>>O>>>>>>>
>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
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>>>>>O>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>O>
>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
>O>>>>>>>>O>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>O>
>>>>>>>>>>>>>>>>>>>>>>>>>>>>>O>>>>>>>>>O>>>>>>>>>>>>>>>
>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
```

Figure 2-3. Output File – Portion of First Time Step in Two-Percent Subsidence Case (> represents an intact compartment and O represents a subsided compartment).

```
                Compartment size: 10.000000
     Total number of compartments: 55
                   Slope length: 550.000000
    Percent subsided compartments: 2.000000
             Flux, intact cover: 0.000880
           Flux, subsided cover: 16.500000
                   Realizations: 100000
=================================================================
Percent subsided/Avg upslope ratio
    2.00/19.15
Percent subsided/Avg upslope ratio single hole
    2.00/31.97
Sample subsided
    2.00
Min/avg/max compartments
    0/1.10/8
Min/median/mean/max length
    0.00/16.00/19.15/54.00
Min/median/mean/max single hole length
    0.00/34.00/31.97/54.00
Slices intact/subsided (%)
    32.92/67.08
Subsided slice intact/subsided (%)
    98.18/1.82
Fluxes notET/intact/runoff (in/yr)
    16.500000/0.000880/16.499120
Fluxes intactAvg/subsidedAvg (in/yr)
    0.000880/544.046831
Fluxes intactDownAvg/subsidedDownAvg/coverDownAvg (in/yr)
    0.000880/9.892625/6.636460
Fluxes intactAcrossAvg/subsidedAcrossAvg/coverAcrossAvg (in/yr)
    0.000880/364.957785/6.636460
Fluxes coverAvg (in/yr)
    6.636460
```

Figure 2-4. Portion of Summary File – First Time Step in Two-Percent Subsidence Case.

Hole/ Compartment Size (ft)	Number of Compartments	Slope Length (ft)	Percent Subsidence	Infiltration Rate Less Evapotranspiration (in/yr)	Intact Infiltration Rate (in/yr)	Number of Realizations	Upslope-to-Subsided Area Ratio	Cap-Averaged Infiltration Rate (in/yr)
10.000000	55	550.000000	2.000000	16.500000	0.000880	100000	31.995842	6.665652
10.000000	55	550.000000	2.000000	16.500000	0.007910	100000	31.964409	6.623364
10.000000	55	550.000000	2.000000	16.500000	0.188810	100000	31.884703	6.732361
10.000000	55	550.000000	2.000000	16.500000	0.204090	100000	31.993873	6.761552
10.000000	55	550.000000	2.000000	16.500000	0.321670	100000	31.974757	6.800015
10.000000	55	550.000000	2.000000	16.500000	0.405130	100000	31.965440	6.872640
10.000000	55	550.000000	2.000000	16.500000	1.457280	100000	32.011360	7.497777
10.000000	55	550.000000	2.000000	16.500000	3.230030	100000	32.057815	8.577174
10.000000	55	550.000000	2.000000	16.500000	7.014940	100000	32.111109	10.845226
10.000000	55	550.000000	2.000000	16.500000	10.649900	100000	31.946176	13.003516
10.000000	55	550.000000	2.000000	16.500000	11.472100	100000	32.074937	13.501232
10.000000	55	550.000000	2.000000	16.500000	11.532000	100000	32.157665	13.545417
10.000000	55	550.000000	2.000000	16.500000	11.631400	100000	31.960888	13.582144
10.000000	55	550.000000	2.000000	16.500000	11.673400	100000	31.882378	13.608076
10.000000	11	110.000000	2.000000	16.500000	0.000880	100000	5.166633	1.855951
10.000000	11	110.000000	2.000000	16.500000	0.007910	100000	5.219773	1.865114
10.000000	11	110.000000	2.000000	16.500000	0.188810	100000	5.195190	1.999367
10.000000	11	110.000000	2.000000	16.500000	0.204090	100000	5.223046	2.057868
10.000000	11	110.000000	2.000000	16.500000	0.321670	100000	5.207385	2.153881
10.000000	11	110.000000	2.000000	16.500000	0.405130	100000	5.208052	2.221363
10.000000	11	110.000000	2.000000	16.500000	1.457280	100000	5.234363	3.170673
10.000000	11	110.000000	2.000000	16.500000	3.230030	100000	5.148410	4.710874
10.000000	11	110.000000	2.000000	16.500000	7.014940	100000	5.173258	8.074283
10.000000	11	110.000000	2.000000	16.500000	10.649900	100000	5.187183	11.311227
10.000000	11	110.000000	2.000000	16.500000	11.472100	100000	5.210228	12.033259
10.000000	11	110.000000	2.000000	16.500000	11.532000	100000	5.212401	12.097638
10.000000	11	110.000000	2.000000	16.500000	11.631400	100000	5.192732	12.175223
10.000000	11	110.000000	2.000000	16.500000	11.673400	100000	5.216353	12.210469

Upslope-to-Subsided Area Ratio: Ratio of intact area upslope of the subsided compartment to the area of the subsided compartment

Figure 2-5. Relevant Portion of Tabular Output File – Two-Percent Subsidence Case.

3.0 Results and Discussion

Table 3-1, Figure 3-1, and Figure 3-2 present spatially averaged infiltration rates as a function of relative time for the intact and 2%, 0.6%, and 0.04% subsidence cases for the E-Area LLWF closure cap design. The intact infiltration-rate profile is based on an upper bound of 2% slope and 585-foot slope length. The reported infiltration rates for the three subsidence cases are slope-length-weighted spatial averages for slope lengths of 545 feet and 110 feet. Probabilistic model results for the six individual subsidence cases (2%, 0.6%, and 0.04% subsidence at slope lengths of 545 feet and 110 feet each) are displayed in Figure F-1 through Figure F-5 in Appendix F. While the modeling approach described in this report applies at any percent subsidence, the infiltration data presented in Table 3-1 apply specifically to the low-percent-subsidence (< 2%) trench units of interest in the upcoming E-Area UDQE.

Table 3-1. Spatially Averaged Infiltration Rates for E-Area LLWF Intact and Subsidence Cases (Intact Case: 2% slope, 585-foot slope length).

Relative Year	Intact Infiltration Rate (in/yr)	Slope-Length-Weighted, Spatially Averaged Infiltration Rate (in/yr)		
		2.0% Subsidence (ST6, ST15-21)	0.6% Subsidence (ST5, ST7, ST14)	0.04% Subsidence (ET2)
0	0.1	N/A	N/A	N/A
100	0.00088	5.858	2.166	0.157
180	0.00791	5.824	2.188	0.165
290	0.18881	5.938	2.336	0.348
300	0.20409	5.972	2.353	0.361
340	0.32167	6.020	2.462	0.477
380	0.40513	6.092	2.514	0.568
480	1.45728	6.771	3.465	1.600
660	3.23003	7.928	4.982	3.358
1100	7.01494	10.380	8.274	7.102
1900	10.64990	12.719	11.416	10.708
2723	11.47210	13.255	12.129	11.520
3300	11.53200	13.302	12.195	11.582
5700	11.63140	13.346	12.271	11.678
10100	11.67340	13.373	12.304	11.720

Year 0: Beginning of institutional control period. Interim runoff cover is installed and maintained for next 100 years (i.e., any subsidence is repaired). Infiltration rate for interim cover is assumed to equal 0.1 inches/year.

Year 100: End of institutional control period; installation date of final closure cap.

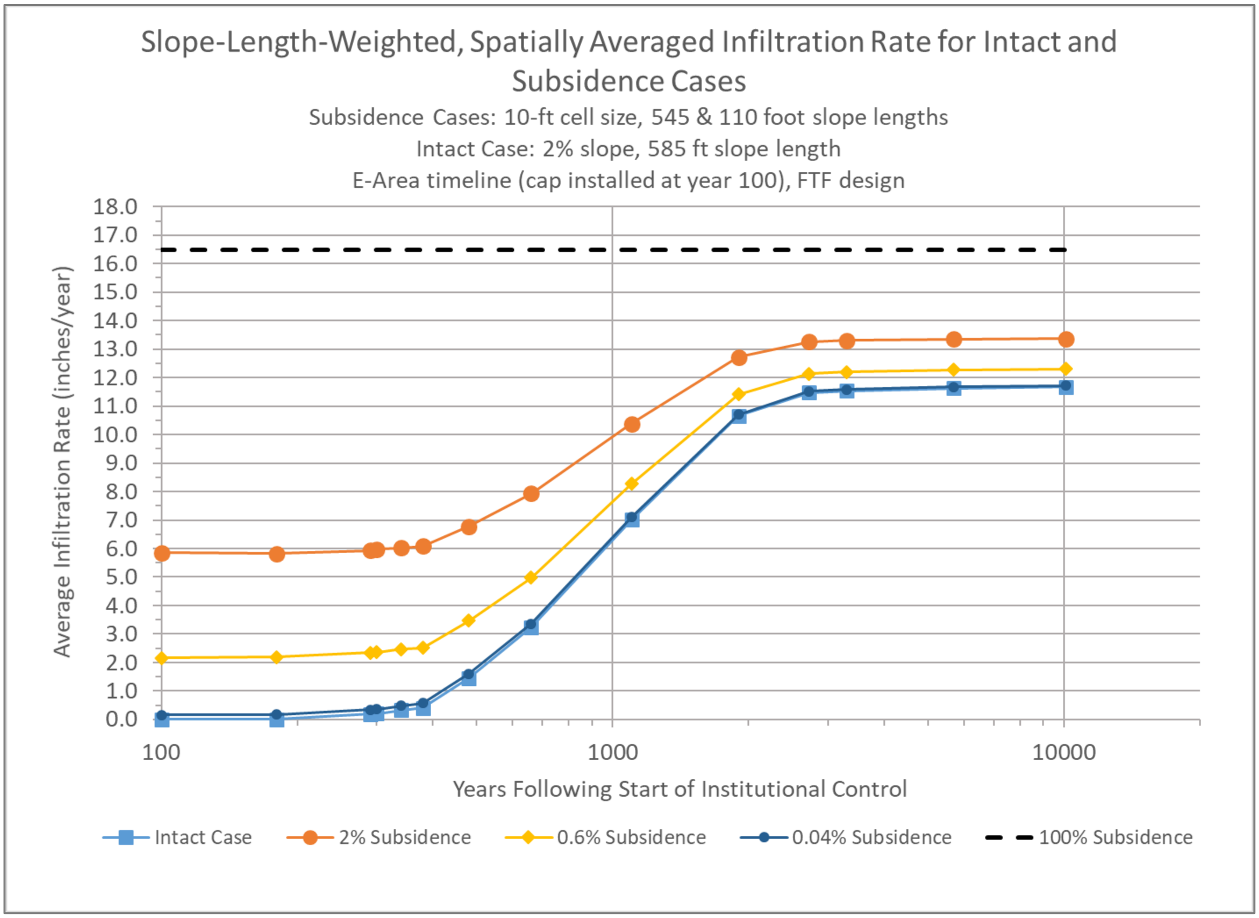

Figure 3-1. Slope-Length-Weighted, Spatially Averaged Infiltration Rate vs. Time for Intact and Subsidence Cases (linear-log).

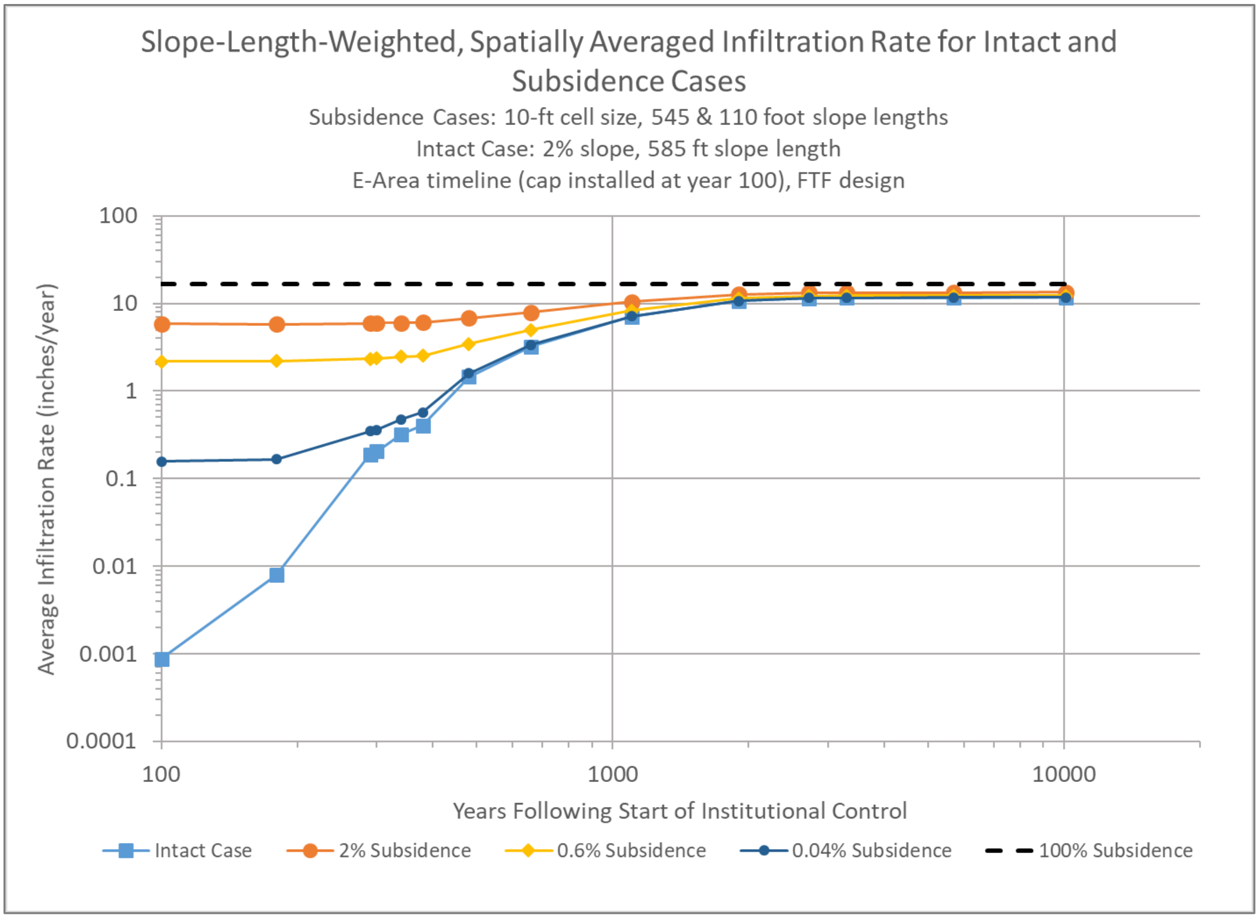

Figure 3-2. Slope-Length-Weighted, Spatially Averaged Infiltration Rate vs. Time for Intact and Subsidence Cases (log-log).

4.0 Conclusions

An efficient method has been developed for generating spatially averaged annual infiltration rates for the E-Area LLWF final closure cap that combines HELP model simulation with a Python-based probabilistic model employing a Monte Carlo sampling technique. The probabilistic model can handle cases ranging from 0% to 100% subsidence using just a single "upper bound" intact infiltration degradation curve. Selection of a single bounding intact infiltration case coupled with limiting the number of different subsidence cases will significantly reduce the number of computationally intensive vadose- and aquifer-zone PORFLOW simulations. While the modeling approach described in this report applies at any percent subsidence, the infiltration data presented herein apply specifically to low-percent-subsidence (< 2%) trench units of interest in the upcoming E-Area UDQE.

5.0 References

C-CT-E-00083, E-Area Low Level Waste Facility (ELLWF) Conceptual Closure Cap (Sheets 1 through 5).

Dixon, K. L. (2017) HELP 4.0 Documentation Updates for Software and Data. SRNL-STI-2017-00104. Savannah River National Laboratory, Aiken, SC.

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Appendix A. HELP Input Parameter Interpolation Tool

Interpolation Tool

Year 1	100
Year 2	300

Middle Backfill Ksat

Year 1	100	
Year 2	300	
Slope	5.85E-04	log(cm/sec)/year
Ksat 1	4.10E-05	
Log Ksat 1	-4.387216	
Log Ksat 2	-4.2703	
Ksat 2	5.37E-05	

Lateral Drainage Layer Ksat

Year 1	100	
Year 2	300	
Slope	-5.92E-04	log(cm/sec)/year
Ksat 1	5.00E-02	
Log Ksat 1	-1.30103	
Log Ksat 2	-1.41943	
Ksat 2	3.81E-02	

Top Soil Thickness

Year 1	100	
Year Pine Trees Cover 100% Cap	380	
Year 2	300	
Slope 1 (grass)	-5.20E-04	in/yr
Slope 2 (pine trees)	-1.30E-04	in/yr
Top Soil Thickness Year 1	6	in
Top Soil Thickness Year 2	5.90	in

Summary

Top Soil Thickness	**5.90**				
Middle Backfill	**0.352**	**0.244**	**0.175**	**0.244**	**5.37E-05**
Lateral Drainage Layer	**0.414**	**0.053**	**0.024**	**0.053**	**3.81E-02**

Middle Backfill Porosity

Year 1	100
Year 2	300
Slope	1.14E-05
η1	0.35
η2	0.352

Lateral Drainage Layer Porosity

Year 1	100
Year 2	300
Slope	-1.41E-05
η1	0.417
η2	0.414

Middle Backfill Field Capacity

Year 1	100
Year 2	300
Slope	-3.97E-05
η1	0.252
η2	0.244

Lateral Drainage Layer Field Capacity

Year 1	100
Year 2	300
Slope	3.93E-05
η1	0.045
η2	0.053

Middle Backfill Wilting Point

Year 1	100
Year 2	300
Slope	-3.09E-05
η1	0.181
η2	0.175

Lateral Drainage Layer Wilting Point

Year 1	100
Year 2	300
Slope	3.13E-05
η1	0.018
η2	0.024

Figure A-1. Screen Capture of Interpolation Tool for HELP Model Input Parameters (HELPModel_Interpolation_Tool.xlsx).

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Appendix B. HELP v4.0 Model Input Parameters for Intact Infiltration Case

Note: The Soil Conservation Service curve number (CN) is calculated internally within the HELP model and accounts for the effect of surface soil texture and vegetation type on surface runoff. A higher value for CN is indicative of increased runoff and, hence, a decrease in the infiltration rate.

Table B-1. HELP Model Input Data for Year 100 (ST00.D10).

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	0.2686 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	2 %
Slope length =	585 ft
Soil Texture =	4 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 46.2	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Lateral Drainage Layer	5	2 (lateral drainage layer)
HDPE Geomembrane	6	4 (geomembrane liner)
GCL	7	3 (barrier soil liner)
Foundation Layer (1E-06)	8	1 (vertical percolation layer)
Foundation Layer (1E-03)	9	1 (vertical percolation layer)

Layer #	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture [2] (Vol/Vol)
1	1	6		0.396	0.109	0.047	0.109
2	1	30		0.35	0.252	0.181	0.252
3	1	12		0.15	0.1	0.07	0.1
4	1	12		0.35	0.252	0.181	0.252
5	2	12		0.417	0.045	0.018	0.045
6	4	0.06					
7	3	0.2		0.75	0.747	0.4	0.75
8	1	12		0.35	0.252	0.181	0.252
9	1	72		0.457	0.131	0.058	0.131

Layer #	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	3.1E-03					
2	1	4.1E-05					
3	1	1.3E-04					
4	1	4.1E-05					
5	2	5.0E-02	585	2			
6	4	2.0E-13					
7	3	5.0E-09					
8	1	1.0E-06					
9	1	1.0E-03					

Layer #	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
6	4	1	4	2	

Table B-2. HELP Model Input Data for Year 180 (ST01.D10).

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	0.2686 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	2 %
Slope length =	585 ft
Soil Texture =	4 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 46.2	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Lateral Drainage Layer	5	2 (lateral drainage layer)
HDPE Geomembrane	6	4 (geomembrane liner)
GCL	7	3 (barrier soil liner)
Foundation Layer (1E-06)	8	1 (vertical percolation layer)
Foundation Layer (1E-03)	9	1 (vertical percolation layer)

Layer #	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture [2] (Vol/Vol)
1	1	5.96		0.396	0.109	0.047	0.109
2	1	30		0.35	0.252	0.181	0.252
3	1	12		0.15	0.1	0.07	0.1
4	1	12		0.351	0.249	0.179	0.249
5	2	12		0.416	0.048	0.021	0.048
6	4	0.06					
7	3	0.2		0.75	0.747	0.4	0.75
8	1	12		0.35	0.252	0.181	0.252
9	1	72		0.457	0.131	0.058	0.131

Layer #	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	3.1E-03					
2	1	4.1E-05					
3	1	1.3E-04					
4	1	4.57E-05					
5	2	4.48E-02	585	2			
6	4	2.0E-13					
7	3	5.0E-08					
8	1	1.0E-06					
9	1	1.0E-03					

Layer #	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
6	4	1	40	2	

Table B-3. HELP Model Input Data for Year 290 (ST02.D10).

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	0.2686 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	2 %
Slope length =	585 ft
Soil Texture =	4 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 46.2	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Lateral Drainage Layer	5	2 (lateral drainage layer)
HDPE Geomembrane	6	4 (geomembrane liner)
GCL	7	3 (barrier soil liner)
Foundation Layer (1E-06)	8	1 (vertical percolation layer)
Foundation Layer (1E-03)	9	1 (vertical percolation layer)

Layer #	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture [2] (Vol/Vol)
1	1	5.90		0.396	0.109	0.047	0.109
2	1	30		0.35	0.252	0.181	0.252
3	1	12		0.15	0.1	0.07	0.1
4	1	12		0.352	0.244	0.175	0.244
5	2	12		0.414	0.052	0.024	0.052
6	4	0.06					
7	3	0.2		0.75	0.747	0.4	0.75
8	1	12		0.35	0.252	0.181	0.252
9	1	72		0.457	0.131	0.058	0.131

Layer #	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	3.1E-03					
2	1	4.1E-05					
3	1	1.3E-04					
4	1	5.29E-05					
5	2	3.86E-02	585	2			
6	4	2.0E-13					
7	3	5.0E-08					
8	1	1.0E-06					
9	1	1.0E-03					

Layer #	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
6	4	1	96	2	

Table B-4. HELP Model Input Data for Year 300 (ST03.D10).

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	0.2686 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	2 %
Slope length =	585 ft
Soil Texture =	4 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 46.2	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Lateral Drainage Layer	5	2 (lateral drainage layer)
HDPE Geomembrane	6	4 (geomembrane liner)
GCL	7	3 (barrier soil liner)
Foundation Layer (1E-06)	8	1 (vertical percolation layer)
Foundation Layer (1E-03)	9	1 (vertical percolation layer)

Layer #	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture [2] (Vol/Vol)
1	1	5.90		0.396	0.109	0.047	0.109
2	1	30		0.35	0.252	0.181	0.252
3	1	12		0.15	0.1	0.07	0.1
4	1	12		0.352	0.244	0.175	0.244
5	2	12		0.414	0.053	0.024	0.053
6	4	0.06					
7	3	0.2		0.75	0.747	0.4	0.75
8	1	12		0.35	0.252	0.181	0.252
9	1	72		0.457	0.131	0.058	0.131

Layer #	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	3.1E-03					
2	1	4.1E-05					
3	1	1.3E-04					
4	1	5.37E-05					
5	2	3.81E-02	585	2			
6	4	2.0E-13					
7	3	5.0E-08					
8	1	1.0E-06					
9	1	1.0E-03					

Layer #	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
6	4	1	101	2	

Table B-5. HELP Model Input Data for Year 340 (ST04.D10).

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	0.2686 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	2 %
Slope length =	585 ft
Soil Texture =	4 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 46.2	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Lateral Drainage Layer	5	2 (lateral drainage layer)
HDPE Geomembrane & GCL	6	4 (geomembrane liner)
Foundation Layer (1E-06)	7	1 (vertical percolation layer)
Foundation Layer (1E-03)	8	1 (vertical percolation layer)

Layer #	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture [2] (Vol/Vol)
1	1	5.88		0.396	0.109	0.047	0.109
2	1	30		0.35	0.252	0.181	0.252
3	1	12		0.15	0.1	0.07	0.1
4	1	12		0.353	0.242	0.174	0.242
5	2	12		0.414	0.054	0.026	0.054
6	4	0.26					
7	1	12		0.35	0.252	0.181	0.252
8	1	72		0.457	0.131	0.058	0.131

Layer #	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	3.1E-03					
2	1	4.1E-05					
3	1	1.3E-04					
4	1	5.66E-05					
5	2	3.60E-02	585	2			
6	4	8.7E-13					
7	1	1.0E-06					
8	1	1.0E-03					

Layer #	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
6	4	1	121	2	

Table B-6. HELP Model Input Data for Year 380 (ST05.D10).

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	0.2686 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	2 %
Slope length =	585 ft
Soil Texture =	4 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 46.2	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Lateral Drainage Layer	5	2 (lateral drainage layer)
HDPE Geomembrane & GCL	6	4 (geomembrane liner)
Foundation Layer (1E-06)	7	1 (vertical percolation layer)
Foundation Layer (1E-03)	8	1 (vertical percolation layer)

Layer #	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture [2] (Vol/Vol)
1	1	5.85		0.396	0.109	0.047	0.109
2	1	30		0.35	0.252	0.181	0.252
3	1	12		0.15	0.1	0.07	0.1
4	1	12		0.353	0.241	0.172	0.241
5	2	12		0.413	0.056	0.027	0.056
6	4	0.26					
7	1	12		0.35	0.252	0.181	0.252
8	1	72		0.457	0.131	0.058	0.131

Layer #	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	3.1E-03					
2	1	4.1E-05					
3	1	1.3E-04					
4	1	5.98E-05					
5	2	3.41E-02	585	2			
6	4	8.7E-13					
7	1	1.0E-06					
8	1	1.0E-03					

Layer #	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
6	4	1	141	2	

Table B-7. HELP Model Input Data for Year 480 (ST06.D10).

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	0.2686 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	2 %
Slope length =	585 ft
Soil Texture =	4 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 46.2	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Lateral Drainage Layer	5	2 (lateral drainage layer)
HDPE Geomembrane & GCL	6	4 (geomembrane liner)
Foundation Layer (1E-06)	7	1 (vertical percolation layer)
Foundation Layer (1E-03)	8	1 (vertical percolation layer)

Layer #	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture [2] (Vol/Vol)
1	1	5.84		0.396	0.109	0.047	0.109
2	1	30		0.35	0.252	0.181	0.252
3	1	12		0.15	0.1	0.07	0.1
4	1	12		0.354	0.237	0.169	0.237
5	2	12		0.412	0.06	0.03	0.06
6	4	0.26					
7	1	12		0.35	0.252	0.181	0.252
8	1	72		0.457	0.131	0.058	0.131

Layer #	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	3.1E-03					
2	1	4.1E-05					
3	1	1.3E-04					
4	1	6.84E-05					
5	2	2.98E-02	585	2			
6	4	8.7E-13					
7	1	1.0E-06					
8	1	1.0E-03					

Layer #	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
6	4	1	479	2	

Table B-8. HELP Model Input Data for Year 660 (ST07.D10).

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	0.2686 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	2 %
Slope length =	585 ft
Soil Texture =	4 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 46.2	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Lateral Drainage Layer	5	2 (lateral drainage layer)
HDPE Geomembrane & GCL	6	4 (geomembrane liner)
Foundation Layer (1E-06)	7	1 (vertical percolation layer)
Foundation Layer (1E-03)	8	1 (vertical percolation layer)

Layer #	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture [2] (Vol/Vol)
1	1	5.82		0.396	0.109	0.047	0.109
2	1	30		0.35	0.252	0.181	0.252
3	1	12		0.15	0.1	0.07	0.1
4	1	12		0.356	0.23	0.164	0.23
5	2	12		0.409	0.067	0.036	0.067
6	4	0.26					
7	1	12		0.35	0.252	0.181	0.252
8	1	72		0.457	0.131	0.058	0.131

Layer #	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	3.1E-03					
2	1	4.1E-05					
3	1	1.3E-04					
4	1	8.71E-05					
5	2	2.33E-02	585	2			
6	4	8.7E-13					
7	1	1.0E-06					
8	1	1.0E-03					

Layer #	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
6	4	1	1115	2	

Table B-9. HELP Model Input Data for Year 1,100 (ST08.D10).

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	0.2686 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	2 %
Slope length =	585 ft
Soil Texture =	4 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 46.2	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Lateral Drainage Layer	5	2 (lateral drainage layer)
HDPE Geomembrane & GCL	6	4 (geomembrane liner)
Foundation Layer (1E-06)	7	1 (vertical percolation layer)
Foundation Layer (1E-03)	8	1 (vertical percolation layer)

Layer #	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture [2] (Vol/Vol)
1	1	5.76		0.396	0.109	0.047	0.109
2	1	30		0.35	0.252	0.181	0.252
3	1	12		0.15	0.1	0.07	0.1
4	1	12		0.361	0.212	0.15	0.212
5	2	12		0.403	0.084	0.049	0.084
6	4	0.26					
7	1	12		0.35	0.252	0.181	0.252
8	1	72		0.457	0.131	0.058	0.131

Layer #	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	3.1E-03					
2	1	4.1E-05					
3	1	1.3E-04					
4	1	1.58E-04					
5	2	1.28E-02	585	2			
6	4	8.7E-13					
7	1	1.0E-06					
8	1	1.0E-03					

Layer #	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
6	4	1	2669	2	

Table B-10. HELP Model Input Data for Year 1,900 (ST09.D10).

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	0.2686 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	2 %
Slope length =	585 ft
Soil Texture =	4 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 46.2	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Lateral Drainage Layer	5	2 (lateral drainage layer)
HDPE Geomembrane & GCL	6	4 (geomembrane liner)
Foundation Layer (1E-06)	7	1 (vertical percolation layer)
Foundation Layer (1E-03)	8	1 (vertical percolation layer)

Layer #	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture [2] (Vol/Vol)
1	1	5.66		0.396	0.109	0.047	0.109
2	1	30		0.35	0.252	0.181	0.252
3	1	12		0.15	0.1	0.07	0.1
4	1	12		0.371	0.181	0.125	0.181
5	2	12		0.392	0.116	0.074	0.116
6	4	0.26					
7	1	12		0.35	0.252	0.181	0.252
8	1	72		0.457	0.131	0.058	0.131

Layer #	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	3.1E-03					
2	1	4.1E-05					
3	1	1.3E-04					
4	1	4.62E-04					
5	2	4.3E-03	585	2			
6	4	8.7E-13					
7	1	1.0E-06					
8	1	1.0E-03					

Layer #	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
6	4	1	5496	2	

Table B-11. HELP Model Input Data for Year 2,723 (ST10.D10).

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	0.2686 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	**CN Input Parameter Value**
Slope =	2 %
Slope length =	585 ft
Soil Texture =	4 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 46.2	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Lateral Drainage Layer (including Middle Backfill)	4	2 (lateral drainage layer)
HDPE Geomembrane & GCL	5	4 (geomembrane liner)
Foundation Layer (1E-06)	6	1 (vertical percolation layer)
Foundation Layer (1E-03)	7	1 (vertical percolation layer)

Layer #	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture [2] (Vol/Vol)
1	1	5.55		0.396	0.109	0.047	0.109
2	1	30		0.35	0.252	0.181	0.252
3	1	12		0.15	0.1	0.07	0.1
4	2	24		0.38	0.148	0.1	0.148
5	4	0.26					
6	1	12		0.35	0.252	0.181	0.252
7	1	72		0.457	0.131	0.058	0.131

Layer #	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	3.1E-03					
2	1	4.1E-05					
3	1	1.3E-04					
4	2	1.4E-03	585	2			
5	4	8.7E-13					
6	1	1.0E-06					
7	1	1.0E-03					

Layer #	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
6	4	1	8403	2	

Table B-12. HELP Model Input Data for Year 3,300 (ST11.D10).

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	0.2686 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches

CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	2 %
Slope length =	585 ft
Soil Texture =	4 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 46.2	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Lateral Drainage Layer (including Middle Backfill)	4	2 (lateral drainage layer)
HDPE Geomembrane & GCL	5	4 (geomembrane liner)
Foundation Layer (1E-06)	6	1 (vertical percolation layer)
Foundation Layer (1E-03)	7	1 (vertical percolation layer)

Layer #	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture [2] (Vol/Vol)
1	1	5.47		0.396	0.109	0.047	0.109
2	1	30		0.35	0.252	0.181	0.252
3	1	12		0.15	0.1	0.07	0.1
4	2	24		0.38	0.148	0.1	0.148
5	4	0.26					
6	1	12		0.35	0.252	0.181	0.252
7	1	72		0.457	0.131	0.058	0.131

Layer #	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	3.1E-03					
2	1	4.1E-05					
3	1	1.3E-04					
4	2	1.4E-03	585	2			
5	4	8.7E-13					
6	1	1.0E-06					
7	1	1.0E-03					

Layer #	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
6	4	1	10442	2	

Table B-13. HELP Model Input Data for Year 5,700 (ST12.D10).

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	0.2686 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	2 %
Slope length =	585 ft
Soil Texture =	4 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 46.2	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Lateral Drainage Layer (including Middle Backfill)	4	2 (lateral drainage layer)
HDPE Geomembrane & GCL	5	4 (geomembrane liner)
Foundation Layer (1E-06)	6	1 (vertical percolation layer)
Foundation Layer (1E-03)	7	1 (vertical percolation layer)

Layer #	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture [2] (Vol/Vol)
1	1	5.16		0.396	0.109	0.047	0.109
2	1	30		0.35	0.252	0.181	0.252
3	1	12		0.15	0.1	0.07	0.1
4	2	24		0.38	0.148	0.1	0.148
5	4	0.26					
6	1	12		0.35	0.252	0.181	0.252
7	1	72		0.457	0.131	0.058	0.131

Layer #	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	3.1E-03					
2	1	4.1E-05					
3	1	1.3E-04					
4	2	1.4E-03	585	2			
5	4	8.7E-13					
6	1	1.0E-06					
7	1	1.0E-03					

Layer #	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
6	4	1	18921	2	

Table B-14. HELP Model Input Data for Year 10,100 (ST13.D10).

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	0.2686 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	2 %
Slope length =	585 ft
Soil Texture =	4 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 46.2	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Lateral Drainage Layer (including Middle Backfill)	4	2 (lateral drainage layer)
HDPE Geomembrane & GCL	5	4 (geomembrane liner)
Foundation Layer (1E-06)	6	1 (vertical percolation layer)
Foundation Layer (1E-03)	7	1 (vertical percolation layer)

Layer #	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture [2] (Vol/Vol)
1	1	4.59		0.396	0.109	0.047	0.109
2	1	30		0.35	0.252	0.181	0.252
3	1	12		0.15	0.1	0.07	0.1
4	2	24		0.38	0.148	0.1	0.148
5	4	0.26					
6	1	12		0.35	0.252	0.181	0.252
7	1	72		0.457	0.131	0.058	0.131

Layer #	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	3.1E-03					
2	1	4.1E-05					
3	1	1.3E-04					
4	2	1.4E-03	585	2			
5	4	8.7E-13					
6	1	1.0E-06					
7	1	1.0E-03					

Layer #	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
6	4	1	34466	2	

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Appendix C. HELP Model Background Information

HELP Model Weather Input

The HELP model requires the input of evapotranspiration, precipitation, temperature, and solar radiation data. Four input options are available for each type of weather data:

1. Historical records for specific cities (HELP model default)
2. Synthetic data generated using the statistical characteristics of historical data for specific cities
3. Synthetic data generated utilizing mean monthly precipitation and temperature data for the specific location of interest
4. Manual data entry (Schroeder et al. 1994a; Schroeder et al. 1994b)

The default historical weather databases included with HELP versions 3.07 and 4.0 are quite limited with respect to the period covered and the number of cities available. A complete set of historical weather data for either the Savannah River Site (SRS) or Augusta, GA (Option 1) is unavailable in the HELP model. Alternatively, the HELP model will generate up to 100 years of synthetic weather data for many more cities than are included in the default historical weather databases (Option 2). For example, synthetic weather data can be generated for Augusta, GA, but not SRS. A third option is to utilize actual monthly precipitation and temperature data from SRS to modify the synthetic data generated for Augusta, GA. Lastly, manual data entry (Option 4) is time consuming to implement because it requires the availability of daily precipitation, temperature, and solar radiation data as well as placement of the data in a fixed format acceptable to HELP. Option 3 is the best choice for SRS.

One hundred years of synthetic daily precipitation, temperature, and solar radiation data were obtained using HELP's synthetic weather data generator for Augusta, GA as modified with SRS-specific mean monthly precipitation and temperature data. SRS collects meteorological data from a network of nine weather stations. SRS precipitation data has been collected primarily at the SRNL (773-A) weather station between 1952 and 1995 and at the Central Climatology site (CLM) since 1995. The closest weather station to the E-Area LLWF and FTF is the 200-F weather station, where precipitation data has been collected from a manual rain gauge daily (with some exceptions) since 1961. The primary source of SRS temperature data is the SRNL (773-A) weather station from 1968 to 1995 and the CLM from 1995 to present. Temperature data is not collected at the 200-F weather station.

SRS monthly precipitation and temperature data from the combined SRNL/CLM weather stations and precipitation data from the 200-F weather station were obtained from the SRNL Atmospheric Technologies Center website (https://weather.srs.gov/weather/). To be consistent with the HELP model simulations for the FTF design, mean monthly precipitation data from the 200-F weather station and mean monthly temperature data from the combined SRNL/CLM weather stations were used in the HELP model simulations for the E-Area LLWF. Phifer et al. (2007) describes in detail how missing precipitation data from the 200-F weather station was addressed.

Table C-1 provides monthly precipitation totals for the years 1961 to 2006 from the 200-F weather station as reported by Phifer et al. (2007). The mean monthly precipitation rate for this 46-year period is shown on the last line of the table.

Table C-1. Monthly Precipitation Data in Inches for 200-F Weather Station (by Phifer et al., 2007).

Year	Jan	Feb	March	April	May	June	July	August	Sept	October	Nov	Dec
1961	3.55	5.53	7.57	7.23	4.21	2.00	2.94	8.55	0.56	0.02	1.80	6.20
1962	4.35	5.28	6.46	3.85	2.61	1.97	1.74	4.36	4.03	1.87	3.31	2.40
1963	6.05	3.59	3.15	3.18	2.37	7.04	2.00	1.54	5.05	0.00	3.24	4.11
1964	7.67	5.69	5.40	5.81	3.56	5.18	10.99	10.87	5.19	6.44	0.77	4.17
1965	2.12	6.24	8.13	2.45	1.70	4.28	9.63	1.75	2.11	3.00	2.18	1.31
1966	6.82	5.42	4.39	3.26	4.87	3.82	3.88	5.17	4.68	1.37	1.18	3.21
1967	3.56	3.71	7.54	2.60	4.56	2.13	6.28	7.31	1.02	0.53	2.37	2.83
1968	3.92	0.97	1.92	1.83	2.91	4.32	4.93	3.14	1.88	3.03	4.14	2.84
1969	1.85	2.13	3.43	4.20	3.41	4.36	1.99	5.43	5.96	1.96	0.34	3.83
1970	2.78	2.62	7.65	1.33	4.99	3.09	2.87	3.20	0.69	4.29	1.83	5.06
1971	5.01	3.97	8.70	2.85	2.03	6.73	11.52	9.40	2.33	4.91	2.16	3.03
1972	7.93	3.66	2.78	0.47	3.75	5.84	2.68	6.88	1.28	0.76	3.62	4.73
1973	5.31	4.82	6.48	4.97	5.17	8.52	4.50	5.83	3.22	1.22	0.35	4.69
1974	2.68	6.60	2.91	2.63	3.86	4.97	4.00	6.98	3.24	0.01	2.05	4.12
1975	5.45	6.19	5.97	3.98	5.48	3.24	7.65	3.95	7.86	1.00	4.43	4.00
1976	4.22	1.50	3.95	2.22	10.86	6.40	3.28	2.41	5.40	5.54	3.89	4.82
1977	3.86	2.20	7.90	1.02	2.61	3.79	4.02	8.43	4.66	5.44	2.07	5.14
1978	8.44	1.45	3.07	4.85	3.33	1.94	4.13	2.72	3.74	0.20	3.54	2.17
1979	3.41	9.31	3.95	5.37	7.44	1.55	7.55	9.14	7.77	1.38	7.34	2.29
1980	4.29	2.33	11.44	2.31	3.57	3.30	0.99	2.86	7.38	1.95	2.21	1.96
1981	0.93	3.91	3.87	2.71	4.51	5.05	4.39	5.92	0.85	2.88	0.91	8.45
1982	4.73	3.86	1.95	4.90	2.37	4.07	10.53	6.45	5.02	3.61	2.06	4.58
1983	4.00	8.06	5.49	4.71	3.00	2.77	3.71	6.21	3.52	2.21	4.98	3.66
1984	3.53	5.34	6.05	7.11	10.73	1.82	6.46	3.52	1.06	0.40	0.97	1.16
1985	2.98	6.36	1.06	0.83	3.49	4.88	9.82	2.90	0.90	3.77	7.51	2.74
1986	1.18	3.05	2.75	0.96	3.47	2.60	2.61	8.59	0.80	3.05	5.76	4.94
1987	6.79	7.50	4.35	0.75	1.86	5.02	5.68	4.20	2.91	0.32	2.28	1.37
1988	3.74	1.03	2.48	4.88	0.97	6.67	2.24	2.98	4.79	3.50	1.92	1.66
1989	1.24	2.91	4.83	5.89	3.36	5.82	9.51	0.39	4.84	5.51	3.65	3.35
1990	2.91	1.84	1.88	0.94	2.16	3.87	7.65	10.65	0.50	17.84	1.25	2.55
1991	6.73	1.80	7.86	5.43	3.93	3.35	14.4	9.79	2.05	0.80	1.47	3.19
1992	3.63	5.32	2.93	2.74	1.54	8.28	5.18	8.70	2.42	6.21	8.57	2.96
1993	8.90	5.09	8.48	1.37	1.56	6.03	2.87	3.48	6.56	0.61	2.29	1.79
1994	4.81	3.38	6.68	0.98	1.20	4.80	5.54	5.29	1.48	10.5	2.56	4.91
1995	5.97	7.50	0.83	0.93	2.10	12.73	4.27	6.69	5.42	2.31	2.13	3.90
1996	3.08	2.08	6.81	1.69	2.40	4.59	5.55	10.58	3.14	2.09	1.46	2.97
1997	4.20	5.56	2.32	3.88	2.42	6.77	7.02	2.33	5.80	5.54	5.49	7.57
1998	8.42	6.59	6.48	5.97	3.63	3.74	4.79	3.63	8.30	0.78	0.76	1.90
1999	5.82	2.60	3.04	1.34	2.55	8.67	4.70	2.87	5.66	2.24	0.65	1.35
2000	5.80	1.06	3.06	2.08	2.27	6.02	2.90	5.84	6.47	0.02	3.86	2.02
2001	3.21	3.55	6.88	1.44	4.00	6.29	5.30	1.78	5.70	0.04	0.97	0.68
2002	2.07	2.13	3.50	2.19	1.54	2.75	4.76	6.02	3.87	3.34	5.64	4.20
2003	1.62	5.97	8.10	9.67	6.60	7.28	5.86	3.09	2.32	3.10	1.30	2.27
2004	4.63	6.81	0.99	1.69	2.47	8.49	3.01	4.21	10.54	3.32	4.11	3.81
2005	2.88	3.96	6.57	1.35	3.82	7.78	5.09	6.00	0.20	4.80	2.42	6.33
2006	3.47	3.37	2.45	3.22	1.53	7.73	5.88	1.49	2.34	2.53	3.25	5.12
Monthly Average Precip.	4.36	4.21	4.88	3.18	3.54	5.05	5.38	5.29	3.82	2.96	2.85	3.53

All precipitation data is from the 200-F Weather Station, except as noted below:

- 200-F Weather Station precipitation data is unavailable in the SRS ATG Climate Data database on the following days: 3/30/1967, 3/31/1967, 4/1/1967 through 4/18/1967, 11/4/1968, 10/31/1970, 1/24/1971, 11/27/1971, and 10/31/1998.

- The monthly data highlighted in grey represents months where some daily precipitation data is missing from the 200-F weather station database (i.e., possible underreporting). For these seven instances, if the monthly precipitation total for the combined SRNL/CLM weather stations exceeded the value reported by the 200-F weather station, the monthly total for the combined SRNL/CLM weather stations was used instead.
    - March 1967: Monthly 200-F precipitation total of 5.29 inches was replaced with the monthly combined SRNL/CLM total of 7.54 inches.
    - April 1967: Monthly 200-F precipitation total of 2.58 inches was replaced with the monthly combined SRNL/CLM total of 2.6 inches.
    - November 1968: Monthly 200-F precipitation total of 2.89 inches was replaced with the monthly combined SRNL/CLM total of 4.14 inches.
    - October 1970: Monthly 200-F precipitation total of 4.29 inches was retained.
    - January 1971: Monthly 200-F precipitation total of 4.47 inches was replaced with the monthly combined SRNL/CLM total of 5.01 inches.
    - November 1971: Monthly 200-F precipitation total of 1.75 inches was replaced with the monthly combined SRNL/CLM total of 2.16 inches.
    - October 1998: Monthly 200-F precipitation total of 0.78 inches was retained.

Table C-2 provides monthly temperature data for the years 1968 through 2006 obtained from the combined SRNL/CLM weather stations. The mean monthly temperature for this 39-year period is shown on the last line of the table.

Evapotranspiration data, which is considered constant from year to year, was based on HELP-model default data for Augusta, GA. The evaporative zone depth is the maximum depth to which the HELP model will allow evapotranspiration to occur. An evaporative zone “fair” depth of 22 inches was chosen based on guidance from the HELP manual (Schroeder et al., 1994b). Twenty-two inches is considered a conservative maximum evaporative-zone depth due to anticipated capillarity associated with the surficial soil types (i.e., topsoil and upper backfill) and the anticipated root depths. The maximum leaf area index (LAI) is a measure of the maximum active biomass that the HELP model allows to be present. The actual LAI utilized by the HELP model is modified from the maximum based upon daily temperature, daily solar radiation, and the beginning and ending dates of the growing season. A maximum LAI equal to 3.5 (good stand of grass) was chosen based on guidance from the HELP manual (Schroeder et al., 1994b).

The methodology used by the HELP model to calculate the evapotranspiration rate is described in detail by Schroeder et al. (1994b). The methodology takes into consideration daily solar radiation, daily temperature, humidity, wind speed, vegetation type, LAI, growing season, surface and soil water content, maximum evaporative depth, soil water transport, and soil capillarity. The vegetative cover for the E-Area LLWF closure cap is initially assumed to be Bahia grass before pine-tree intrusion 160 years after cap installation. Figure C-1 displays the HELP model evapotranspiration input file FEVAP.D11 used in the E-Area LLWF intact infiltration simulations.

FEVAP.D11

```
 1
AUGUSTA                       GEORGIA
33.22        68 323 3.5     22.     6.5   68.0 70.0 77.0 73.0

```

Figure C-1. FEVAP.D11 file used in E-Area LLWF intact infiltration HELP model simulations.

Table C-2. Monthly Temperature Data in Degrees Fahrenheit for SRNL/CLM Weather Station.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1968	43.5	43.4	57.1	66.5	71.3	80	83.1	82.8	77	67	55.4	45.9
1969	46.5	46.6	51.5	64.5	70.5	80.3	83.3	77.6	72.8	66.1	52.1	45.4
1970	39	47.2	55.9	66.8	74.2	79	81.1	80.8	78.6	67	51.6	49.3
1971	44.6	46.4	49.5	63.4	70.7	81.3	80.7	80.4	75.2	70.2	55.5	56.9
1972	51.7	45.6	57.6	67.4	72.4	75.3	79.7	80.6	77.2	64.8	54.4	53.2
1973	46.1	45.9	60.7	61.9	70.5	77.7	79.1	74.5	70.5	62.4	59	50.3
1974	59.6	50.8	62.2	66.2	75.3	77.5	81.5	80.9	75.3	64.5	56.6	49
1975	51.4	53.2	55.8	63.9	75.6	79.1	79.7	82.4	75.7	68.7	59.3	48.5
1976	44.2	55.7	61.5	64.8	68.9	75.6	80.4	78	73.1	60.1	48.7	44.8
1977	35.3	47.1	60	66.9	73.3	80.6	83.6	80.6	77.9	62.1	58.2	46.7
1978	39.3	41.3	54.2	65.7	70.9	79.7	82.1	81.2	77.1	65.6	60.7	49.6
1979	42.1	44.6	57.5	64.5	71.3	75.1	79.6	80.5	73.4	64.8	57.4	47.4
1980	45.9	44.3	52.6	63.5	71.2	78.3	83.8	82.5	79.2	62.7	52.8	46
1981	40.4	48.5	53	67	68.6	81.3	81.3	76.3	74	62.1	54.4	43.2
1982	43	50	58.9	62.4	75.7	78.8	80.9	80.1	75	66.2	58.7	54.8
1983	43.3	48	55.3	59.4	66.8	76.7	84.3	83.9	74.8	67.2	56.4	45.8
1984	45	51.7	56.5	62.6	71.9	80.1	80.1	80.8	74	73.4	53.4	56.9
1985	42.9	49.5	60.2	67.5	74.5	80.8	81.1	79.7	75.7	70.8	65.5	45.4
1986	45.4	54.6	57.9	66.4	74.4	82.7	86.9	80.1	78.4	67.1	61.3	49.3
1987	46.2	48.6	56.5	62.3	74.5	79.9	82.8	83.8	76.6	60.7	59.1	52.9
1988	42.3	47.8	56.8	64.2	70.4	76.8	81.6	81.4	75.4	61.2	58	49.1
1989	52.2	52	58.3	64.2	70.6	79.8	81.4	80.9	75.3	67.3	52.4	44.2
1990	54.9	57.5	60	64	72.9	80.5	83.7	83.8	79	69.4	59.9	54.6
1991	47.9	54.1	60.3	69.2	76.9	79.5	83.6	81.2	77.4	68.1	55.4	54
1992	49.5	54.1	57.2	65	71.2	78.9	83.7	80.7	76.9	65	57.1	48
1993	51.7	47.8	53.2	58.9	69.7	78.2	83.6	80	75.2	62.8	55.2	43.6
1994	41.5	50.1	60.2	68	71.2	82.3	81.8	81.2	77.4	67.2	62.3	53.3
1995	45.5	49.9	58.6	65.9	73.5	75	79.9	79	71.8	65.9	50.8	43.8
1996	44.6	50.1	50.6	61.6	72.9	76.5	79.3	76	72.7	62.1	51.6	48.8
1997	48.2	52.9	63.3	61.2	68.5	74	80.2	79	75	64.1	51.6	47
1998	49.7	51.1	53.6	62.7	74.6	82.1	82.6	80.3	75.8	66.9	60.5	53.6
1999	51.9	51.6	53.4	67.2	69.7	76.6	80.7	82.9	73.8	64.3	58.1	48.6
2000	44.4	50.2	58.5	60.7	75.1	78	79.9	77.6	71.7	62.5	53.1	38.2
2001	43.8	52.4	53	63.9	71.3	75.3	77.7	78.8	71.2	62.2	60	52.4
2002	47.3	48	57.6	68.1	70.2	77.5	80.5	78.4	75.4	66.7	51.7	44.5
2003	42	47.5	57.6	61.6	70.6	75.2	77.3	77.7	71.9	63.7	58.2	42.9
2004	43.7	45.2	58.5	63.4	74	77.7	80.1	77.3	73.2	66.2	56.1	45.8
2005	47.9	49	53.1	60.9	68	75.4	79.4	78.8	77	64.7	56.1	44.3
2006	50.8	47.3	55.3	66.3	70.1	76.2	80.3	80.5	72.9	62.4	53.6	50.6
Mean	**46.0**	**49.3**	**56.8**	**64.4**	**71.9**	**78.3**	**81.3**	**80.1**	**75.1**	**65.3**	**56.2**	**48.4**

Appendix D. Python Source Code for Revised Probabilistic Model (Rev. 6, Design-Checked)

```
#!/bin/env python

import sys
import random
import numpy

print "Running:", sys.argv[0]

### Read filenames
prefixFile             = sys.argv[1]  # prefix for output files
compartmentsSize = float(sys.argv[2]) # size of compartment (feet)
compartmentsTotal  = int(sys.argv[3]) # total number of compartments
percentSubsided  = float(sys.argv[4]) # percent subsidence
F_notET          = float(sys.argv[5]) # annual average rainfall minus evapotranspiration
F_intact         = float(sys.argv[6]) # intact infiltration rate
realizations       = int(sys.argv[7]) # (number of Monte Carlo realizations)
debugArg               = sys.argv[8]  # debug flag (true or false)
graphicArg             = sys.argv[9]  # graphic flag for .out file (>>>>>>O>>>>>>)
appendFlag            = sys.argv[10]  # append flag for summary file (w for overwrite or a for append)

slopeLength = compartmentsSize*float(compartmentsTotal)

F_netRunoff = F_notET - F_intact

outputFile = prefixFile + ".out"
summaryFile = prefixFile + ".sum"
tabFile = prefixFile + ".tab"

if debugArg == "True":
    debugFlag = 1
else:
    debugFlag = 0

if graphicArg == "True":
    graphicFlag = 1
else:
    graphicFlag = 0

print "    compartmentsSize:", compartmentsSize
print "   compartmentsTotal:", compartmentsTotal
print "         slopeLength:", slopeLength
print "     percentSubsided:", percentSubsided
print "             F_notET:", F_notET
print "            F_intact:", F_intact
print "        realizations:", realizations
print "          outputFile:", outputFile
```

```
output = open(outputFile, 'w')
output.write("                 Compartment size: %f\n" % (compartmentsSize))
output.write("     Total number of compartments: %d\n" % (compartmentsTotal))
output.write("                     Slope length: %f\n" % (slopeLength))
output.write("    Percent subsided compartments: %f\n" % (percentSubsided))
output.write("               Flux, intact cover: %f\n" % (F_intact))
output.write("             Flux, subsided cover: %f\n" % (F_notET))
output.write("                     Realizations: %d\n" % (realizations))

summary = open(summaryFile, 'w')
summary.write("                 Compartment size: %f\n" % (compartmentsSize))
summary.write("     Total number of compartments: %d\n" % (compartmentsTotal))
summary.write("                     Slope length: %f\n" % (slopeLength))
summary.write("    Percent subsided compartments: %f\n" % (percentSubsided))
summary.write("               Flux, intact cover: %f\n" % (F_intact))
summary.write("             Flux, subsided cover: %f\n" % (F_notET))
summary.write("                     Realizations: %d\n" % (realizations))

tabdelimited = open(tabFile, 'w')


### Subsided trench compartments
if debugFlag or graphicFlag: output.write("================================================================================\n")
if debugFlag:
    output.write("Subsided compartments followed by upslope ratios\n")
elif graphicFlag:
    output.write("Subsided compartments\n")

compartments = range(1,compartmentsTotal+1)
if debugFlag: print "compartments:", compartments

stringIntact = []
for key in compartments:
    stringIntact.append(">")
if debugFlag: print stringIntact

realization = 0

countSubsided = 0
countTotal = 0

maxCompartments = 0
minCompartments = [compartmentsTotal]
avgCompartments = float(0)

slicesIntact = 0
slicesSubsided = 0
slicesTotal = 0

avgLength = float(0)
avgCount = 0
```

```
lengths = []

avgLengthSingleHole = float(0)
avgCountSingleHole = 0

lengthsSingleHole = []

infiltration = float(0)

precise = 1000

while realization < realizations:    #Monte Carlo loop
    realization += 1
    if debugFlag: print realization

    ### Randomly place subsided compartments
    subsided = []
    localCount = 0
    for i in compartments:
        draw = float(random.uniform(0,100*precise))/float(precise)
        countTotal += 1
        if draw < percentSubsided:
            countSubsided += 1
            subsided.append(i)
            localCount += 1
    maxCompartments = max(maxCompartments, localCount)
    minCompartments = min(minCompartments, localCount)
    avgCompartments = avgCompartments + float(localCount)

    if debugFlag: print "subsided:", subsided

    sortedSubsided = sorted(subsided, key=float)
    if debugFlag: print "sortedSubsided:", sortedSubsided

    stringSubsided = list(stringIntact)
    for key in sortedSubsided:
        stringSubsided[int(key)-1] = 'O'
    if debugFlag: print "stringSubsided:", "".join(stringSubsided)

    ### Tally subsided versus intact slices (realizations)
    slicesTotal += 1
    if len(sortedSubsided) == 0:
        slicesIntact += 1
    else:
        slicesSubsided += 1

    ### Compute upslope length for slices with holes
    lengthSubsided = []

    for i in range(len(sortedSubsided)):
```

```
        if i == 0:
            length = sortedSubsided[i] - 1
        else:
            length = sortedSubsided[i] - sortedSubsided[i-1] - 1
        lengths.append(length)

        if debugFlag: print "i, sortedSubsided[i], length:", i, sortedSubsided[i], length

        lengthSubsided.append(length)

    if debugFlag: print "lengthSubsided:", lengthSubsided

    if debugFlag: print >> output, sortedSubsided
    if graphicFlag: print >> output, "".join(stringSubsided)

    for i in range(len(lengthSubsided)):
        avgCount += 1
        avgLength += lengthSubsided[i]
        if debugFlag: output.write("%s\n" % (lengthSubsided[i]))

    ### Compute upslope length after consolidating to 1 hole
    if len(sortedSubsided) > 0:
        iBottomHole = len(sortedSubsided)-1
        lengthSingleHole = sortedSubsided[iBottomHole] - 1
        lengthsSingleHole.append(lengthSingleHole)

        if debugFlag: print "iBottomHole, sortedSubsided[iBottomHole], lengthSingleHole:", iBottomHole, sortedSubsided[iBottomHole],
lengthSingleHole

        avgCountSingleHole += 1
        avgLengthSingleHole += lengthSingleHole

        if debugFlag: output.write("%s single hole\n" % (lengthSingleHole))

    ### Compute infiltration
    infiltration = infiltration + float(compartmentsTotal - localCount)*F_intact

    for i in range(len(sortedSubsided)):
        if i == 0:
            length = sortedSubsided[i] - 1
        else:
            length = sortedSubsided[i] - sortedSubsided[i-1] - 1

        infiltration += F_notET + length*F_netRunoff


### Compute statistics / proportions
avgCompartments /= float(realizations)

sampleSubsided = float(countSubsided)/float(countTotal)*100
```

```
if avgCount > 0:
    avgLength /= float(avgCount)
else:
    avgLength = -999

if len(lengths) > 0:
    medianLength = numpy.median(lengths)
    meanLength = numpy.mean(lengths)
    minLength = numpy.min(lengths)
    maxLength = numpy.max(lengths)
else:
    medianLength = -999
    meanLength = -999
    minLength = -999
    maxLength = -999

if avgCountSingleHole > 0:
    avgLengthSingleHole /= float(avgCountSingleHole)
else:
    avgLengthSingleHole = -999

if len(lengthsSingleHole) > 0:
    medianLengthSingleHole = numpy.median(lengthsSingleHole)
    meanLengthSingleHole = numpy.mean(lengthsSingleHole)
    minLengthSingleHole = numpy.min(lengthsSingleHole)
    maxLengthSingleHole = numpy.max(lengthsSingleHole)
else:
    medianLengthSingleHole = -999
    meanLengthSingleHole = -999
    minLengthSingleHole = -999
    maxLengthSingleHole = -999

fractionSlicesIntact = float(slicesIntact)/float(slicesTotal)
fractionSlicesSubsided = float(slicesSubsided)/float(slicesTotal)

### Compute infiltration, assuming one hole per subsided slice

# Monte Carlo average
F_coverAvg = infiltration/(float(realizations)*float(compartmentsTotal))

# preparation
f_subsidedSliceIntact   = (float(compartmentsTotal) - 1.)/float(compartmentsTotal)
f_subsidedSliceSubsided =                              1./float(compartmentsTotal)

F_runonAvg = avgLengthSingleHole*F_netRunoff

# local
F_intactAvg = F_intact
F_subsidedAvg = F_notET + F_runonAvg

# aligned with slope
```

```
F_intactDownAvg = F_intactAvg
F_subsidedDownAvg = f_subsidedSliceIntact*F_intactAvg + f_subsidedSliceSubsided*F_subsidedAvg

F_coverDownAvg = fractionSlicesIntact*F_intactDownAvg + fractionSlicesSubsided*F_subsidedDownAvg

# transverse to slope
F_intactAcrossAvg = F_intactAvg
F_subsidedAcrossAvg = fractionSlicesIntact*F_intactAvg + fractionSlicesSubsided*F_subsidedAvg

F_coverAcrossAvg = f_subsidedSliceIntact*F_intactAcrossAvg + f_subsidedSliceSubsided*F_subsidedAcrossAvg

###write output to file
output.write("================================================================================\n")
output.write("Percent subsided/Avg upslope ratio\n")
output.write("\t%.2f/%.2f\n" % (percentSubsided, avgLength))

output.write("Percent subsided/Avg upslope ratio single hole\n")
output.write("\t%.2f/%.2f\n" % (percentSubsided, avgLengthSingleHole))

output.write("Sample subsided\n")
output.write("\t%.2f\n" % (sampleSubsided))

output.write("Min/avg/max compartments\n")
output.write("\t%d/%.2f/%d\n" % (minCompartments, avgCompartments, maxCompartments))

output.write("Min/median/mean/max length\n")
output.write("\t%.2f/%.2f/%.2f/%.2f\n" % (minLength, medianLength, meanLength, maxLength))

output.write("Min/median/mean/max single hole length\n")
output.write("\t%.2f/%.2f/%.2f/%.2f\n" % (minLengthSingleHole, medianLengthSingleHole, meanLengthSingleHole, maxLengthSingleHole))

output.write("Slices intact/subsided (%)\n")
output.write("\t%.2f/%.2f\n" % (fractionSlicesIntact*100, fractionSlicesSubsided*100))

output.write("Subsided slice intact/subsided (%)\n")
output.write("\t%.2f/%.2f\n" % (f_subsidedSliceIntact*100, f_subsidedSliceSubsided*100))

output.write("Fluxes notET/intact/runoff (in/yr)\n")
output.write("\t%f/%f/%f\n" % (F_notET,F_intact,F_netRunoff))

output.write("Fluxes intactAvg/subsidedAvg (in/yr)\n")
output.write("\t%f/%f\n" % (F_intactAvg,F_subsidedAvg))

output.write("Fluxes intactDownAvg/subsidedDownAvg/coverDownAvg (in/yr)\n")
output.write("\t%f/%f/%f\n" % (F_intactDownAvg,F_subsidedDownAvg,F_coverDownAvg))

output.write("Fluxes intactAcrossAvg/subsidedAcrossAvg/coverAcrossAvg (in/yr)\n")
output.write("\t%f/%f/%f\n" % (F_intactAcrossAvg,F_subsidedAcrossAvg,F_coverAcrossAvg))

output.write("Fluxes coverAvg (in/yr)\n")
output.write("\t%f\n" % (F_coverAvg))
```

```
summary.write("================================================================================\n")
summary.write("Percent subsided/Avg upslope ratio\n")
summary.write("\t%.2f/%.2f\n" % (percentSubsided, avgLength))

summary.write("Percent subsided/Avg upslope ratio single hole\n")
summary.write("\t%.2f/%.2f\n" % (percentSubsided, avgLengthSingleHole))

summary.write("Sample subsided\n")
summary.write("\t%.2f\n" % (sampleSubsided))

summary.write("Min/avg/max compartments\n")
summary.write("\t%d/%.2f/%d\n" % (minCompartments, avgCompartments, maxCompartments))

summary.write("Min/median/mean/max length\n")
summary.write("\t%.2f/%.2f/%.2f/%.2f\n" % (minLength, medianLength, meanLength, maxLength))

summary.write("Min/median/mean/max single hole length\n")
summary.write("\t%.2f/%.2f/%.2f/%.2f\n" % (minLengthSingleHole, medianLengthSingleHole, meanLengthSingleHole, maxLengthSingleHole))

summary.write("Slices intact/subsided (%)\n")
summary.write("\t%.2f/%.2f\n" % (fractionSlicesIntact*100, fractionSlicesSubsided*100))

summary.write("Subsided slice intact/subsided (%)\n")
summary.write("\t%.2f/%.2f\n" % (f_subsidedSliceIntact*100, f_subsidedSliceSubsided*100))

summary.write("Fluxes notET/intact/runoff (in/yr)\n")
summary.write("\t%f/%f/%f\n" % (F_notET,F_intact,F_netRunoff))

summary.write("Fluxes intactAvg/subsidedAvg (in/yr)\n")
summary.write("\t%f/%f\n" % (F_intactAvg,F_subsidedAvg))

summary.write("Fluxes intactDownAvg/subsidedDownAvg/coverDownAvg (in/yr)\n")
summary.write("\t%f/%f/%f\n" % (F_intactDownAvg,F_subsidedDownAvg,F_coverDownAvg))

summary.write("Fluxes intactAcrossAvg/subsidedAcrossAvg/coverAcrossAvg (in/yr)\n")
summary.write("\t%f/%f/%f\n" % (F_intactAcrossAvg,F_subsidedAcrossAvg,F_coverAcrossAvg))

summary.write("Fluxes coverAvg (in/yr)\n")
summary.write("\t%f\n" % (F_coverAvg))

###write output to screen
print ("percentSubsided/avgLength/avgLengthSingleHole: \n\t%.2f/%.2f/%.2f" % (percentSubsided, avgLength, avgLengthSingleHole))

print ("sampleSubsided: %.2f" % (sampleSubsided))

print ("Slices intact/subsided (%)")
print ("\t%.2f/%.2f" % (fractionSlicesIntact*100, fractionSlicesSubsided*100))

print ("Subsided slice intact/subsided (%)")
print ("\t%.2f/%.2f" % (f_subsidedSliceIntact*100, f_subsidedSliceSubsided*100))
```

```
print ("Fluxes notET/intact/runoff (in/yr)")
print ("\t%f/%f/%f" % (F_notET,F_intact,F_netRunoff))

print ("Fluxes intactAvg/subsidedAvg (in/yr)")
print ("\t%f/%f" % (F_intactAvg,F_subsidedAvg))

print ("Fluxes intactDownAvg/subsidedDownAvg/coverDownAvg (in/yr)")
print ("\t%f/%f/%f" % (F_intactDownAvg,F_subsidedDownAvg,F_coverDownAvg))

print ("Fluxes intactAcrossAvg/subsidedAcrossAvg/coverAcrossAvg (in/yr)")
print ("\t%f/%f/%f" % (F_intactAcrossAvg,F_subsidedAcrossAvg,F_coverAcrossAvg))

print ("Fluxes coverAvg (in/yr)")
print ("\t%f" % (F_coverAvg))

### write one-line, tab-delimited, results summary
tabdelimited.write("%f\t%d\t%f\t%f\t%f\t%f\t%d\t%f\t%f\t%f\t%f\t%f\t%f\n" %
(compartmentsSize,compartmentsTotal,slopeLength,percentSubsided,F_notET,F_intact,realizations,avgLengthSingleHole,fractionSlicesIntact
,fractionSlicesSubsided,f_subsidedSliceIntact,f_subsidedSliceSubsided,F_coverAvg))
```

Appendix E. Windows Batch File for Python Probabilistic Model (runPython_rev6.bat)

```
SubsidedAverage_rev6.py Case_2Percent 10. 55 2.0 16.5 0.00088 100000 False True w
SubsidedAverage_rev6.py Case_2Percent 10. 55 2.0 16.5 0.00791 100000 False True a
SubsidedAverage_rev6.py Case_2Percent 10. 55 2.0 16.5 0.18881 100000 False True a
SubsidedAverage_rev6.py Case_2Percent 10. 55 2.0 16.5 0.20409 100000 False True a
SubsidedAverage_rev6.py Case_2Percent 10. 55 2.0 16.5 0.32167 100000 False True a
SubsidedAverage_rev6.py Case_2Percent 10. 55 2.0 16.5 0.40513 100000 False True a
SubsidedAverage_rev6.py Case_2Percent 10. 55 2.0 16.5 1.45728 100000 False True a
SubsidedAverage_rev6.py Case_2Percent 10. 55 2.0 16.5 3.23003 100000 False True a
SubsidedAverage_rev6.py Case_2Percent 10. 55 2.0 16.5 7.01494 100000 False True a
SubsidedAverage_rev6.py Case_2Percent 10. 55 2.0 16.5 10.6499 100000 False True a
SubsidedAverage_rev6.py Case_2Percent 10. 55 2.0 16.5 11.4721 100000 False True a
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Appendix F. Probabilistic Model Results for 2%, 0.6%, and 0.04% Subsidence Cases

Relative Year	Hole/ Compartment Size (ft)	Number of Compartments	Slope Length (ft)	Percent Subsidence	Infiltration Rate Less Evapotranspiration (in/yr)	Intact Infiltration Rate (in/yr)	Number of Realizations	Upslope-to-Subsided Area Ratio	Spatially Averaged Infiltration Rate (in/yr)
100	10	55	545	2.0	16.5	0.00088	100000	31.995842	6.666
180	10	55	545	2.0	16.5	0.00791	100000	31.964409	6.623
290	10	55	545	2.0	16.5	0.189	100000	31.884703	6.732
300	10	55	545	2.0	16.5	0.204	100000	31.993873	6.762
340	10	55	545	2.0	16.5	0.322	100000	31.974757	6.800
380	10	55	545	2.0	16.5	0.405	100000	31.96544	6.873
480	10	55	545	2.0	16.5	1.457	100000	32.01136	7.498
660	10	55	545	2.0	16.5	3.230	100000	32.057815	8.577
1100	10	55	545	2.0	16.5	7.015	100000	32.111109	10.845
1900	10	55	545	2.0	16.5	10.650	100000	31.946176	13.004
2723	10	55	545	2.0	16.5	11.472	100000	32.074937	13.501
3300	10	55	545	2.0	16.5	11.532	100000	32.157665	13.545
5700	10	55	545	2.0	16.5	11.631	100000	31.960888	13.582
10100	10	55	545	2.0	16.5	11.673	100000	31.882378	13.608
100	10	11	110	2.0	16.5	0.00088	100000	5.166633	1.856
180	10	11	110	2.0	16.5	0.00791	100000	5.219773	1.865
290	10	11	110	2.0	16.5	0.189	100000	5.19519	1.999
300	10	11	110	2.0	16.5	0.204	100000	5.223046	2.058
340	10	11	110	2.0	16.5	0.322	100000	5.207385	2.154
380	10	11	110	2.0	16.5	0.405	100000	5.208052	2.221
480	10	11	110	2.0	16.5	1.457	100000	5.234363	3.171
660	10	11	110	2.0	16.5	3.230	100000	5.14841	4.711
1100	10	11	110	2.0	16.5	7.015	100000	5.173258	8.074
1900	10	11	110	2.0	16.5	10.650	100000	5.187183	11.311
2723	10	11	110	2.0	16.5	11.472	100000	5.210228	12.033
3300	10	11	110	2.0	16.5	11.532	100000	5.212401	12.098
5700	10	11	110	2.0	16.5	11.631	100000	5.192732	12.175
10100	10	11	110	2.0	16.5	11.673	100000	5.216353	12.210

Upslope-to-Subsided Area Ratio: Ratio of intact area upslope of the subsided compartment to the area of the subsided compartment

Figure F-1. Probabilistic Model Results for 2% Subsidence Case at 545 feet and 110 feet Slope Lengths.

Relative Year	Hole/ Compartment Size (ft)	Number of Compartments	Slope Length (ft)	Percent Subsidence	Infiltration Rate Less Evapotranspiration (in/yr)	Intact Infiltration Rate (in/yr)	Number of Realizations	Upslope-to-Subsided Area Ratio	Spatially Averaged Infiltration Rate (in/yr)
100	10	55	545	0.6	16.5	0.00088	100000	28.555825	2.485
180	10	55	545	0.6	16.5	0.00791	100000	28.559915	2.509
290	10	55	545	0.6	16.5	0.189	100000	28.475616	2.652
300	10	55	545	0.6	16.5	0.204	100000	28.392882	2.668
340	10	55	545	0.6	16.5	0.322	100000	28.481532	2.778
380	10	55	545	0.6	16.5	0.405	100000	28.432932	2.826
480	10	55	545	0.6	16.5	1.457	100000	28.46334	3.763
660	10	55	545	0.6	16.5	3.230	100000	28.430699	5.242
1100	10	55	545	0.6	16.5	7.015	100000	28.636351	8.460
1900	10	55	545	0.6	16.5	10.650	100000	28.44012	11.528
2723	10	55	545	0.6	16.5	11.472	100000	28.329704	12.226
3300	10	55	545	0.6	16.5	11.532	100000	28.561735	12.293
5700	10	55	545	0.6	16.5	11.631	100000	28.450759	12.366
10100	10	55	545	0.6	16.5	11.673	100000	28.464227	12.397
100	10	11	110	0.6	16.5	0.00088	100000	5.086258	0.586
180	10	11	110	0.6	16.5	0.00791	100000	5.0892	0.601
290	10	11	110	0.6	16.5	0.189	100000	5.062192	0.773
300	10	11	110	0.6	16.5	0.204	100000	5.079834	0.790
340	10	11	110	0.6	16.5	0.322	100000	5.099797	0.896
380	10	11	110	0.6	16.5	0.405	100000	5.021406	0.969
480	10	11	110	0.6	16.5	1.457	100000	5.047359	1.988
660	10	11	110	0.6	16.5	3.230	100000	5.002485	3.696
1100	10	11	110	0.6	16.5	7.015	100000	5.054658	7.351
1900	10	11	110	0.6	16.5	10.650	100000	5.0702	10.858
2723	10	11	110	0.6	16.5	11.472	100000	5.029262	11.651
3300	10	11	110	0.6	16.5	11.532	100000	5.050615	11.707
5700	10	11	110	0.6	16.5	11.631	100000	5.047422	11.800
10100	10	11	110	0.6	16.5	11.673	100000	5.025455	11.845

Upslope-to-Subsided Area Ratio: Ratio of intact area upslope of the subsided compartment to the area of the subsided compartment

Figure F-2. Probabilistic Model Results for 0.6% Subsidence Case at 545 feet and 110 feet Slope Lengths.

Relative Year	Hole/ Compartment Size (ft)	Number of Compartments	Slope Length (ft)	Percent Subsidence	Infiltration Rate Less Evapotranspiration (in/yr)	Intact Infiltration Rate (in/yr)	Number of Realizations	Upslope-to-Subsided Area Ratio	Spatially Averaged Infiltration Rate (in/yr)
100	10	55	545	0.04	16.5	0.00088	100000	26.561726	0.181
180	10	55	545	0.04	16.5	0.00791	100000	27.062992	0.190
290	10	55	545	0.04	16.5	0.189	100000	26.944268	0.372
300	10	55	545	0.04	16.5	0.204	100000	27.633975	0.385
340	10	55	545	0.04	16.5	0.322	100000	27.353738	0.500
380	10	55	545	0.04	16.5	0.405	100000	26.921834	0.592
480	10	55	545	0.04	16.5	1.457	100000	26.620562	1.621
660	10	55	545	0.04	16.5	3.230	100000	27.585934	3.378
1100	10	55	545	0.04	16.5	7.015	100000	26.796537	7.115
1900	10	55	545	0.04	16.5	10.650	100000	26.490838	10.717
2723	10	55	545	0.04	16.5	11.472	100000	26.746697	11.528
3300	10	55	545	0.04	16.5	11.532	100000	26.869094	11.590
5700	10	55	545	0.04	16.5	11.631	100000	27.100554	11.685
10100	10	55	545	0.04	16.5	11.673	100000	26.380135	11.727
100	10	11	110	0.04	16.5	0.00088	100000	4.898004	0.041
180	10	11	110	0.04	16.5	0.00791	100000	4.629545	0.045
290	10	11	110	0.04	16.5	0.189	100000	4.924107	0.228
300	10	11	110	0.04	16.5	0.204	100000	5.113786	0.245
340	10	11	110	0.04	16.5	0.322	100000	5.201717	0.364
380	10	11	110	0.04	16.5	0.405	100000	5.145089	0.445
480	10	11	110	0.04	16.5	1.457	100000	4.893905	1.493
660	10	11	110	0.04	16.5	3.230	100000	4.906475	3.260
1100	10	11	110	0.04	16.5	7.015	100000	4.934272	7.037
1900	10	11	110	0.04	16.5	10.650	100000	5.147992	10.665
2723	10	11	110	0.04	16.5	11.472	100000	4.955882	11.483
3300	10	11	110	0.04	16.5	11.532	100000	4.813084	11.543
5700	10	11	110	0.04	16.5	11.631	100000	4.936916	11.643
10100	10	11	110	0.04	16.5	11.673	100000	5.046948	11.685

Upslope-to-Subsided Area Ratio: Ratio of intact area upslope of the subsided compartment to the area of the subsided compartment

Figure F-3. Probabilistic Model Results for 0.04% Subsidence Case at 545 feet and 110 feet Slope Lengths.

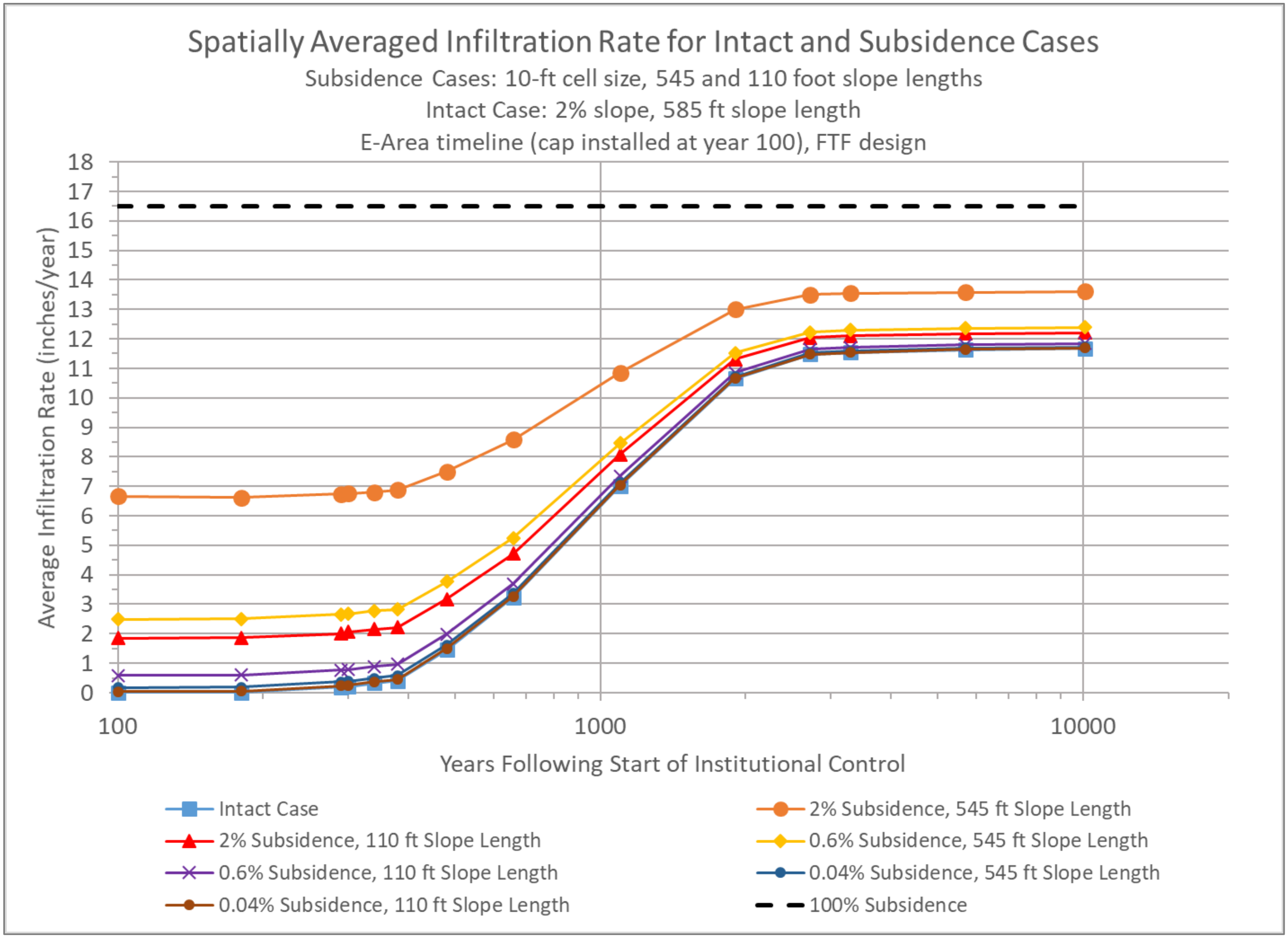

Figure F-4. Spatially Averaged Infiltration Rate vs. Time for Individual Intact and Subsidence Cases (linear-log).

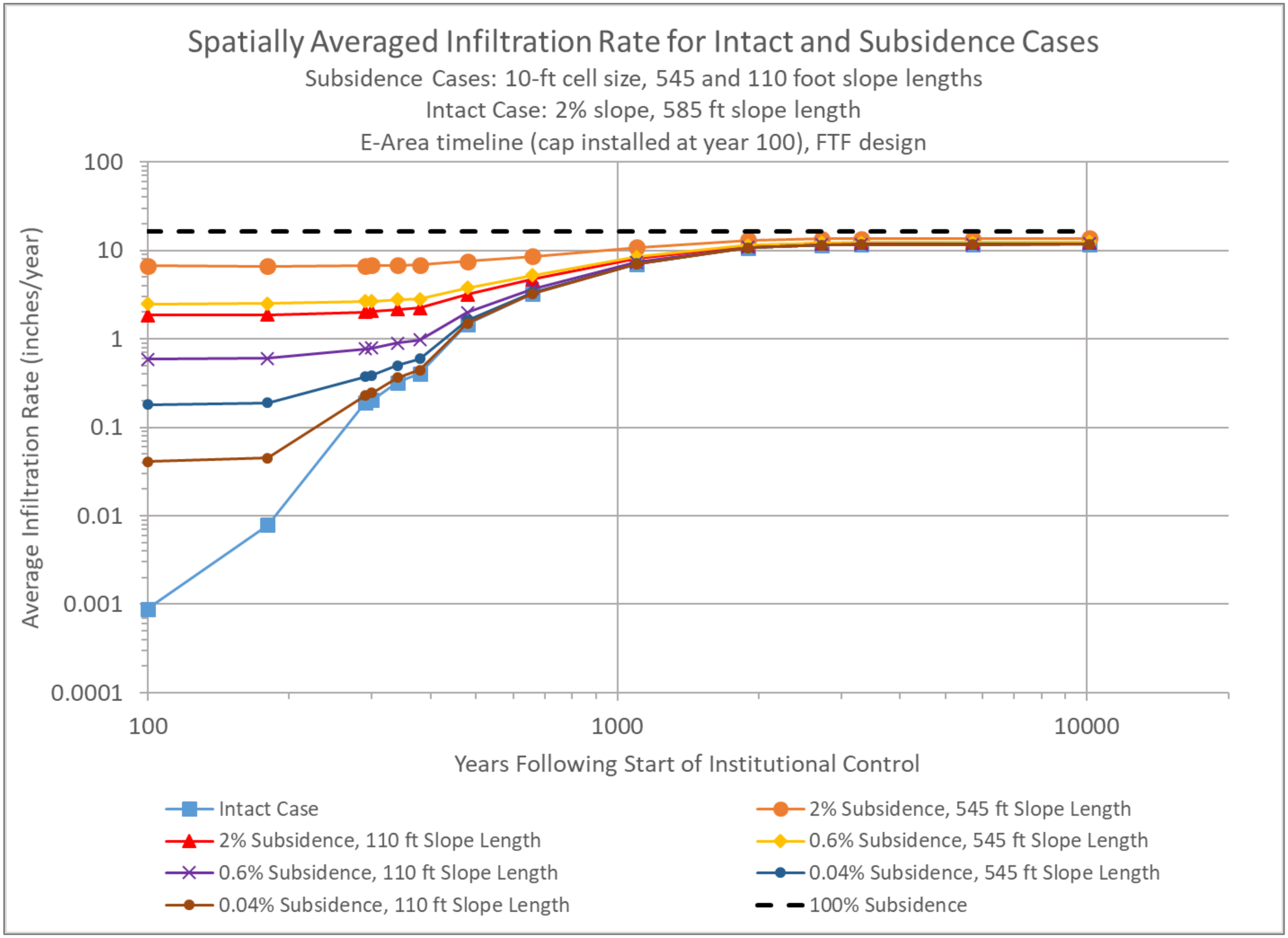

Figure F-5. Spatially Averaged Infiltration Rate vs. Time for Individual Intact and Subsidence Cases (log-log).

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