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Title:	Rainier Mesa CAU Infiltration Model using INFILv3
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Rainier Mesa CAU
Infiltration Model using INFILv3

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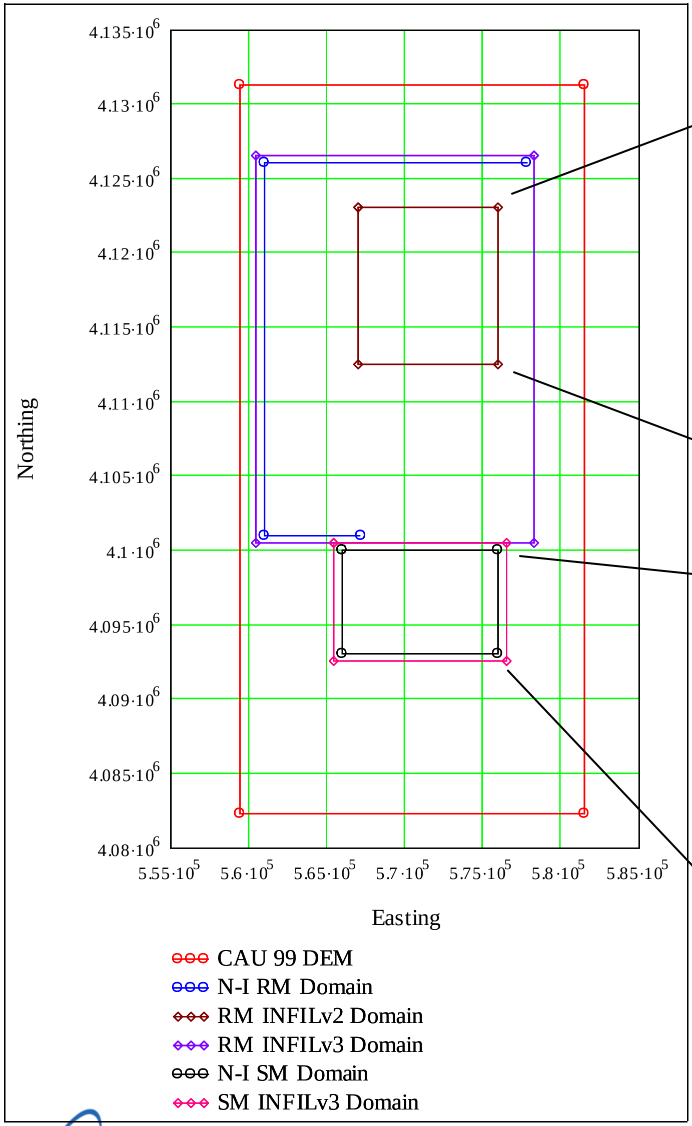
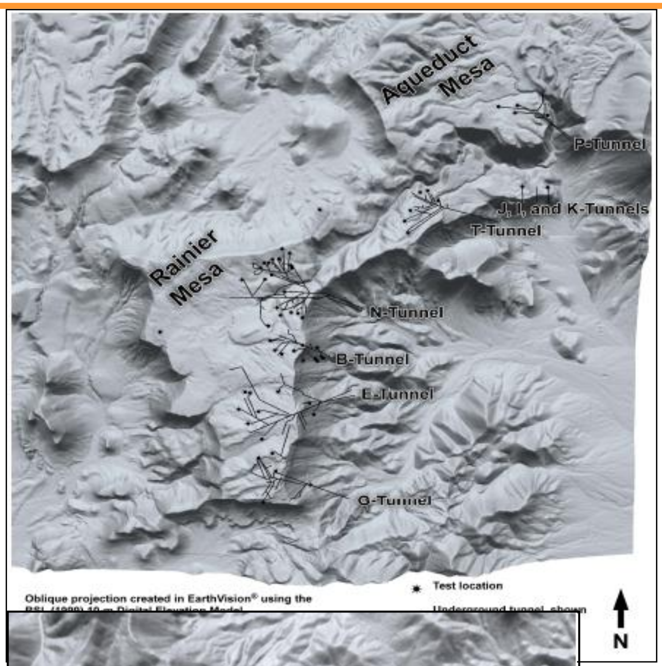
Rainier Mesa/Shoshone Mtn CAU Pre-emptive Review Meeting
July 11, 2012

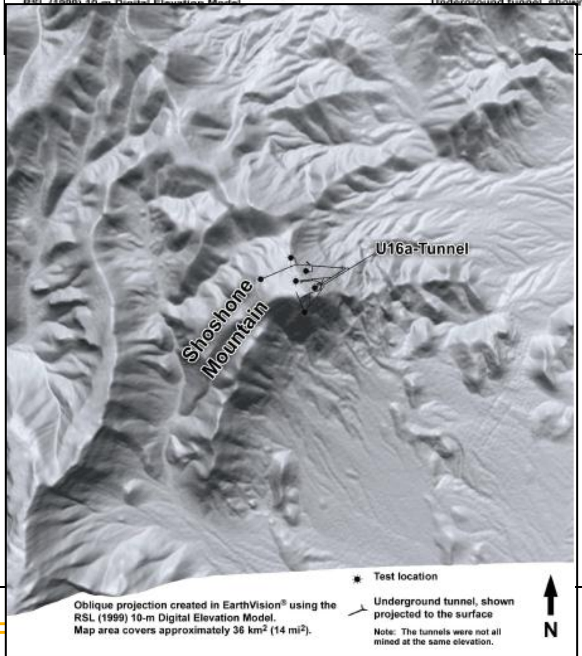
Outline

- Model Inputs
  - DEM, Precipitation, Air temp, Soil props, Surface geology, Vegetation
- Model Pre-processing
  - Runoff Routing and sinks
  - Slope and Azimuth
  - Soil Ksat reduction with slope (to mitigate bathtub ring)
  - Soil-Bedrock Interface permeabilities
- Model Calibration
  - ET using PEST
  - Chloride mass balance data
  - Streamflow using PEST
- Model Validation
  - Streamflow data not used for calibration
- Uncertainty Analysis
- Results

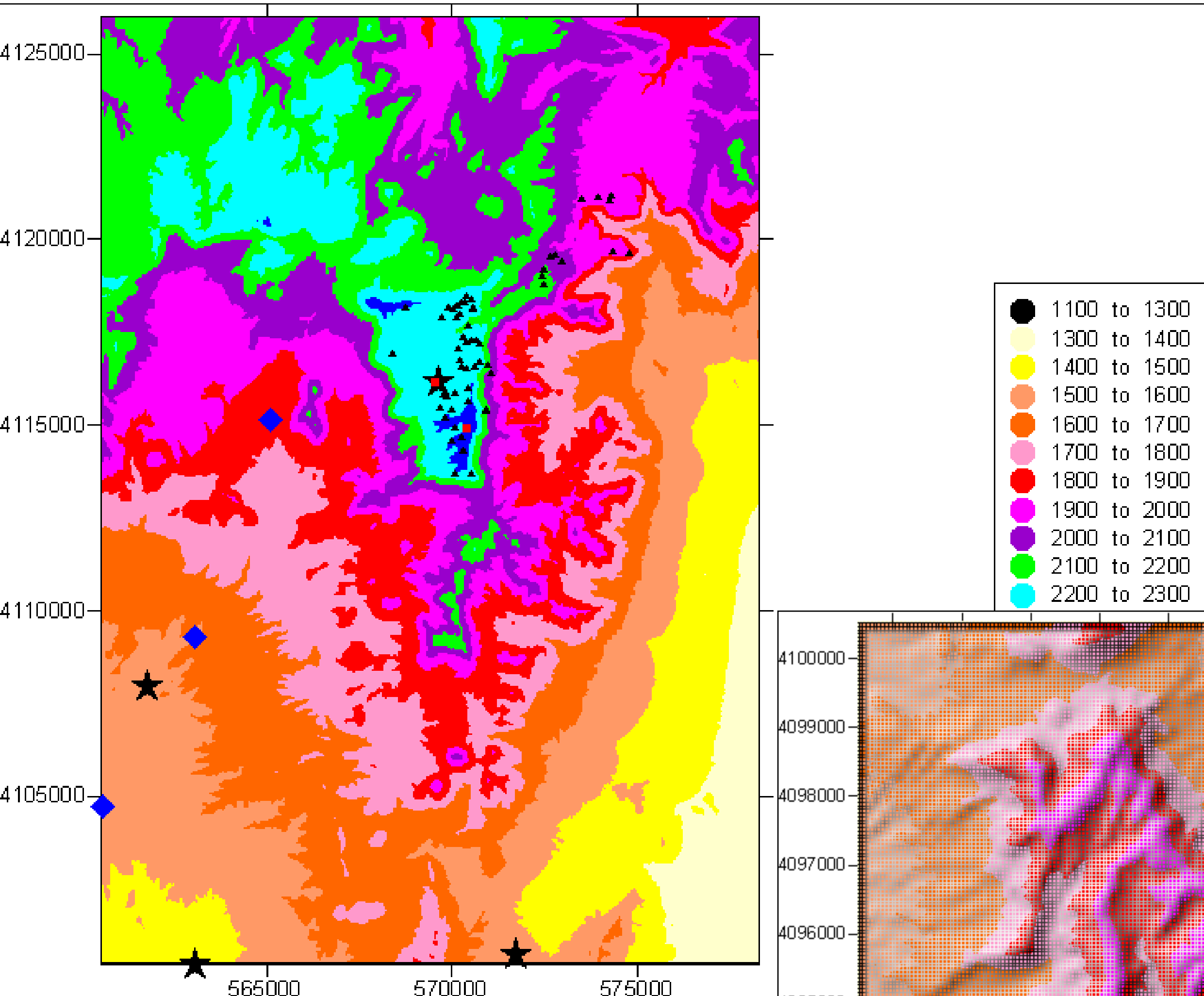
Model Domains and DEM



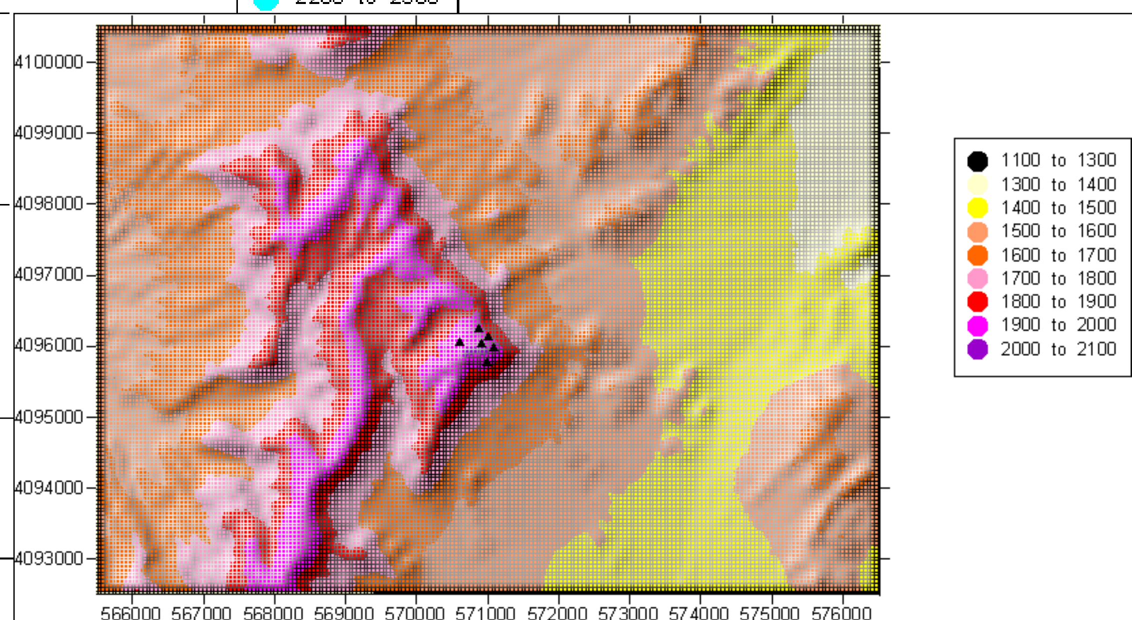




Model Domains and DEM



Met station
Test location
USGS ET data
Streamflow observation



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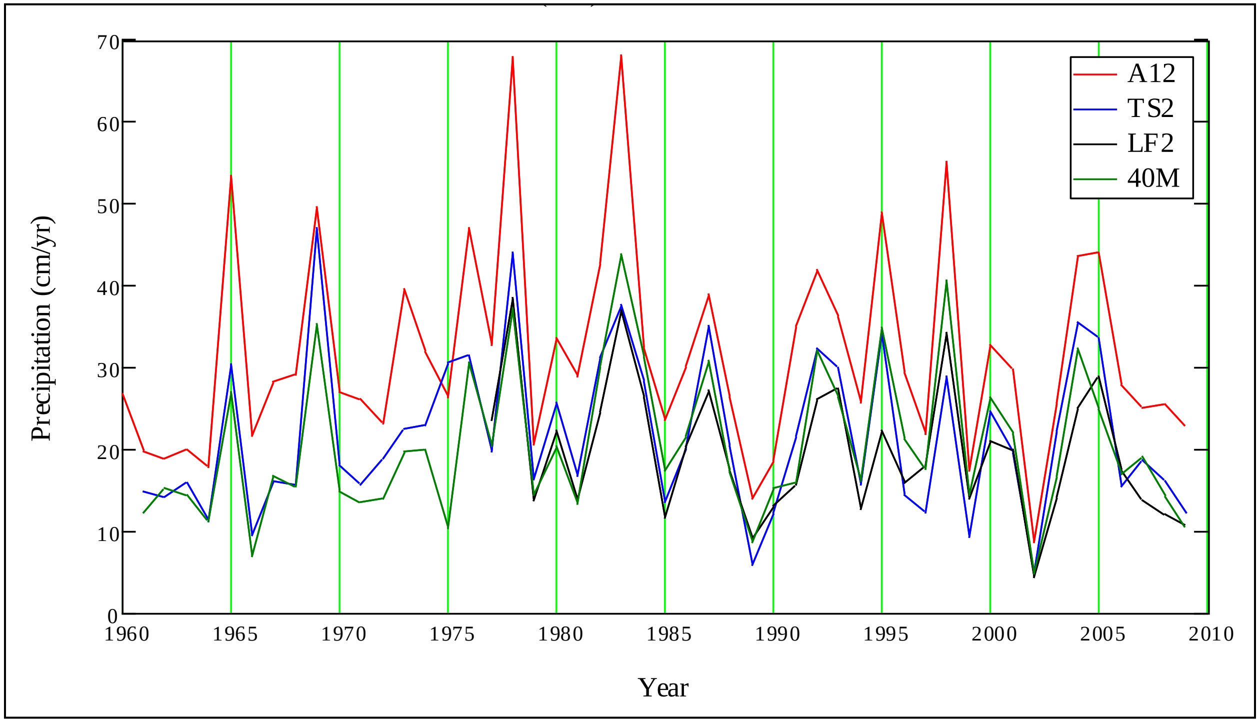
Model Inputs

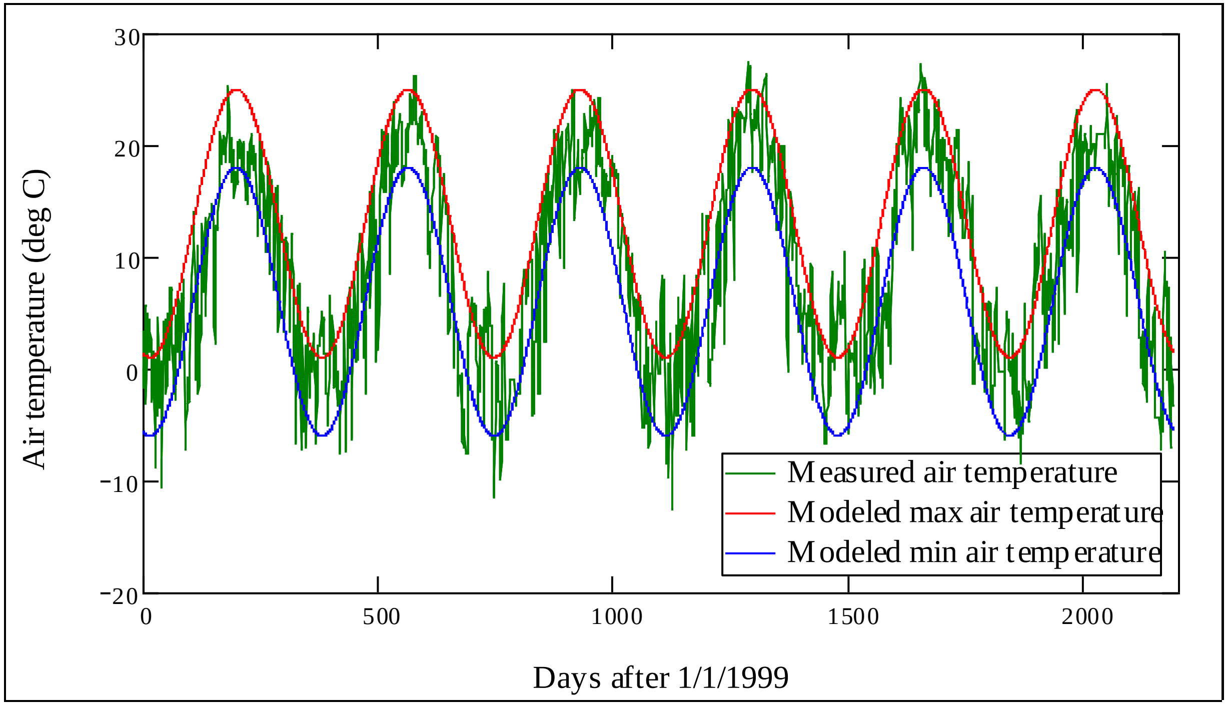
- Precipitation
  - Source: NOAA ARL SORD (www.sord.nv.doe.gov)

		Easting	Northing	Elevation	Precipitation	Data record	
Site ID	Site Name	UTM (m)	UTM (m)	(m)	(cm/yr)	Years	# of years
A12	Rainier Mesa	569,635	4,116,182	2,283.0	31.37	1960-2009	50
TS2	Tippipah Springs 2	571,714	4,100,766	1,517.9	21.73	1961-2009	49
LF2	Little Feller 2	563,071	4,100,512	1,560.6	19.79	1977-2009	33
40M	40 Mile Canyon	561,798	4,107,970	1,469.1	20.35	1961-2009	49



Model Inputs

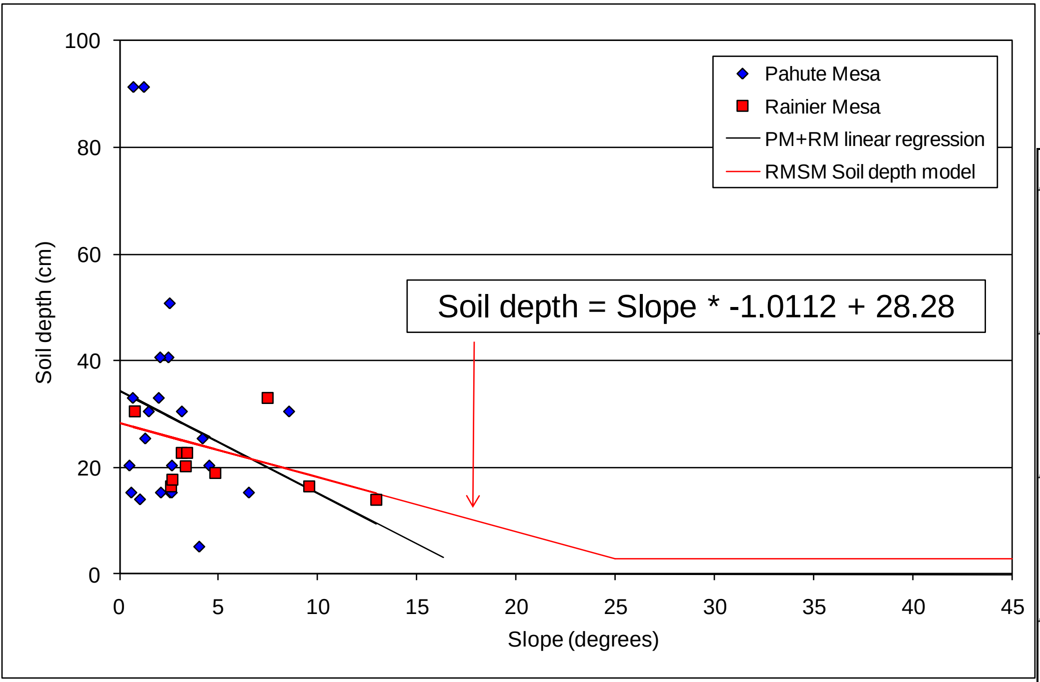
- Air temperature
  - Six years from A12 station (from Yucca Mtn Project report)

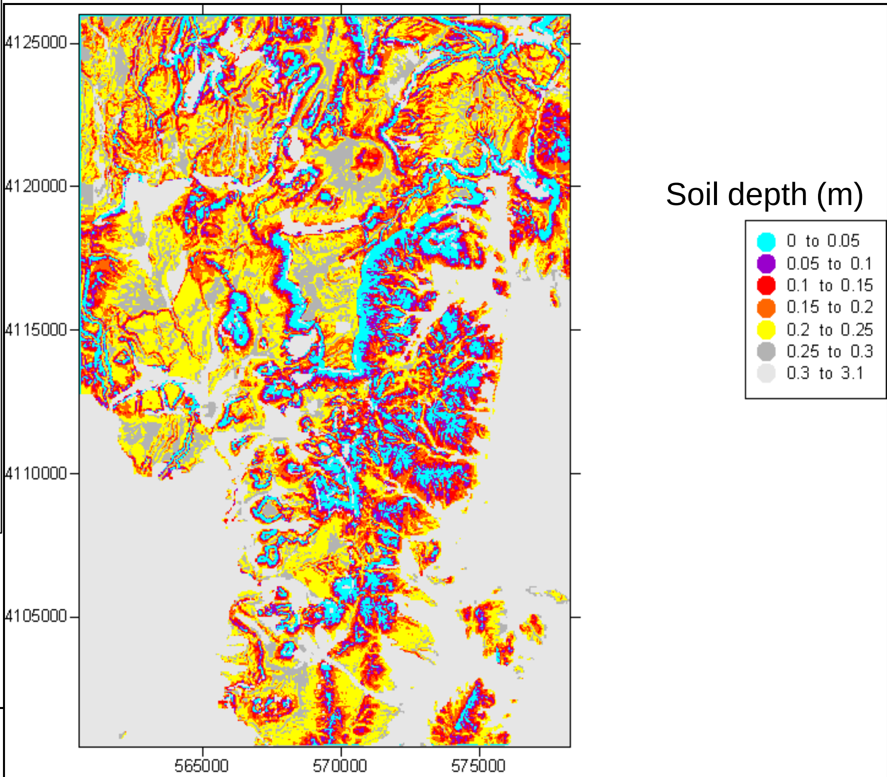


$$T = A - 12 * \sin\left(\frac{DOY}{365.25} * 2 * \pi + 1.3\right) \qquad \text{Eqn. 1}$$

Model Inputs

- Soil Depth
  - Measurements taken in July 2010
  - PM avg = 31 cm; RM avg = 21 cm
  - Weak relationship between soil depth and slope





Model Inputs

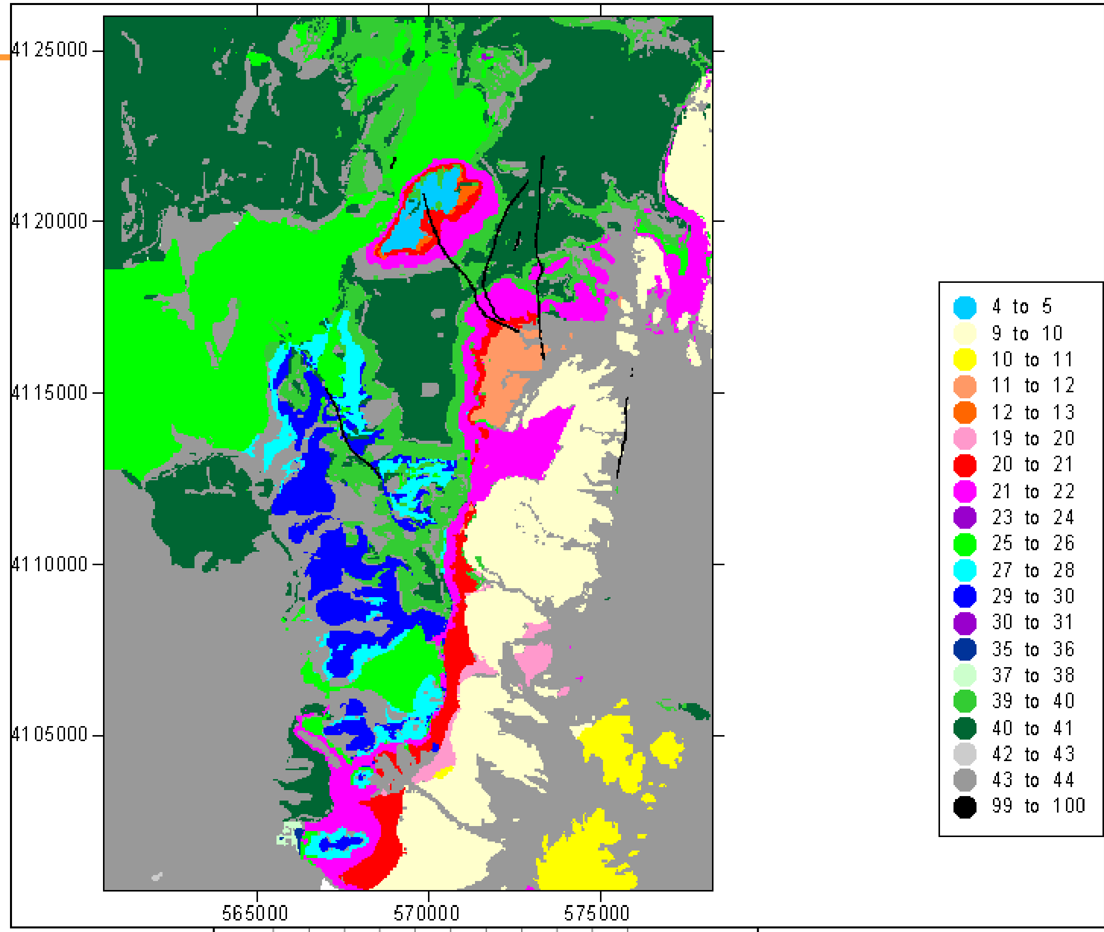
- Soil Hydraulic properties
  - Soil samples collected in July 2010 from PM and RM
  - Unconsolidated samples (loose, not core), repacked to target density
  - Analysis by D.B. Stephens & Co.

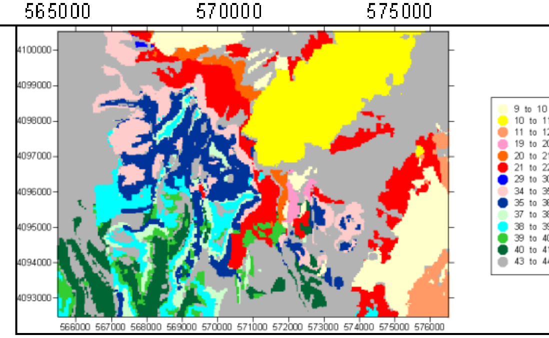
Sample	Ksat	Ksat	Sat. water content	Res. Water content	alpha	N	Field capacity*
	(cm/sec)	(mm/day)	(% vol)	(% vol)	(cm^{-1})		(% vol)
RM-01	3.85E-05	33.3	39.87	1.71	0.0037	1.37	31.98
RM-02	1.32E-06	1.1	39.38	3.21	0.0032	1.44	32.06
RM-03	1.33E-04	114.7	41.19	4.05	0.0068	1.48	27.08
RM-04	1.04E-05	9.0	41.06	1.92	0.0034	1.49	32.21
RM-05	1.95E-06	1.7	30.90	2.68	0.0021	1.49	26.88
RM-06	1.81E-05	15.7	34.52	1.67	0.0042	1.60	24.18
RM-07	5.23E-05	45.2	44.37	2.06	0.0044	1.54	31.46
RM-08	8.52E-05	73.6	29.98	2.33	0.0026	1.40	25.67
RM-09	1.36E-05	11.8	36.43	1.28	0.0025	1.67	29.60
RM-10	1.01E-04	87.5	40.16	0.50	0.0099	1.31	26.72
Minimum	1.32E-06	1.1	29.98	0.50	0.0021	1.31	24.18
Maximum	1.33E-04	114.7	44.37	4.05	0.0099	1.67	32.21
Mean	4.55E-05	39.35	37.79	2.14	0.0043	1.48	28.78
Geometric mean	2.08E-05	17.97			0.0038		

Model Inputs

- Uppermost geological layer

	Included in Domain?			
Material #	RM	SM	Abbreviation	Unit Name
4	Y	N	MGCU	Mesozoic granite confining unit
9	Y	Y	UCCU	Upper clastic confining unit
10	Y	Y	UCA	Lower carbonate aquifer, upper thrust plate
11	Y	Y	LCA3	Lower carbonate aquifer, upper thrust plate
12	Y	N	LCCU1	Lower clastic confining unit, upper thrust plate
19	Y	Y	RVA	Redrock Valley aquifer
20	Y	Y	OSBCUv2	Oak Spring Butte confining unit
21	Y	Y	LTCUv2	Lower tuff confining unit
23	Y	N	BRCU	Belted Range confining unit
25	Y	N	BRAv2	Belted Range aquifer
27	Y	N	LVTA2	Lower vitric-tuff aquifer 2
29	Y	Y	SWA	Stockade Wash aquifer
34	Y	Y	LVTA	Lower vitric-tuff aquifer
35	Y	Y	TSA	Topopah Spring aquifer
37	Y	Y	PVTA	Paintbrush vitric-tuff aquifer
38	N	Y	TCA	Tiva Canyon aquifer
39	Y	Y	TMLVTAv2	Timber Mtn. lower vitric-tuff aquifer
40	Y	Y	TMWTAv2	Timber Mtn. welded-tuff aquifer
42	Y	N	FCCM	Fortymile Canyon composite unit
43	Y	Y	AAv4	Alluvial aquifer
99	Y	N	faults	Faults

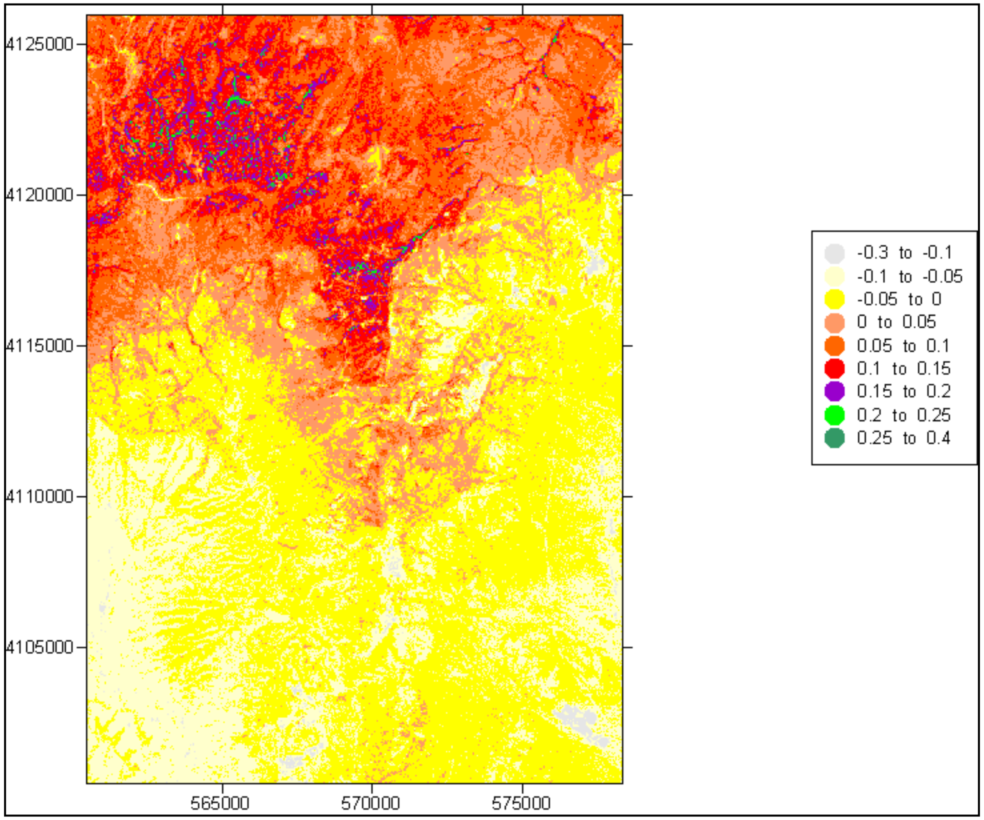




Model Inputs

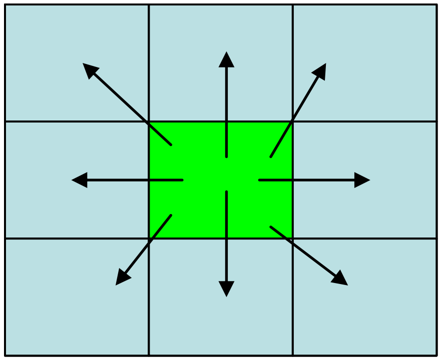
- Vegetation density derived from Satellite-acquired Normalized Difference Vegetation Index (NDVI)

$$\mathrm{NDVI} = \frac{(\mathrm{NIR} - \mathrm{RED})}{(\mathrm{NIR} + \mathrm{RED})}$$



Model Pre-processing

- Runoff routing



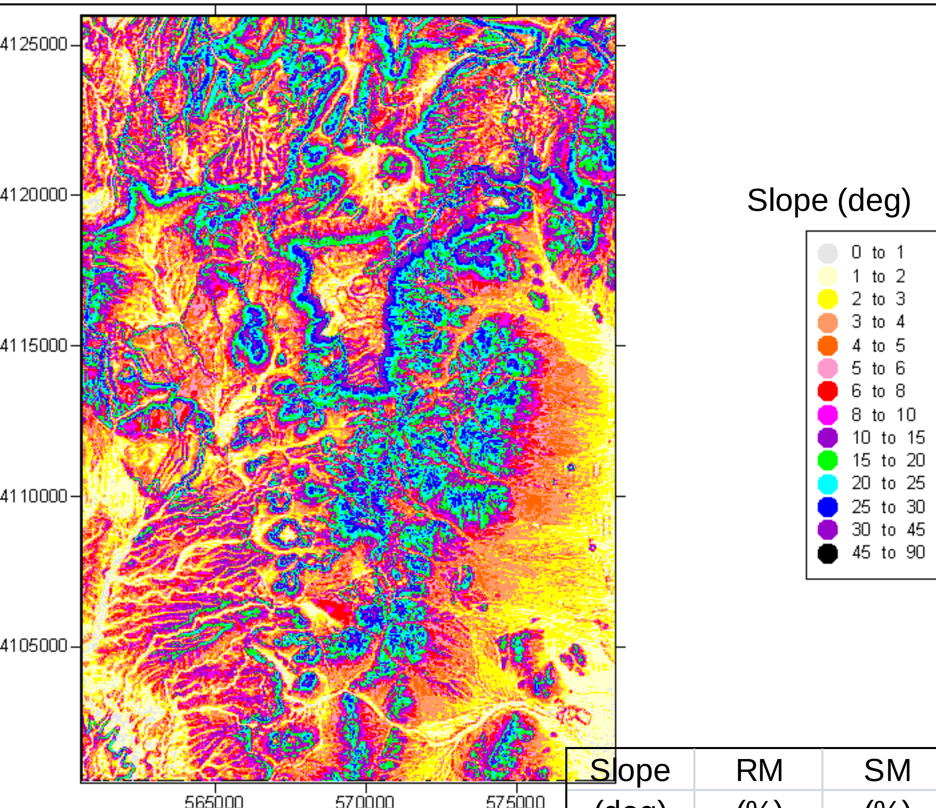
- Topographic sinks in washes are filled; others are not filled
- Slope and Azimuth calculated from routing results

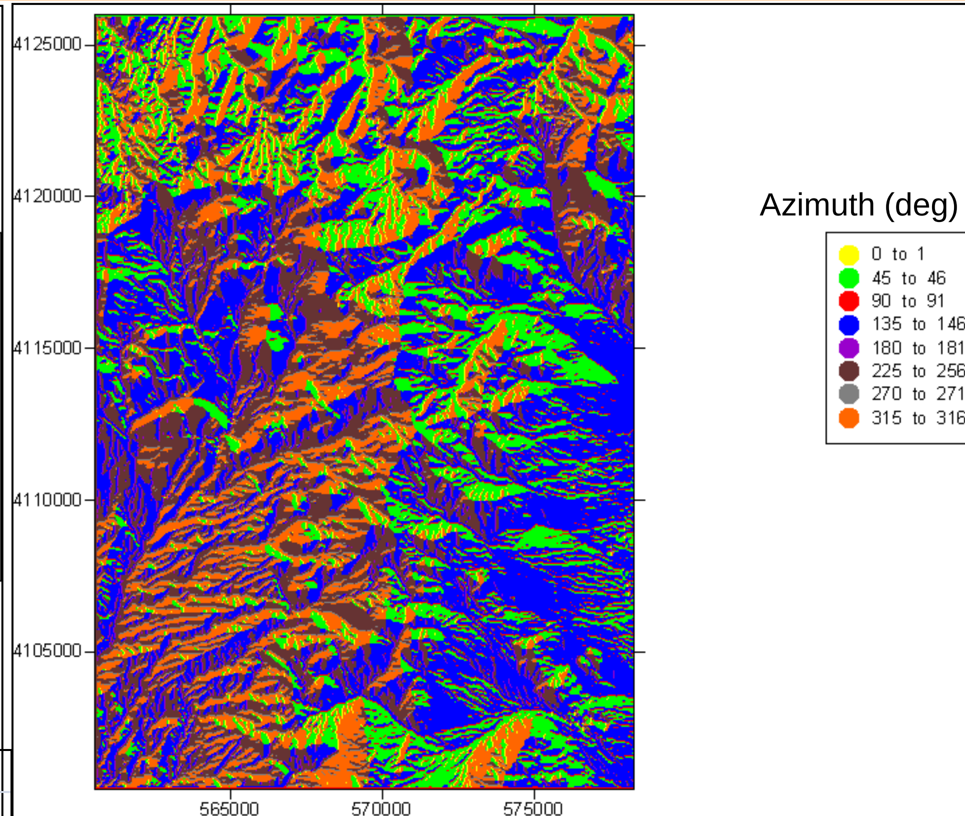
	RM (deg)	SM (deg)
Min	0.0	0.0
Avg	9.2	8.9
Max	51.4	46.7

Slope (deg)	RM (%)	SM (%)
<5	38.57	33.61
5-10	24.38	25.36
10-15	13.37	16.14
15-20	9.52	10.84
20-25	7.45	7.54
25-30	4.56	4.57
30-35	1.71	1.72
35-40	0.37	0.19
40-45	0.05	0.02
>45	0.005	0.002

Azimuth (deg)	Azimuth (dir)	RM %	SM %
0	N	1.9	2.3
45	NE	18.0	22.5
90	E	4.0	4.7
135	SE	32.7	28.5
180	S	3.6	2.5
225	SW	20.5	16.4
270	W	2.6	3.0
315	NW	16.6	20.1

Model Pre-processing





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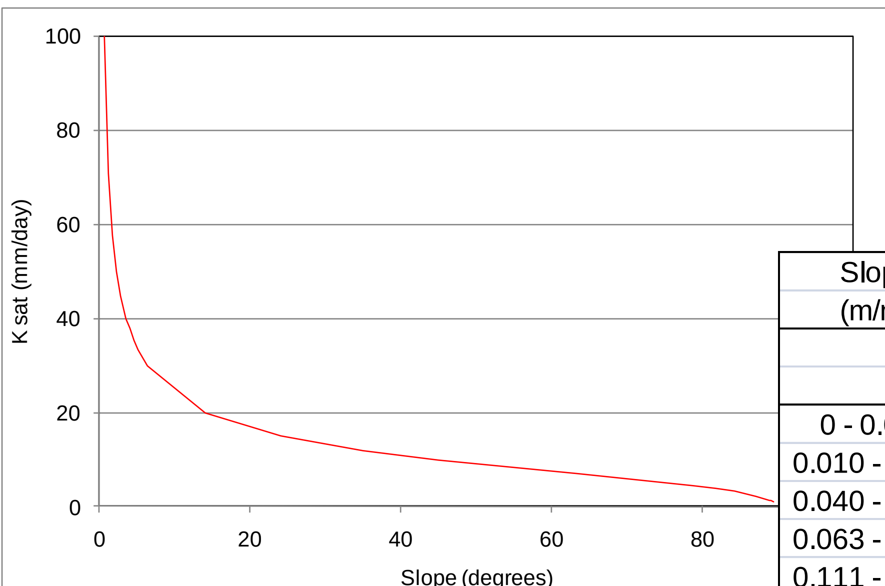
Model Pre-processing

- Soil Ksat reduction with slope
  - To mitigate “bathtub ring” on steep slopes in preliminary results using INFILv2
  - Approach based on Mannings Equation

$$v = \frac{k}{n} * R_h^{\,0.67} * S^{0.5}$$

$$\Downarrow$$

$$Ksat' = Ksat_0 * (S_0 / S)^{0.5}$$

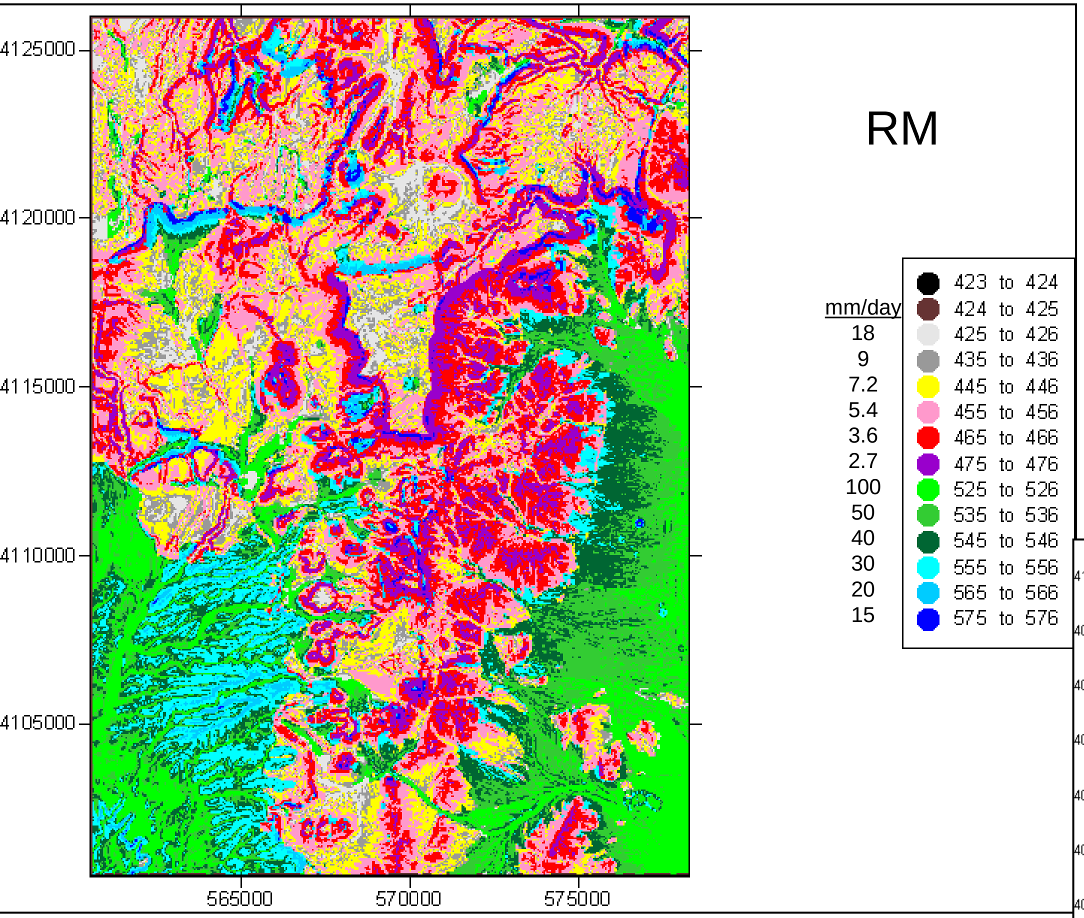


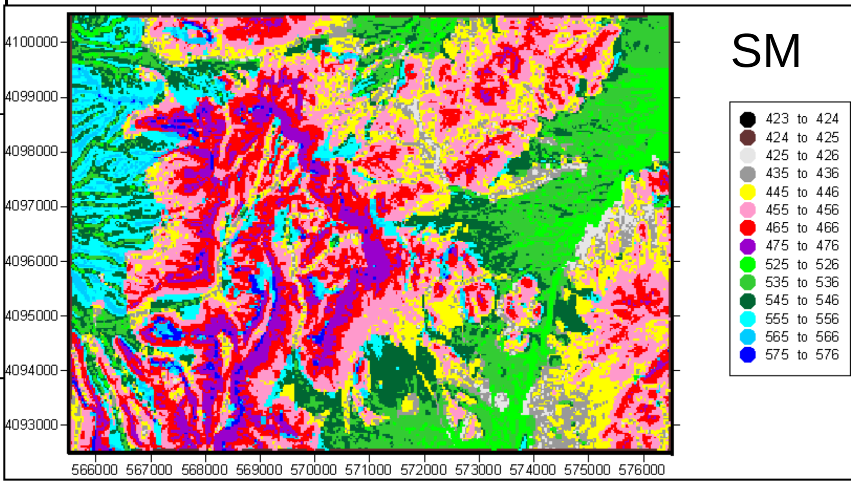
Slope (m/m)	Slope (degrees)	Δt'/Δt	Soil Ksat (mm/day)	AA Ksat (mm/day)	Soil Ksat Class #	AA Ksat* Class #
			0.00		423	
			1.00		424	
0 - 0.010	0 - 0.57	1.00	18.00	100.00	425	525
0.010 - 0.040	0.57 - 2.29	0.50	9.00	50.00	435	535
0.040 - 0.063	2.29 - 3.58	0.40	7.20	40.00	445	545
0.063 - 0.111	3.58 - 6.34	0.30	5.40	30.00	455	555
0.111 - 0.250	6.34 - 14.04	0.20	3.60	20.00	465	565
0.250 - 0.445	14.04 - 23.99	0.15	2.70	14.99	475	575
0.445 - 1.0	23.99 - 45.00	0.10	1.80	10.00	485	585

* AA Ksat indicates soil overlying alluvial aquifer surface geologic unit

Model Pre-processing

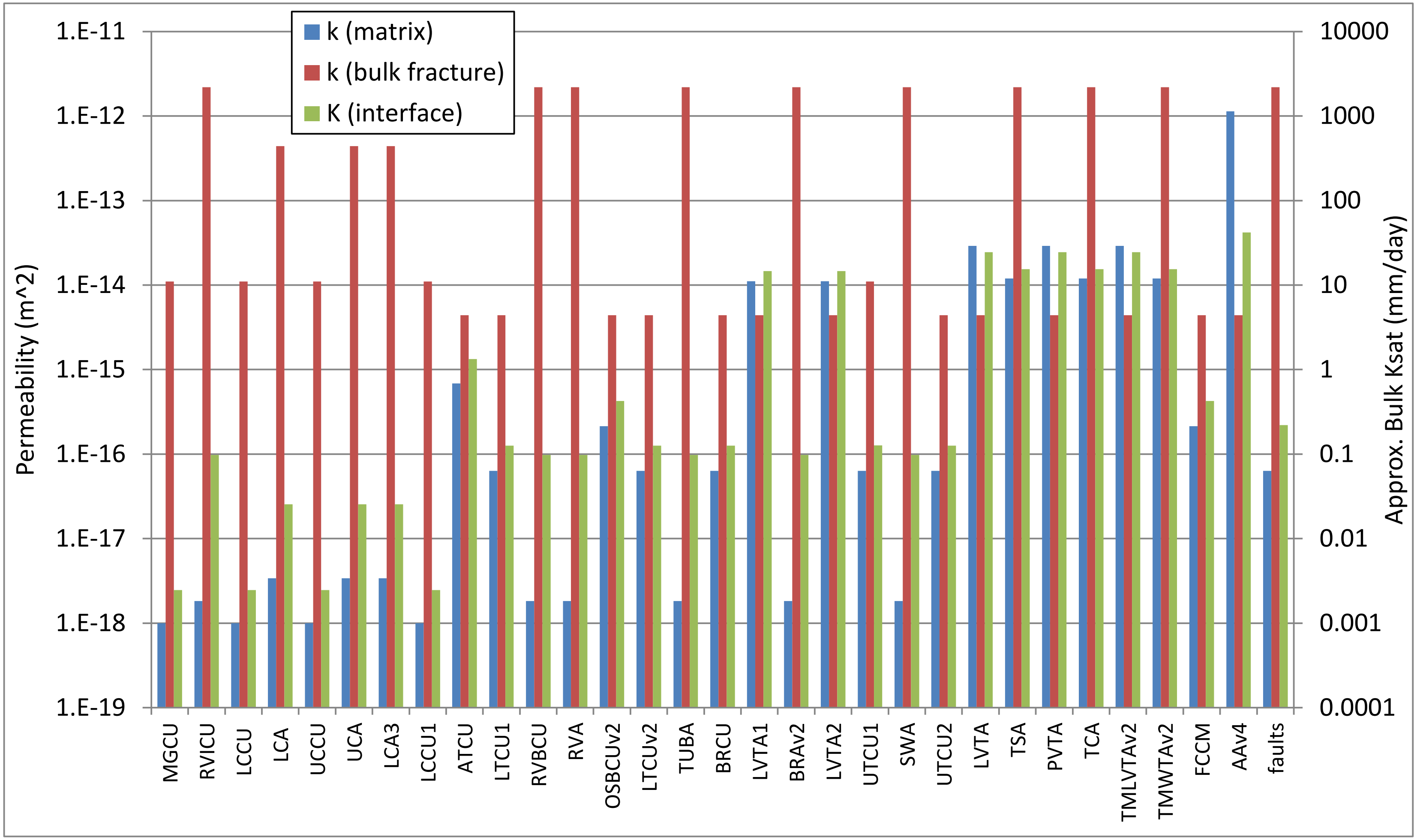
- Modeled soil Ksat (class)





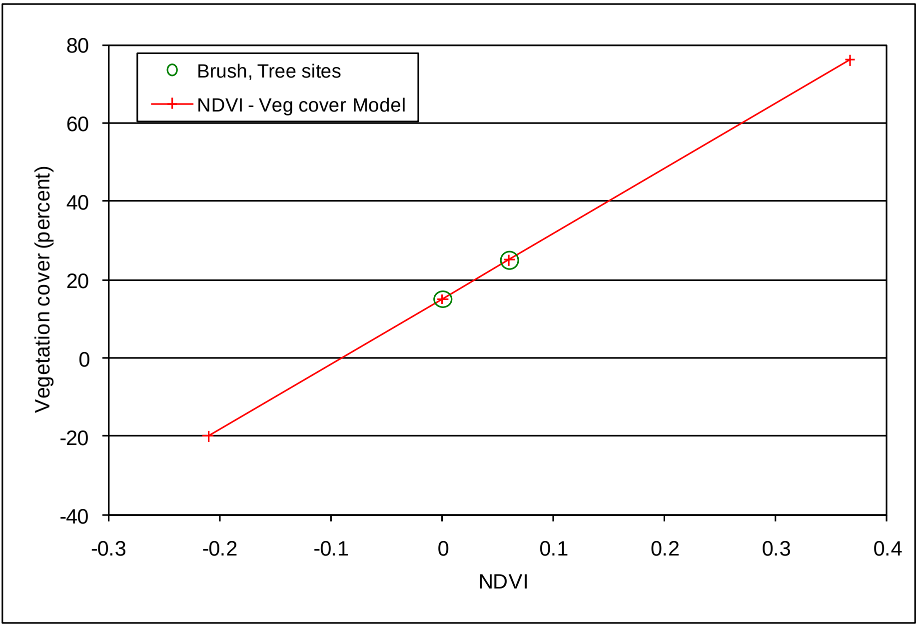
Assumed Interface Permeabilities

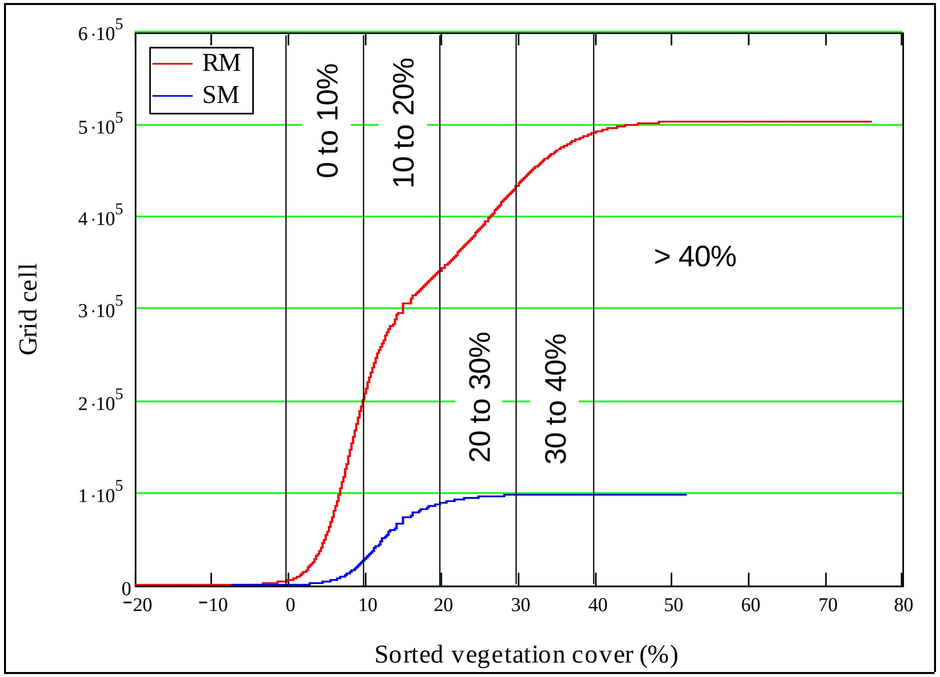
- $K_{interface}$ permeabilities were used to estimate drainage from the soil to the underlying bedrock



Model Pre-processing

- Calculation of vegetation density from NDVI

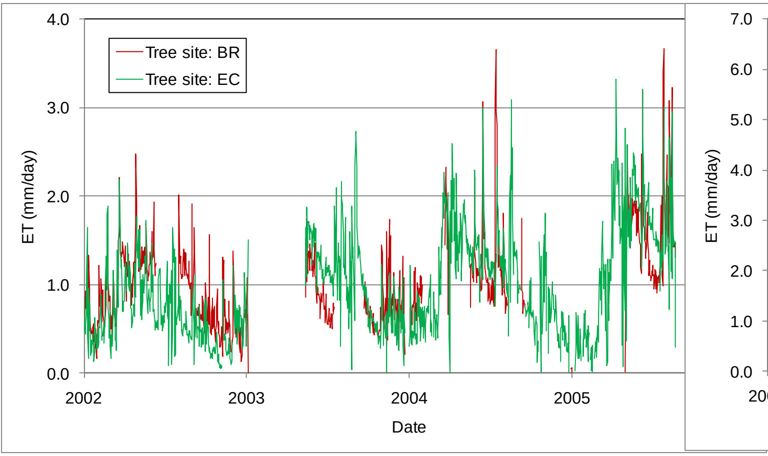


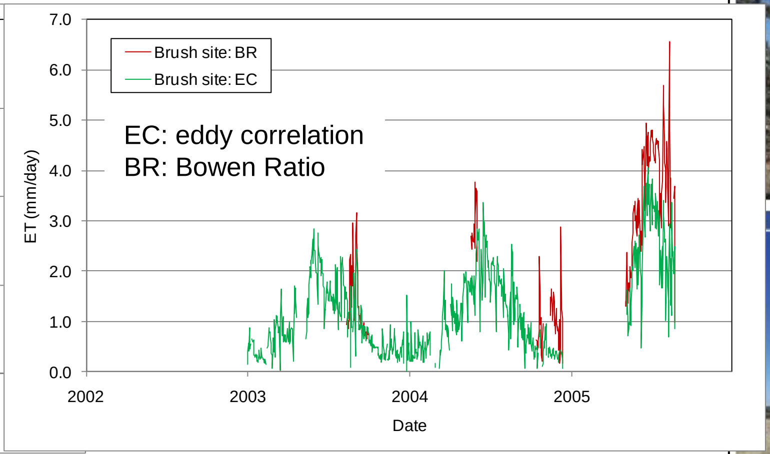


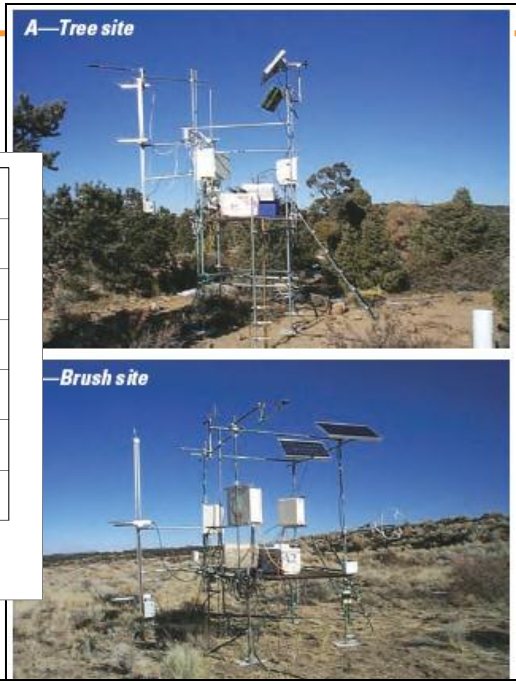
$$Veg = NDVI * 166.113 + 15$$

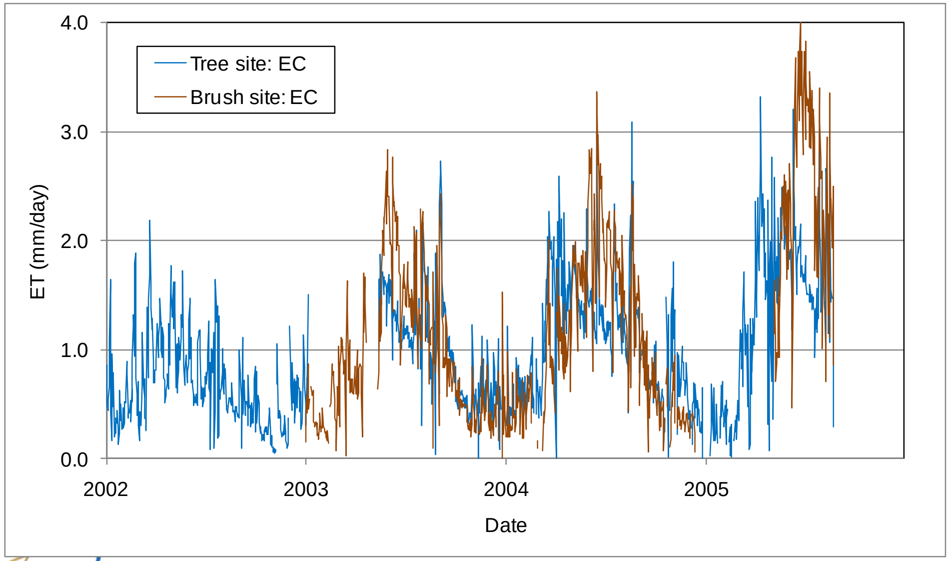
Model Calibration

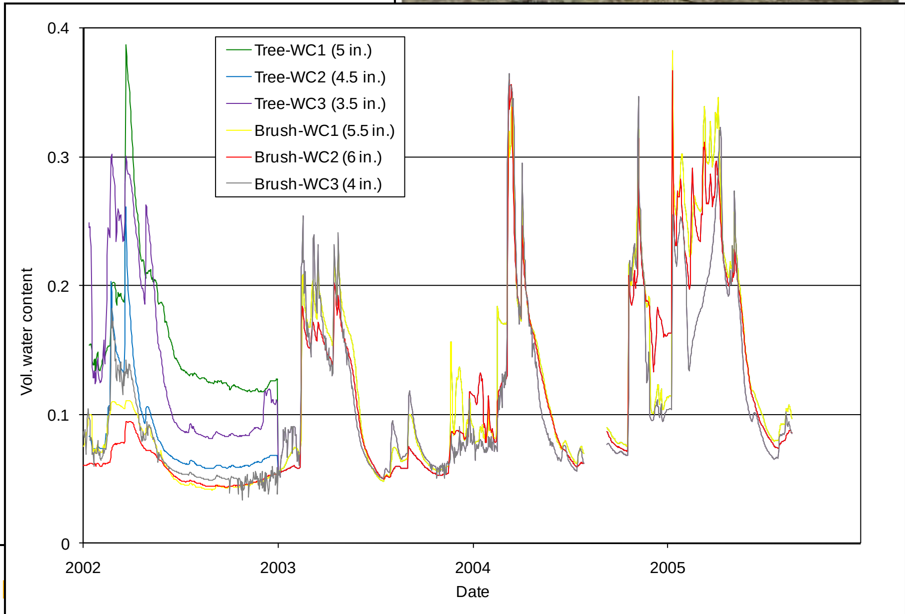
- Measured ET and soil water content data











Model Calibration

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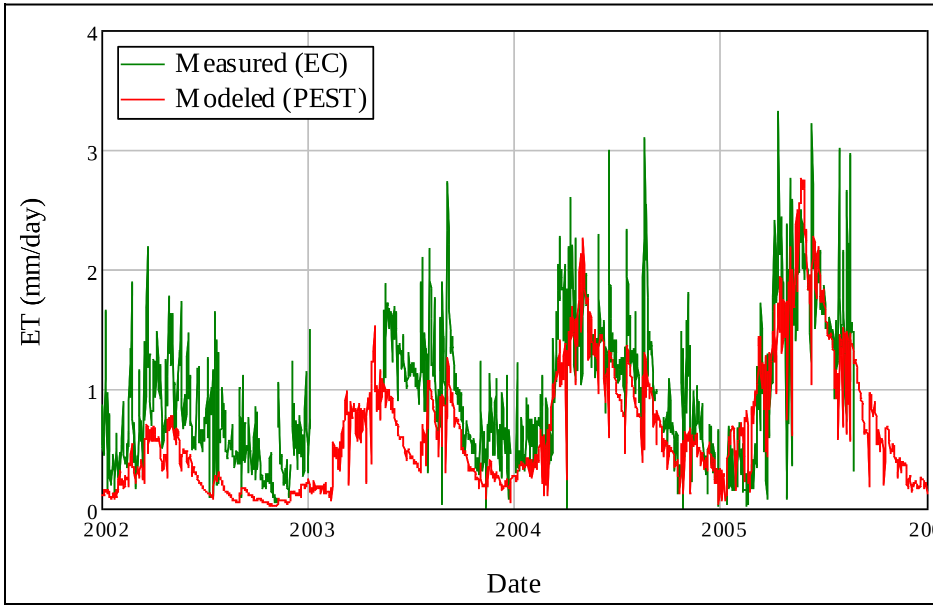
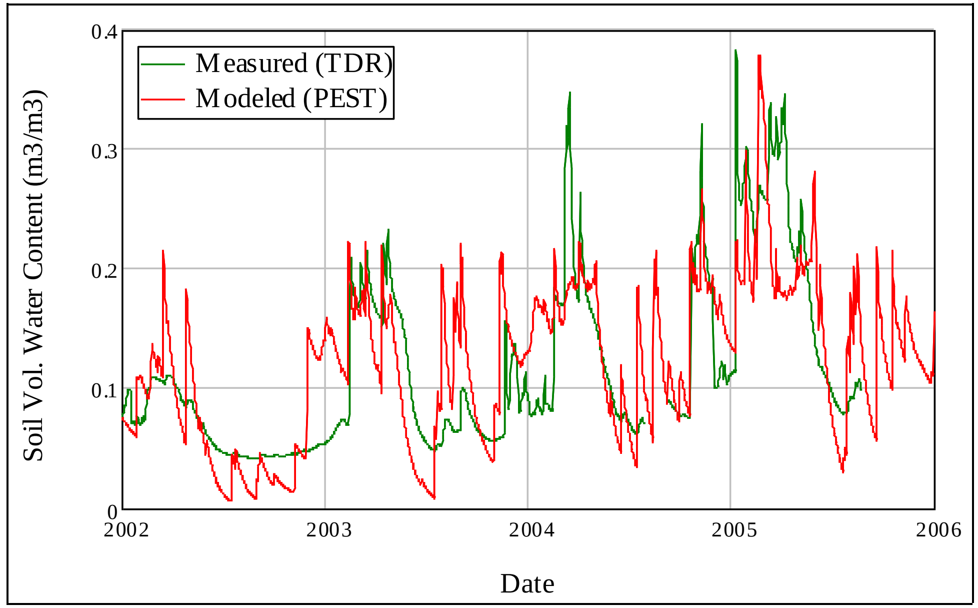
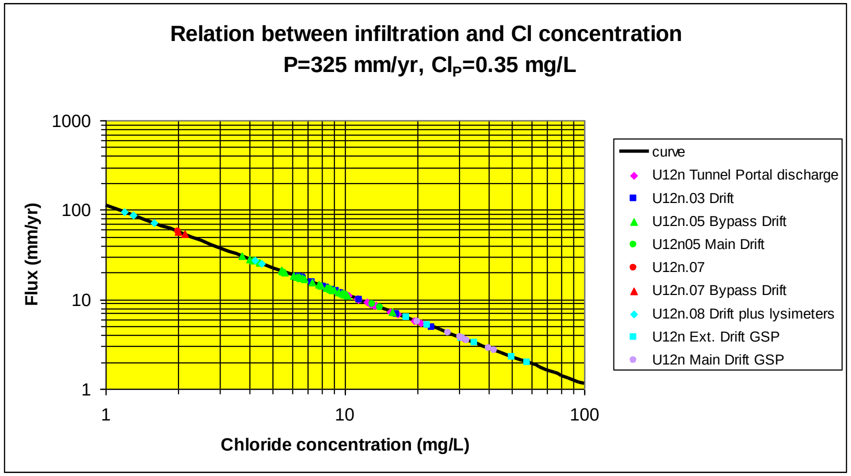


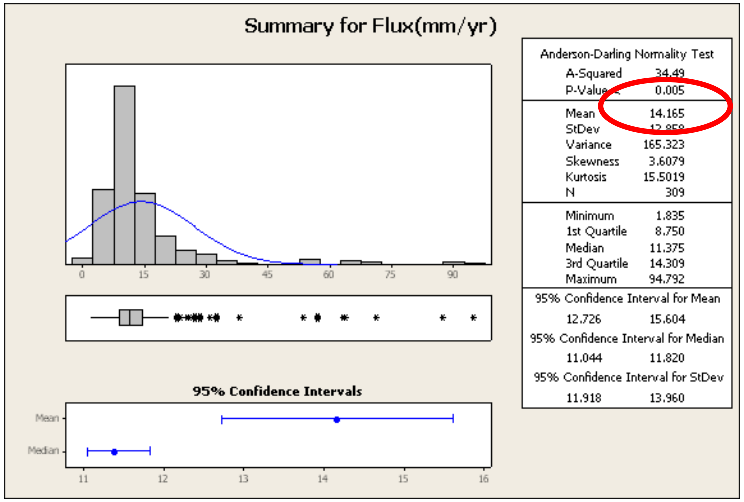


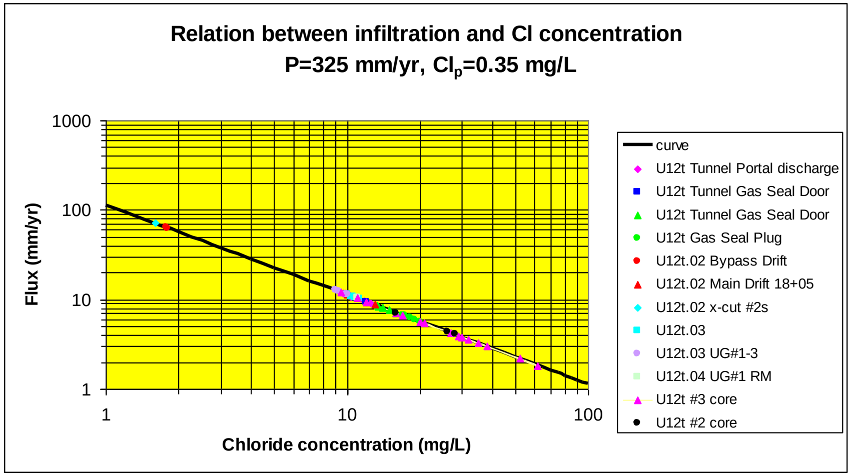
Parameter Name	Parameter Abbrev.	Units	PEST Type	Optimized	95% Confidence Limits Lower	95% Confidence Limits Upper
Bare-soil PT parameter beta	barsoil1	none	Log	-0.500	-0.598	-0.401
Bare-soil PT parameter alpha	barsoil2	none	Log	0.448	0.281	0.716
Rock PT parameter beta	rocket1	none	Fixed	-0.100		
Rock PT parameter alpha	rocket2	none	Fixed	6.500		
Vegetation PT parameter beta	soilet1	none	Log	-0.103	-0.180	-0.026
Vegetation PT parameter alpha	soilet2	none	Fixed	4.500		
PET multiplier	etfact	none	Log	1.678	1.405	2.005
Sublimation parameter 1	subpar1	none	Log	0.094	0.055	0.160
Sublimation parameter 2	subpar2	none	Log	0.053	0.041	0.070
Soil porosity	por	m3/m3	Log	0.378	0.358	0.399
Soil field capacity	fc	m3/m3	Tied (to por)	0.269		
Soil wilting point	wp	m3/m3	Log	0.001	7.3E-09	137.7
Soil drainage parameter	b	none	Log	2.306	1.250	4.255
Soil Ksat	ksat01	mm/day	Log	267	37	1915
Bedrock porosity	rzpor	none	Fixed	0.002		
Bedrock maximum Kunsat	ksatr1	mm/day	Fixed	0.001		
Bedrock maximum Ksat	ksatr2	mm/day	Log	1.214	1.066	1.383

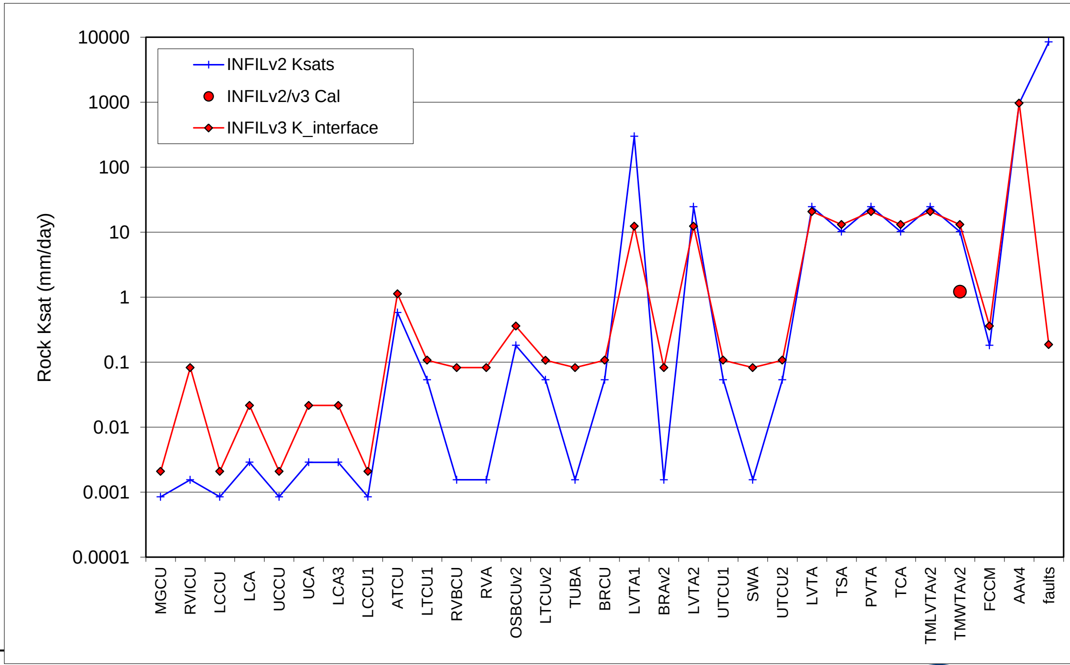
Model Calibration

- Chloride Mass Balance (CMB) data



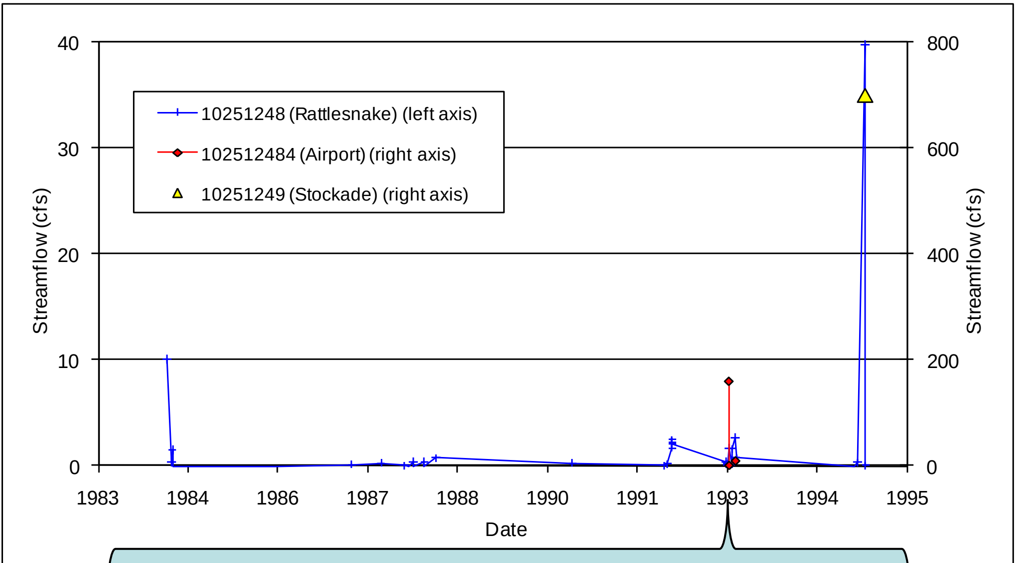


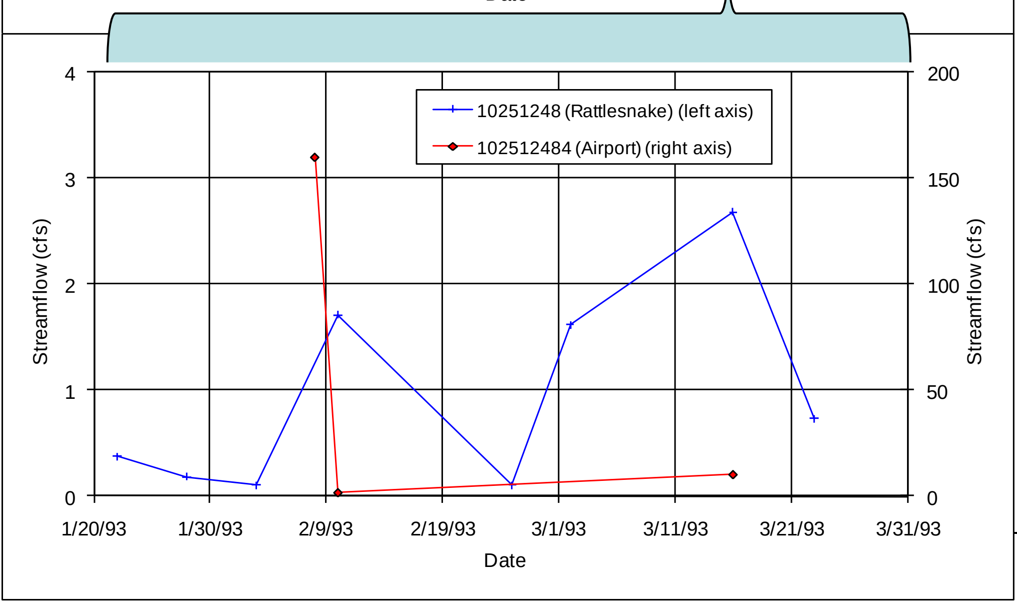


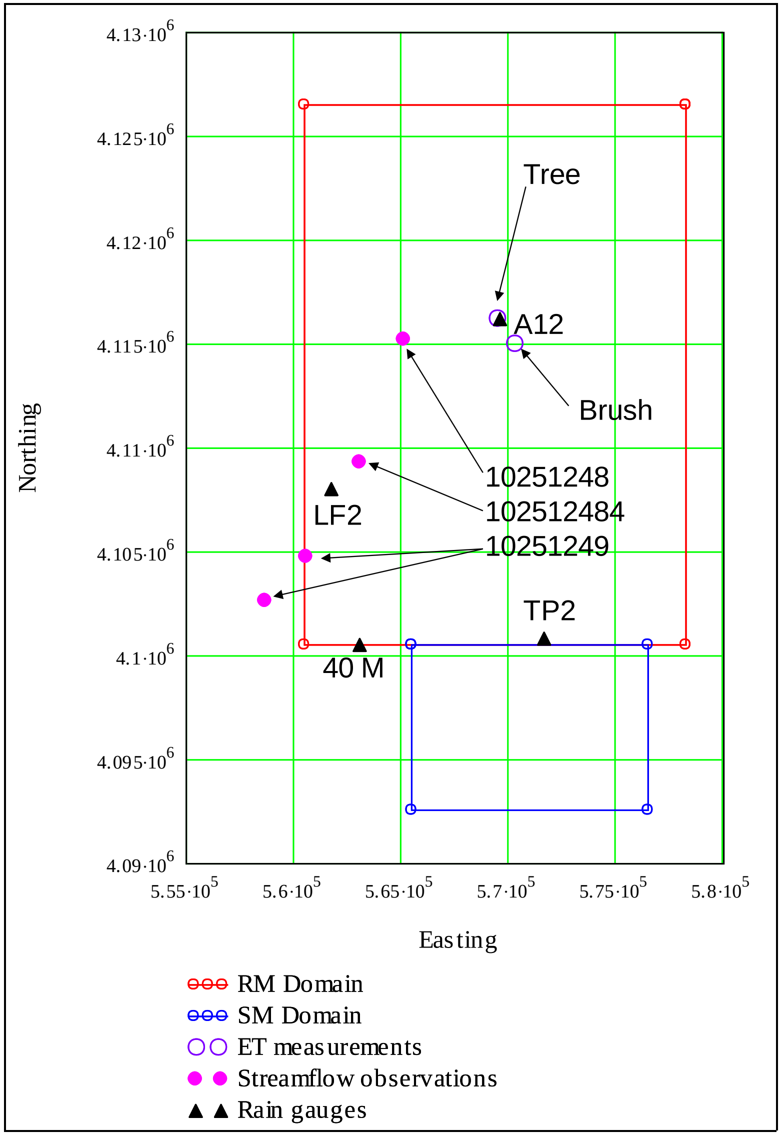


Model Calibration

- Streamflow observations

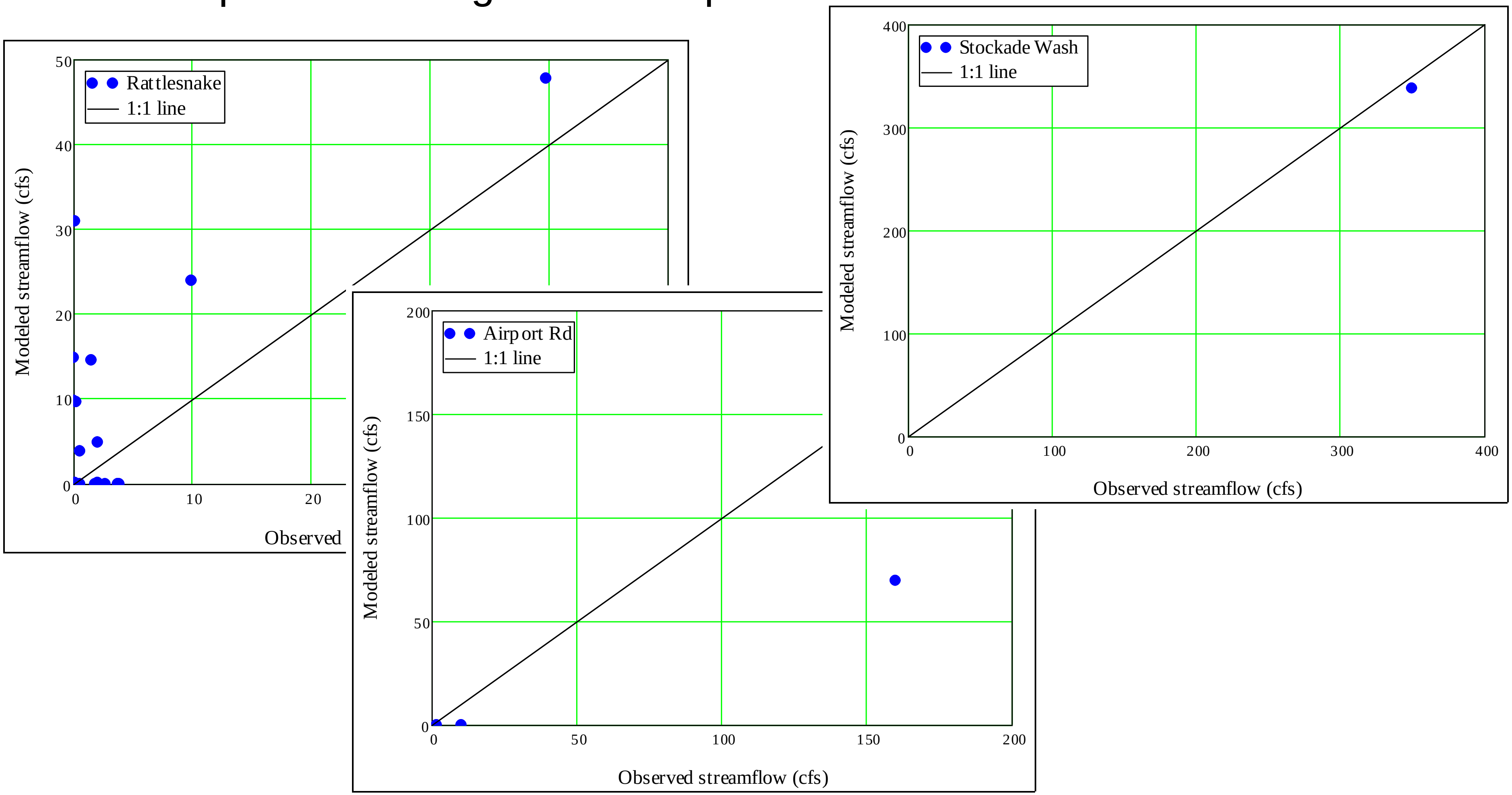






Model Calibration

- Comparisons using combined parameter set



	Parameter		PEST			
Parameter Name	Abbrev.	Units	Type	Optimized	Lower	Upper
Effective flow-area fraction	flarea	none	Log	0.231	0.10	1.00
Soil Ksat multiplier	sksfact	none	Log	0.897	0.50	2.00

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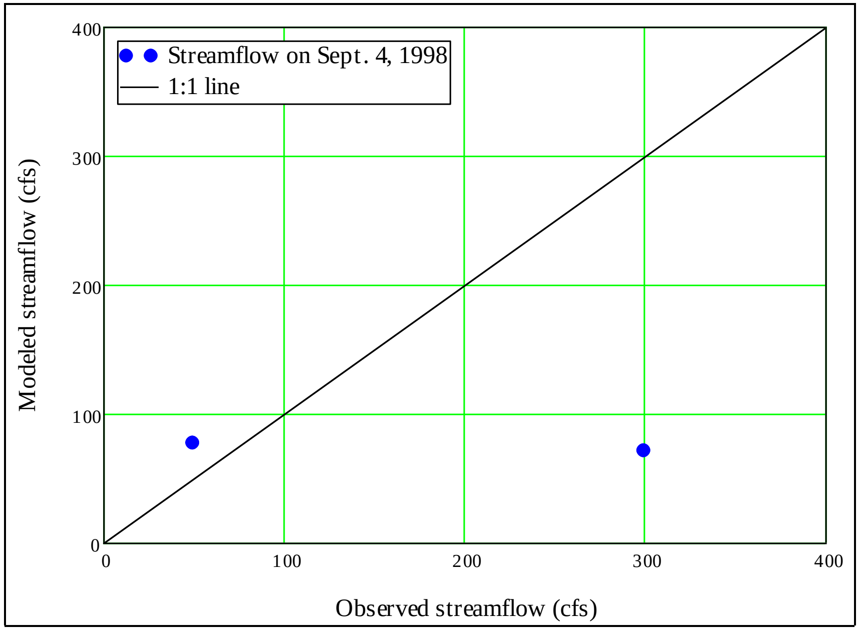
Model Validation

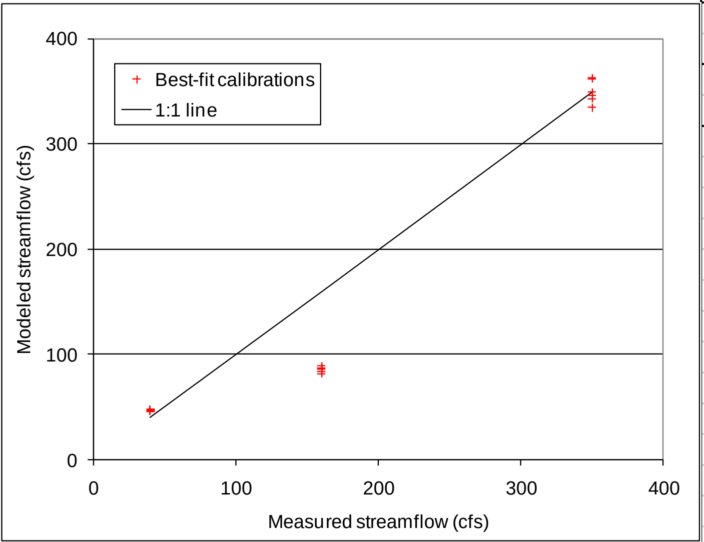
- Streamflow observations
  - INFIL calculated streamflow on 1 of 2 days with measured streamflow

USGS Number	USGS Station Name	Validation Name	Peak Streamflow Date	Peak Streamflow (cfs)
10251247	STOCKADE WASH BLW PAHUTE MESA RD, NTS, NV	V1	9/9/1998	200
102512481	STOCKADE WASH TRIB BLW RATTLESNAKE RIDGE, NTS, NV	V2	9/9/1998	20
102512482	STOCKADE WASH TRIB BLW LANDMARK ROCK, NTS, NV	V3	9/9/1998	700
102512485	STOCKADE WASH AT LANDING STRIP, NTS, NV	V4	9/4/1998	300
102512487	STOCKADE WASH BLW TIPPIPAH SPGS RD, NTS, NV	V5	9/4/1998	50



Uncertainty Analysis

- Monte Carlo sampling of uncertain parameters generated 100 datasets
- Parameters found to be highly sensitive to ET were kept constant
- Ran INFIL with 50 of 100 datasets
- Best 6 fits to streamflow observations (max at 3 locations) were kept



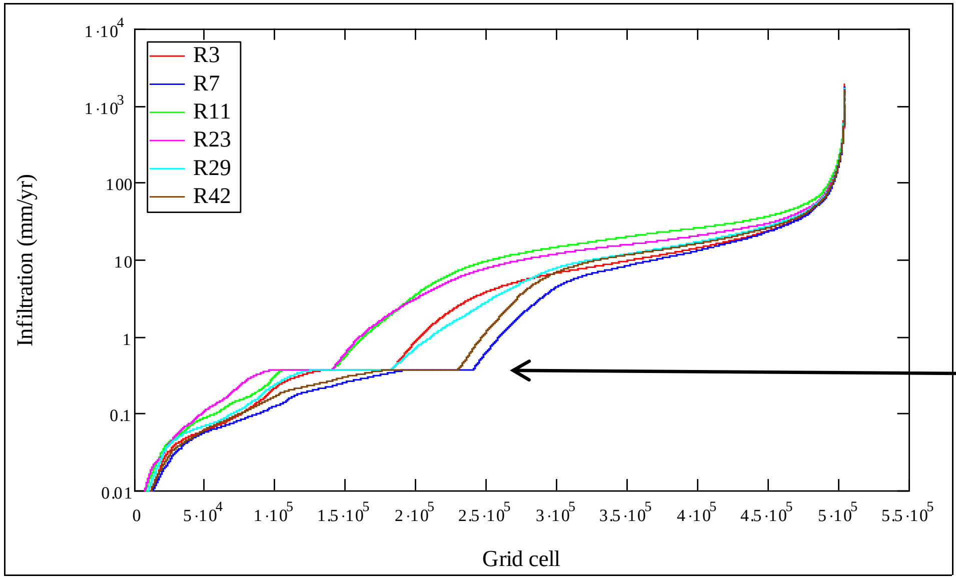
Parameter Name	Parameter Type	Units	Nominal	R3	R7	R11	R23	R29	R42
por	Soils	none	0.378	0.363	0.372	0.368	0.366	0.384	0.360
b	Soils	none	2.306	3.737	3.748	1.516	2.613	2.942	2.886
Flarea	Runoff	none	0.250	0.305	0.222	0.208	0.177	0.239	0.213
SKSfact	Runoff	none	1.000	0.845	0.901	0.807	0.983	0.862	0.829
MGCU	Bedrock	mm/day	0.002	0.011	0.006	0.003	0.002	0.001	0.000
UCCU	Bedrock	mm/day	0.002	0.000	0.002	0.010	0.017	0.000	0.009
UCA	Bedrock	mm/day	0.022	0.015	0.073	0.003	0.002	0.006	0.045
LCA3	Bedrock	mm/day	0.022	0.002	0.015	0.084	0.005	0.119	0.026
LCCU1	Bedrock	mm/day	0.002	0.001	0.005	0.000	0.003	0.006	0.000
RVA	Bedrock	mm/day	0.082	0.021	0.092	0.064	0.254	0.123	0.534
OSBCU	Bedrock	mm/day	0.358	0.693	0.264	0.155	1.371	0.048	0.475
LTCU	Bedrock	mm/day	0.107	0.239	0.021	0.014	0.174	0.978	0.020
BRCU	Bedrock	mm/day	0.107	0.350	0.405	0.280	0.022	0.016	0.446
BRA	Bedrock	mm/day	0.082	0.495	0.010	0.808	0.651	0.237	0.034
LVTA2	Bedrock	mm/day	12.333	1.815	11.820	18.122	9.281	11.179	64.646
SWA	Bedrock	mm/day	0.082	0.012	0.016	0.300	0.017	0.012	0.029
LVTA	Bedrock	mm/day	20.755	2.710	41.149	6.310	134.716	58.597	8.825
TSA	Bedrock	mm/day	13.052	2.682	4.839	50.677	2.940	1.340	13.914
PVTA	Bedrock	mm/day	20.755	53.156	3.396	11.505	5.401	3.006	3.813
TCA	Bedrock	mm/day	13.052	74.096	1.368	38.932	2.506	127.762	59.958
TM-LVTA	Bedrock	mm/day	20.755	13.229	4.489	4.765	2.990	14.539	3.598
TMWTAv2	Bedrock	mm/day	1.214	1.214	1.214	1.214	1.214	1.214	1.214
FCCM	Bedrock	mm/day	0.358	0.065	0.471	0.682	2.481	0.594	0.329
AA	Bedrock	mm/day	967.3	3360.9	7951.2	218.7	156.8	414.4	2248.3
faults	Bedrock	mm/day	0.186	0.098	0.024	0.188	1.720	0.031	0.559

Model Results: Rainier Mesa

Rep	Infiltration (mm/year) Min	Median	Mean	Max
R3	0.0	3.9	11.9	1981
R7	0.0	0.7	10.6	1801
R11	0.0	9.7	17.8	1608
R23	0.0	7.8	15.0	1570
R29	0.0	2.9	12.7	1759
R42	0.0	1.3	12.0	1685

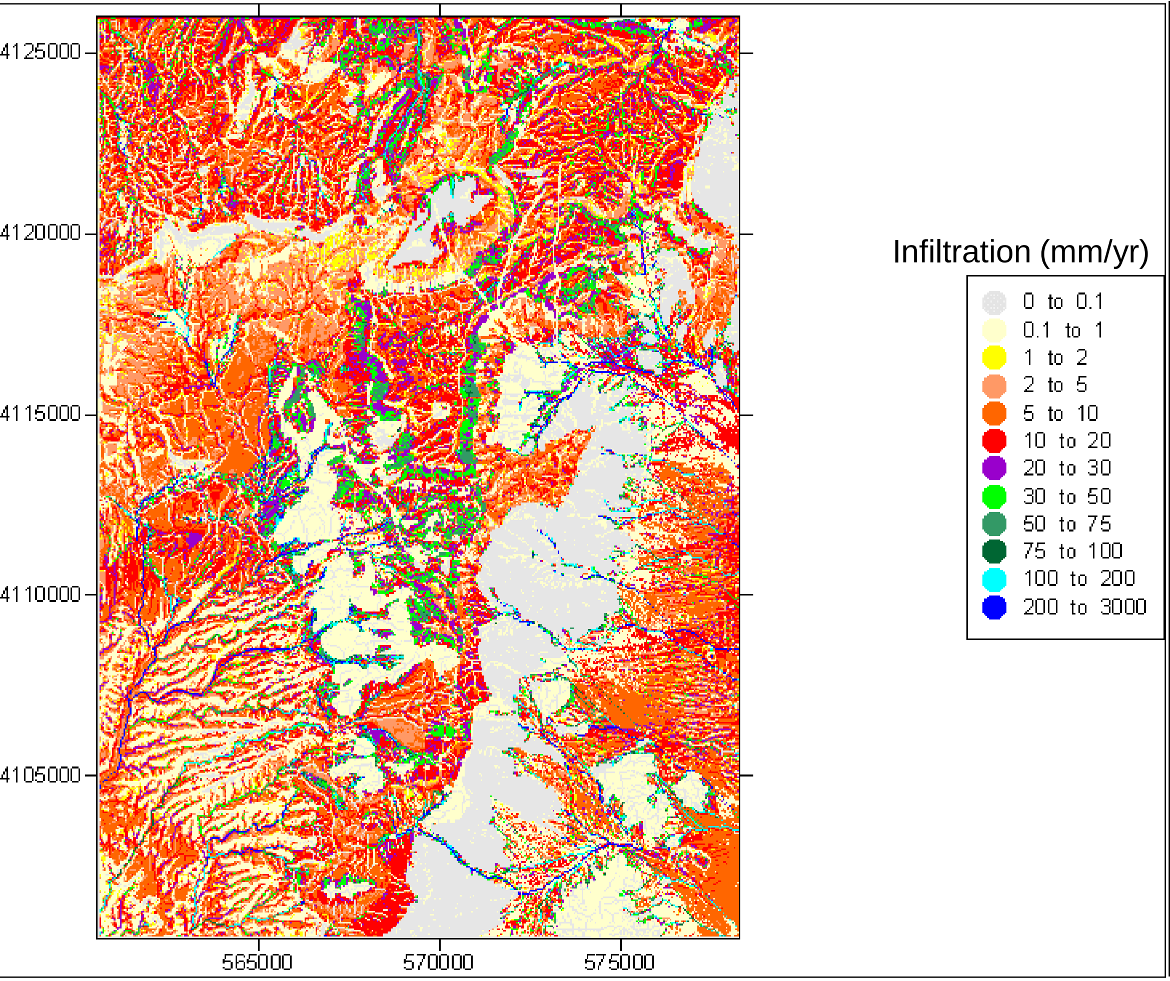
Replicate	Precipitation (mm/year)	Infiltration (mm/year)	ET (mm/year)	Sublimation (mm/year)	Outflow (mm/year)
R3	254.6	11.9	178.1	5.4	21.3
R7	254.6	10.6	179.1	5.4	21.4
R11	254.6	17.8	173.8	5.4	21.1
R23	254.6	15.0	177.5	5.4	20.6
R29	254.6	12.7	179.0	5.4	20.6
R42	254.6	12.0	176.2	5.4	22.0

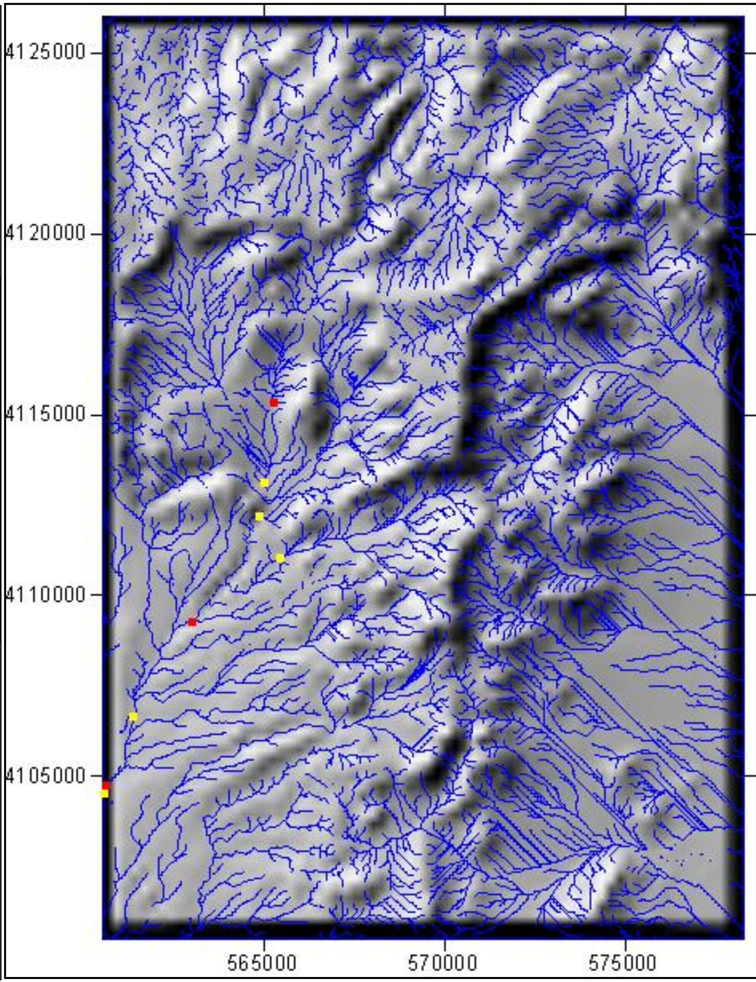
Replicate	Infiltration (% of Precip)	ET (% of Precip)	Sublimation (% of Precip)	Outflow (% of Precip)	Other (% of Precip)
R3	4.66%	69.98%	2.13%	8.39%	14.85%
R7	4.16%	70.36%	2.13%	8.39%	14.96%
R11	7.00%	68.27%	2.13%	8.27%	14.33%
R23	5.88%	69.72%	2.13%	8.08%	14.18%
R29	5.00%	70.32%	2.13%	8.10%	14.44%
R42	4.70%	69.20%	2.13%	8.63%	15.33%



Artifact of Bulk Rock Unsat-K setting

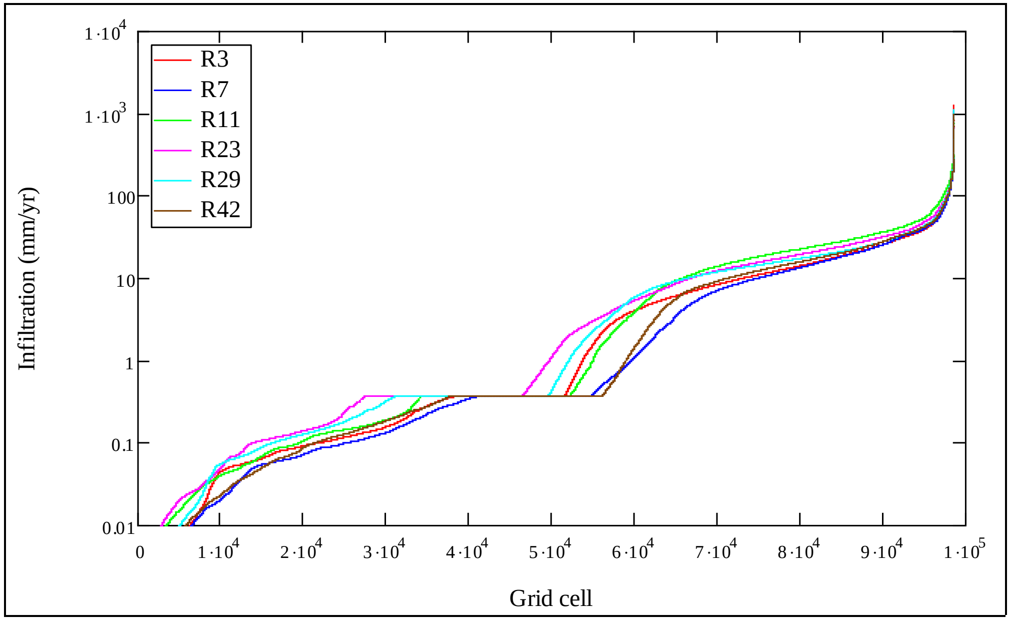
Model Results: Rainier Mesa



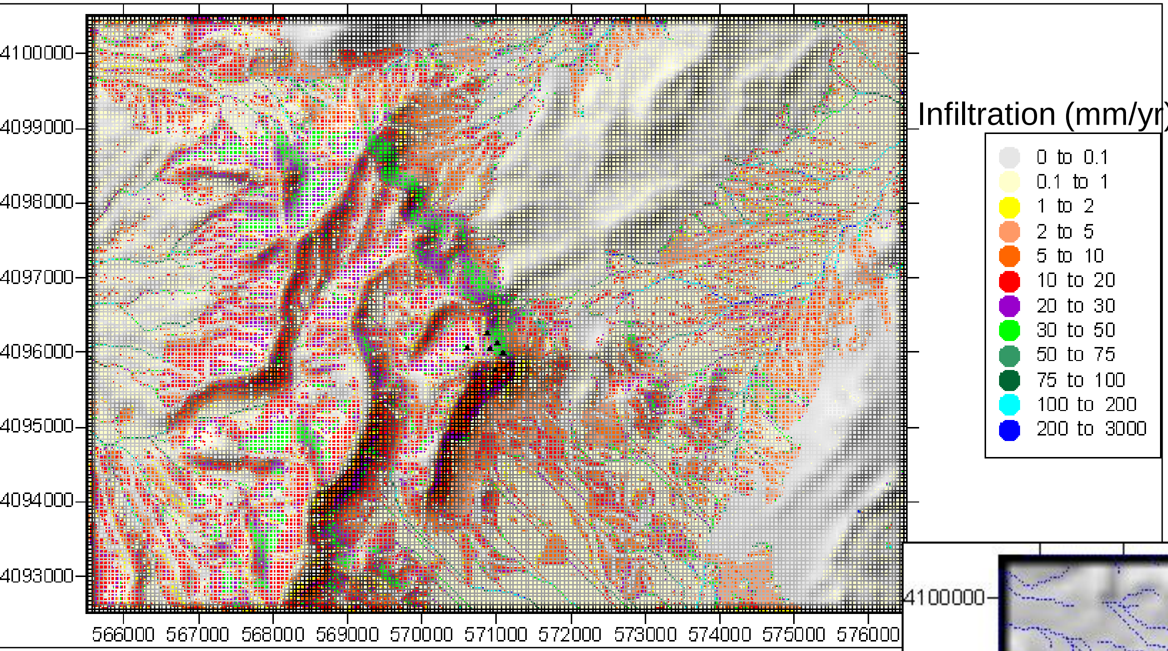


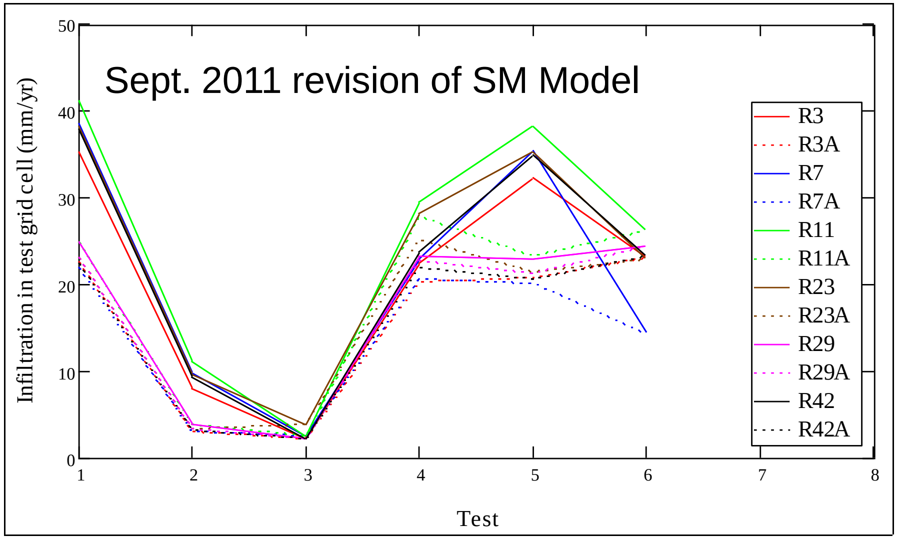
Model Results: Shoshone Mtn

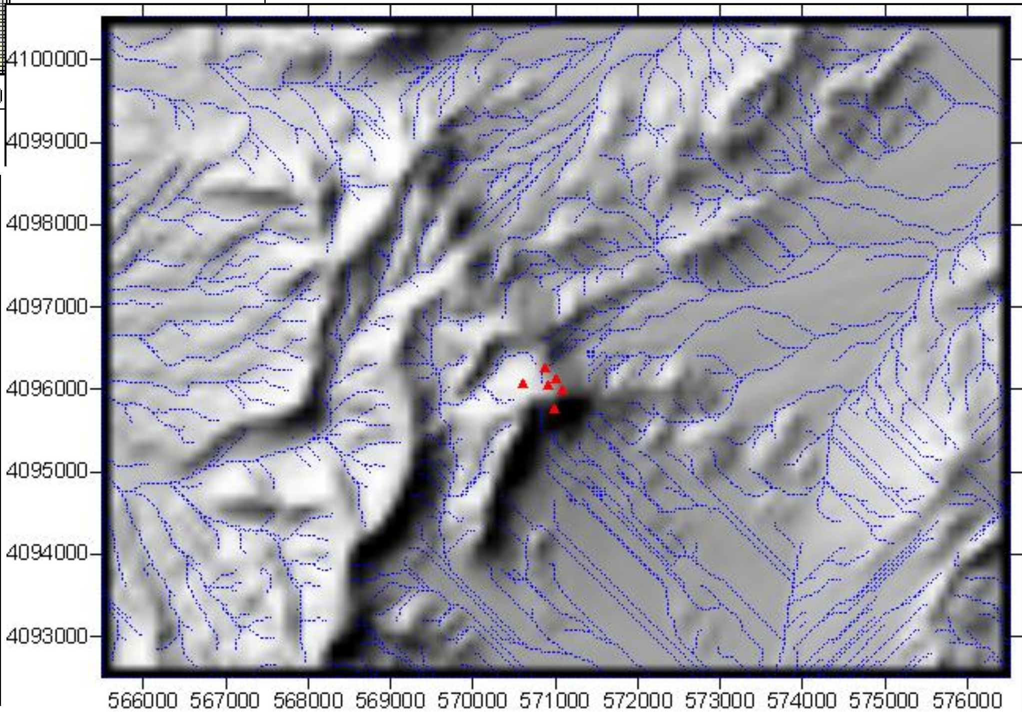
Replicate	Precipitation (mm/year)	Infiltration (mm/year)	ET (mm/year)	Sublimation (mm/year)	Outflow (mm/year)	
R3	225.1	8.1	159.3	0.8	52.1	
R7	225.1	7.3	160.5	0.8	51.8	
R11	225.1	11.2	156.9	0.8	51.3	
R23	225.1	10.0	159.4	0.8	49.9	
R29	225.1	9.5	160.0	0.8	50.1	
R42	225.1	8.2	157.9	0.8	53.2	
Replicate		Infiltration (% of Precip)	ET (% of Precip)	Sublimation (% of Precip)	Outflow (% of Precip)	Other (% of Precip)
R3		3.59%	70.77%	0.34%	23.14%	2.16%
R7		3.23%	71.29%	0.34%	22.99%	2.15%
R11		4.99%	69.68%	0.34%	22.78%	2.21%
R23		4.44%	70.79%	0.34%	22.18%	2.25%
R29		4.20%	71.09%	0.34%	22.25%	2.13%
R42		3.63%	70.14%	0.34%	23.62%	2.28%



Model Results: Shoshone Mtn







Conclusions

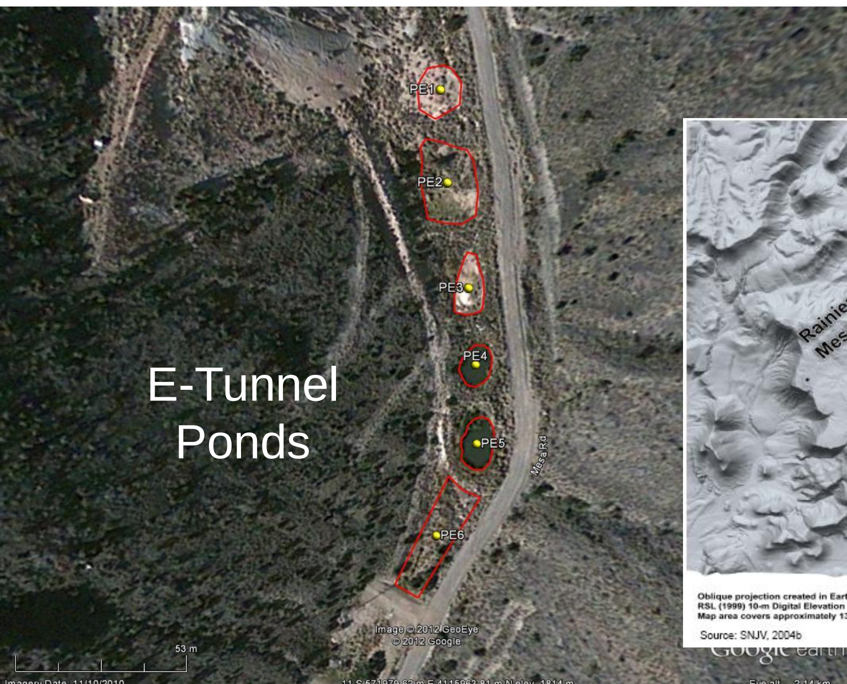
- Average annual infiltration rates =11 to 18 mm/year for RM domain
- Average annual infiltration rates = 7 to 11 mm/year for SM domain
- ET = 70% of precipitation for both domains
- Runoff = 8-9% for RM; and 22-24% for SM
  - Apparently high average runoff is caused by the truncation of the lower-elevation portions of watersheds where much of the infiltration of runoff waters would otherwise occur
- Model results are calibrated to measured ET, CMB data, and streamflow observations
- Model results are validated using streamflow observations discovered after model calibration was complete
- Use of soil Ksat reduction with slope to mitigate bathtub ring was successful (based on calibration results)
- Soil-bedrock K_interface is innovative approach

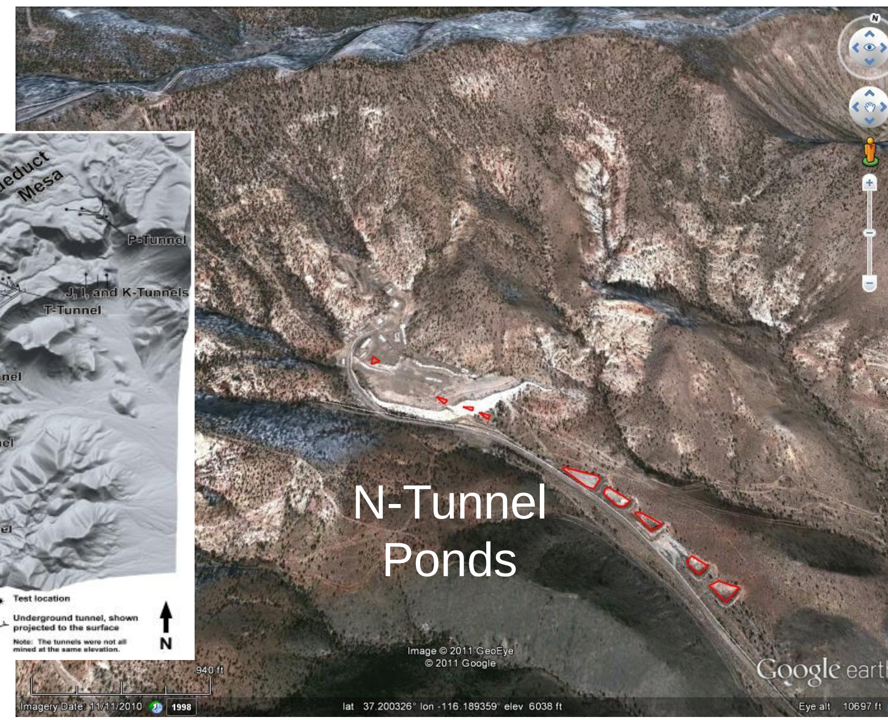
E- and N-Tunnel Ponds Infiltration Models

Daniel Levitt, Kay Birdsell, Edward Kwicklis, and Naomi Becker
Earth and Environmental Sciences Division
Los Alamos National Laboratory

Rainier Mesa/Shoshone Mtn CAU Pre-emptive Review Meeting

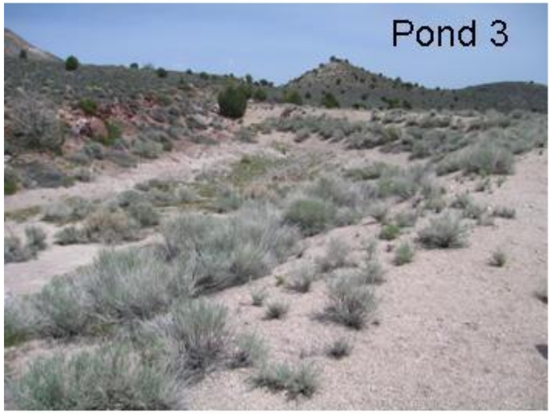
July 11, 2012

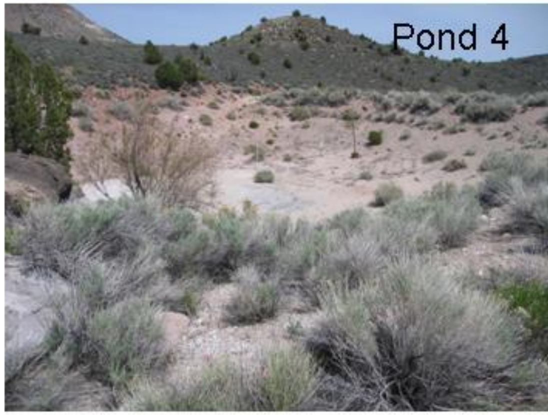




N-Tunnel Ponds: Background

- 22 nuclear tests in N-Tunnel Complex
- 9 ponds used to contain tunnel effluent from 1961-1994
- Tests at depths below ground surface of 30-454 m
- Tests at 220-890 m above water table





Photos taken in 2009

E-Tunnel Ponds

- 9 nuclear tests in E-Tunnel Complex
- 5-8 ponds used to contain tunnel effluent from 1957-current (due to seeps from tunnel portal)
- New berms constructed in 2008-2009 to create ponds 6a, 6b, and 6c

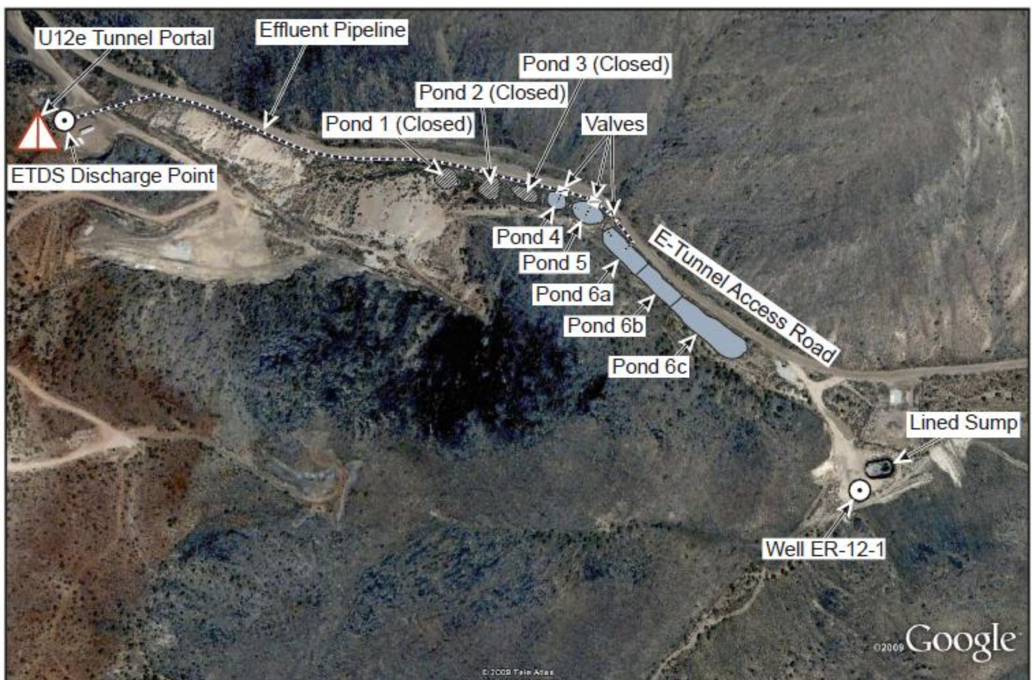


FIGURE 1
E-TUNNEL WASTEWATER DISPOSAL SYSTEM AND WELL ER-12-1
SITE LAYOUT

Source: Andres letter dated June 2, 2009

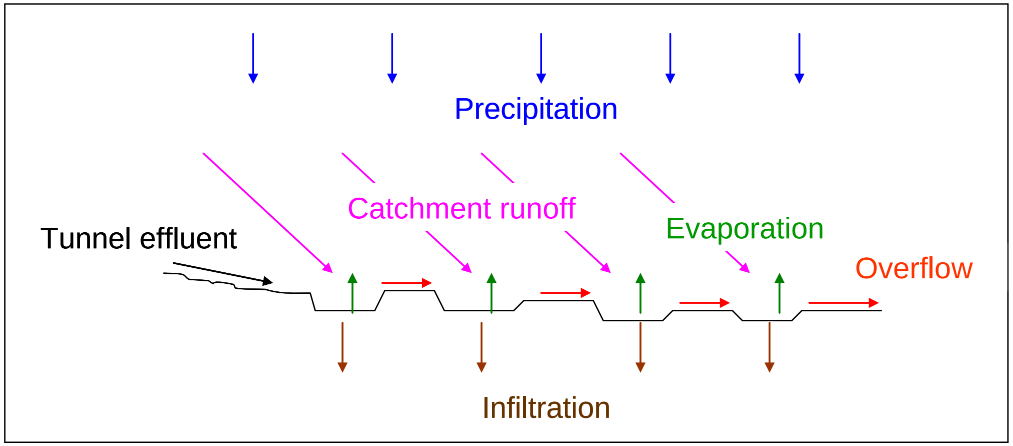
PHOTOGRAPHS OF U12 E-TUNNEL BERMS AFTER CONSTRUCTION ACTIVITIES

Photograph 3. Overflow Pipe at Upper Berm (12/11/2008)

Photograph 4. Ponding behind Upper Berm (12/11/2008)

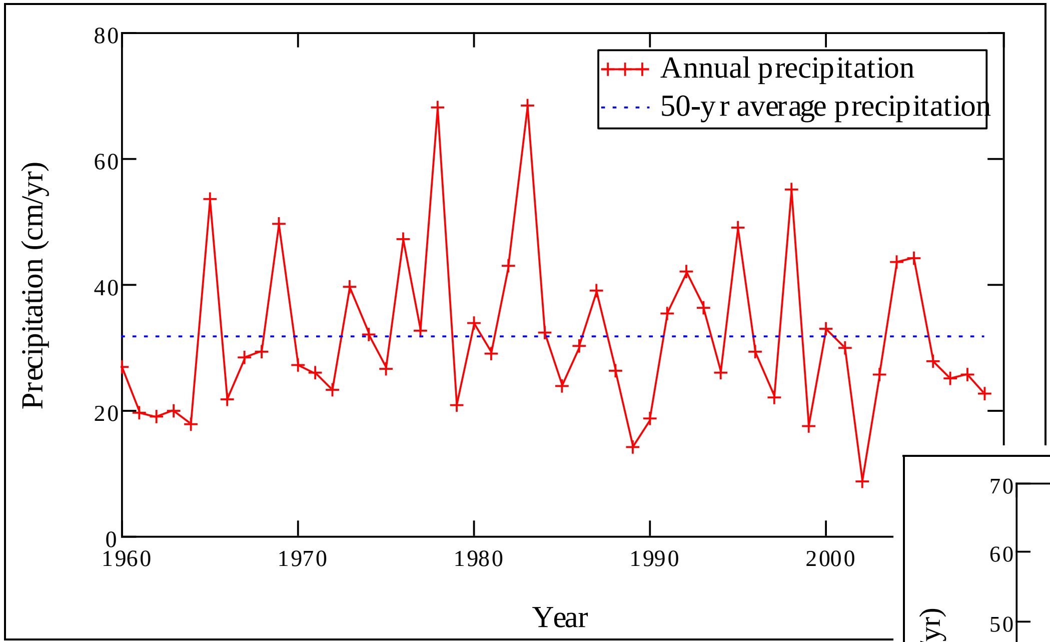
Tunnel Ponds Infiltration: Conceptual Model

- Infiltration model built using Excel spreadsheet
- Inputs:
  - Precipitation
  - Tunnel Effluent
  - Runoff into ponds (from precipitation)
  - Potential Evaporation estimates
  - Pond floor Ksat estimates (acquired from model calibration)

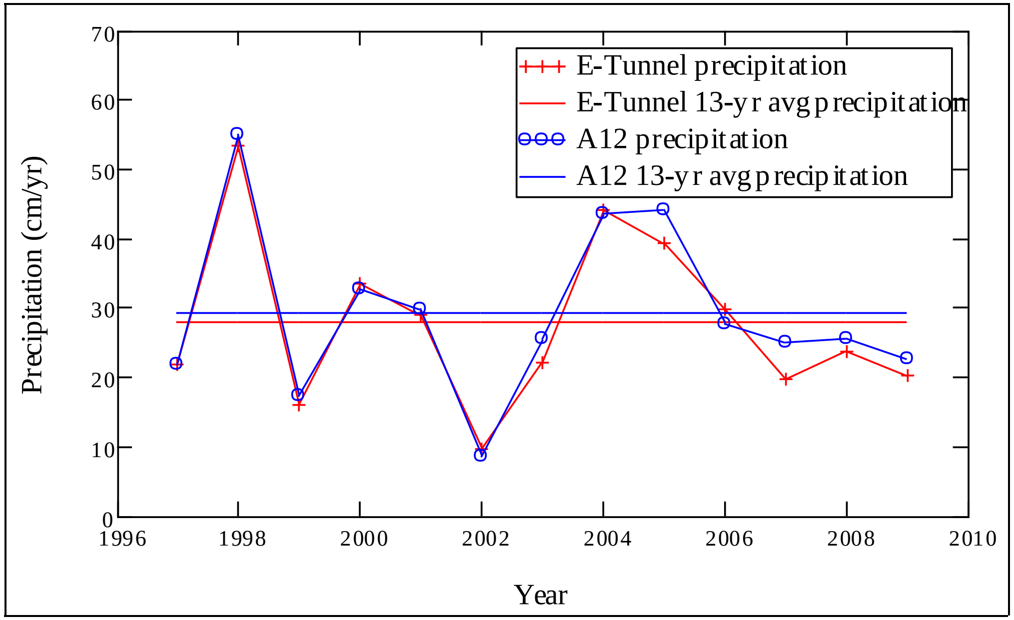


Tunnel Ponds: Precipitation

- 50-year avg annual precipitation = 314 mm/yr (12.4 in/yr)
- Measured at top of RM (A12 station)



- Did not use E-Tunnel data (short record, and very similar to A12)

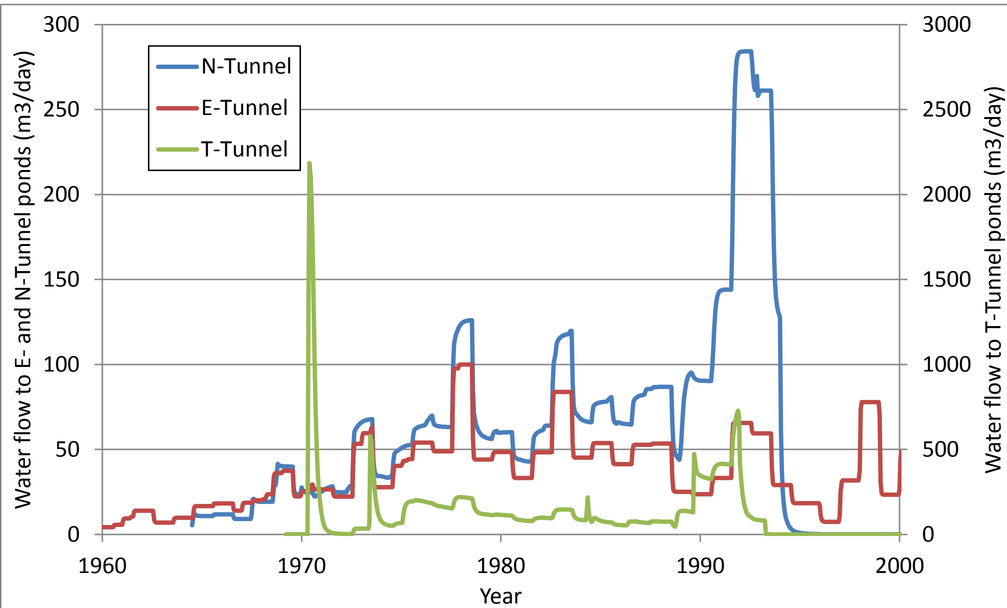


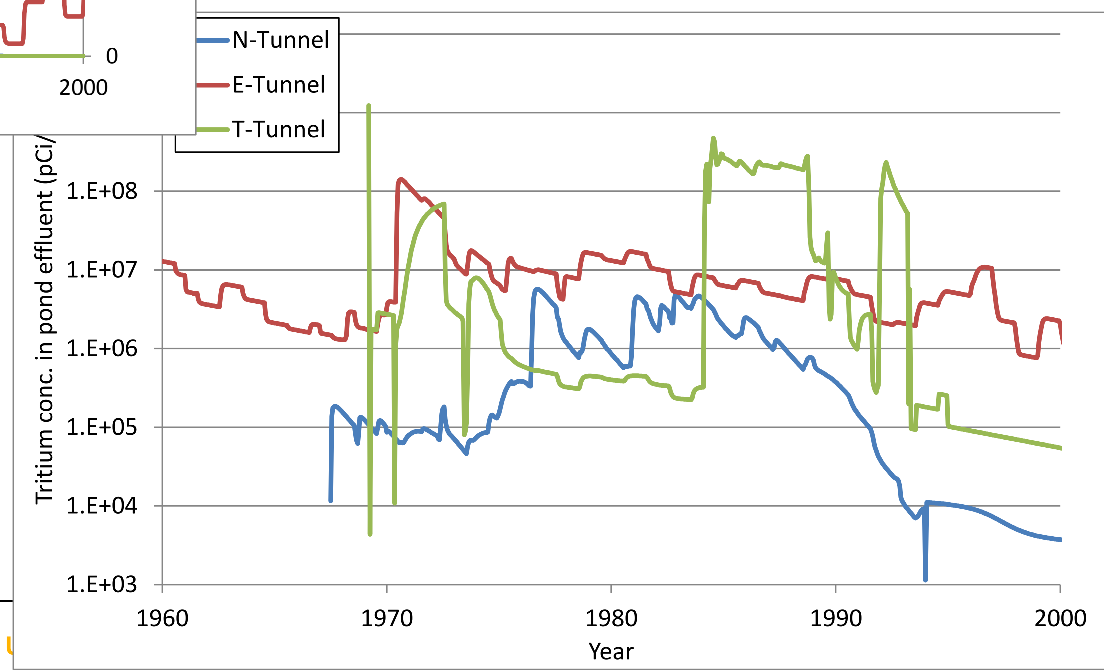
Los Alamos NATIONAL LABORATORY EST. 1943

UNC

Tunnel Ponds: Tunnel discharge

- Tunnel discharge estimated by LLNL for E-, N-, and T-Tunnels

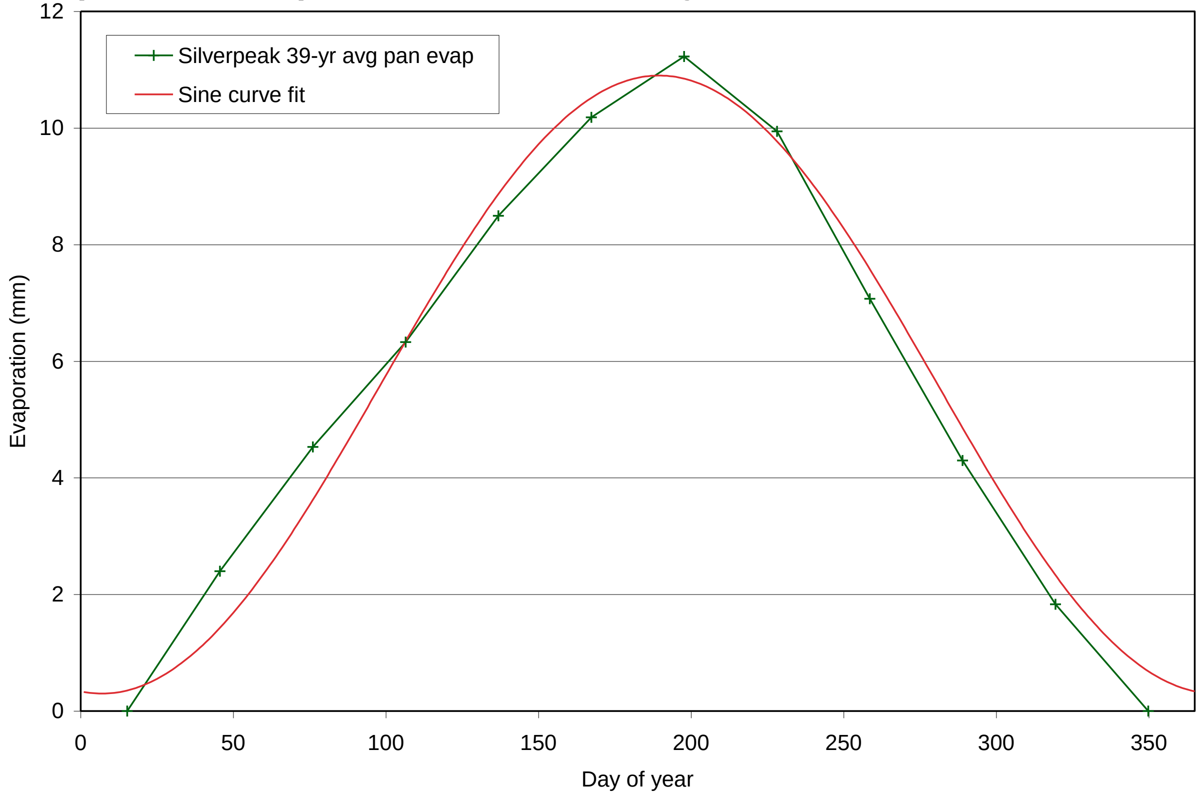




Source: Excel files received from LLNL on July 1, 2010

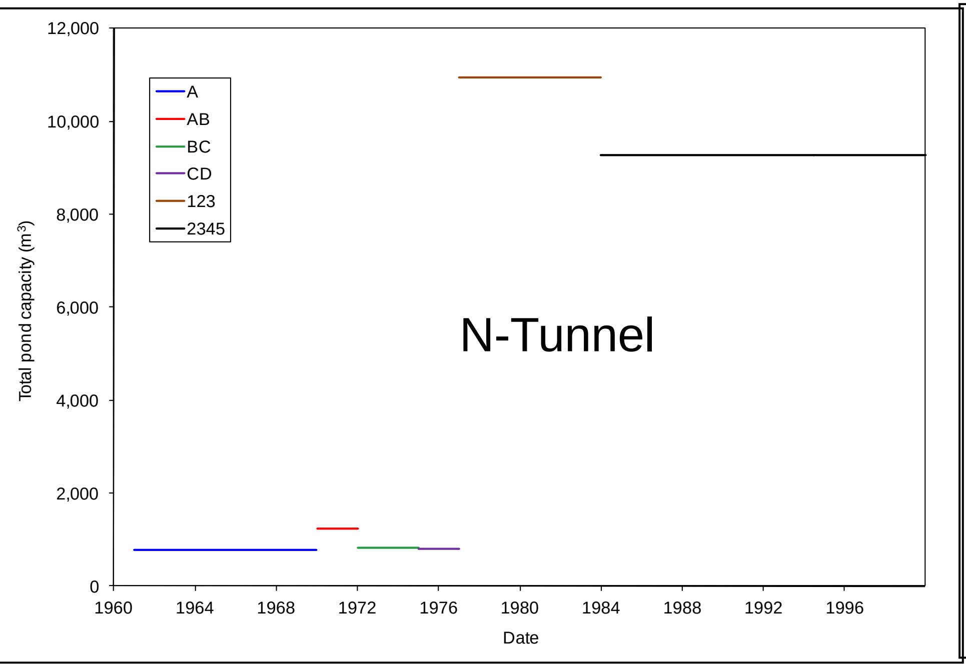
Tunnel Ponds: Potential Evaporation

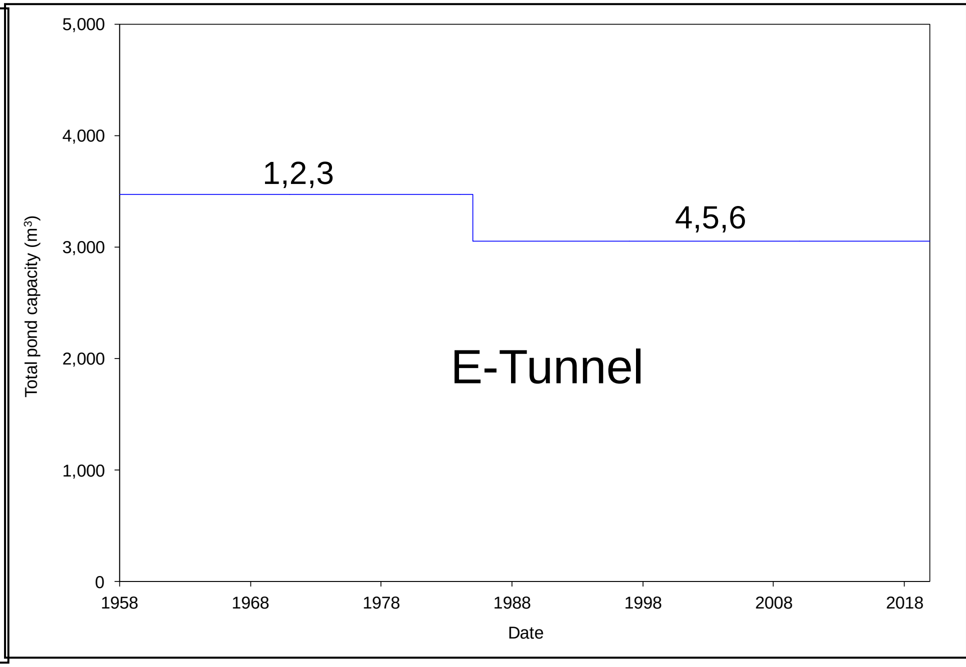
- Estimated from pond evaporation data
- Reduced by 25% to account for scaling from pan to pond
- Potential pond evaporation =~ 2 m/yr

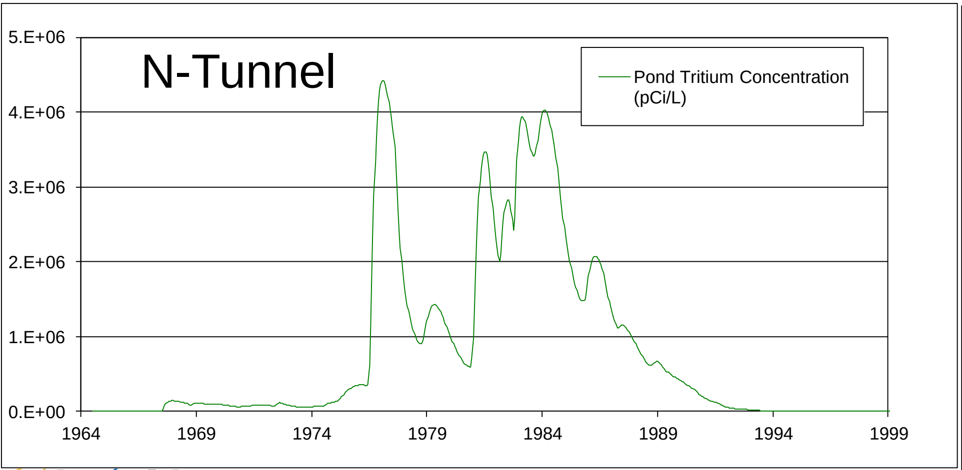


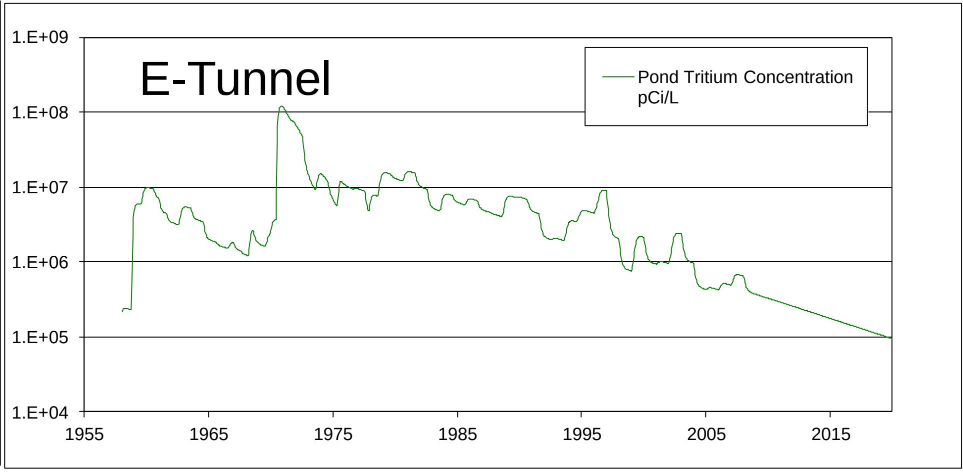
$$Evaporation\_(mm/day) = 5.6 - 5.3 * \sin\left(\frac{DOY * 2 * \pi}{365.25} + 1.45\right)$$ **x 0.75**

Tunnel Ponds Capacity Histories







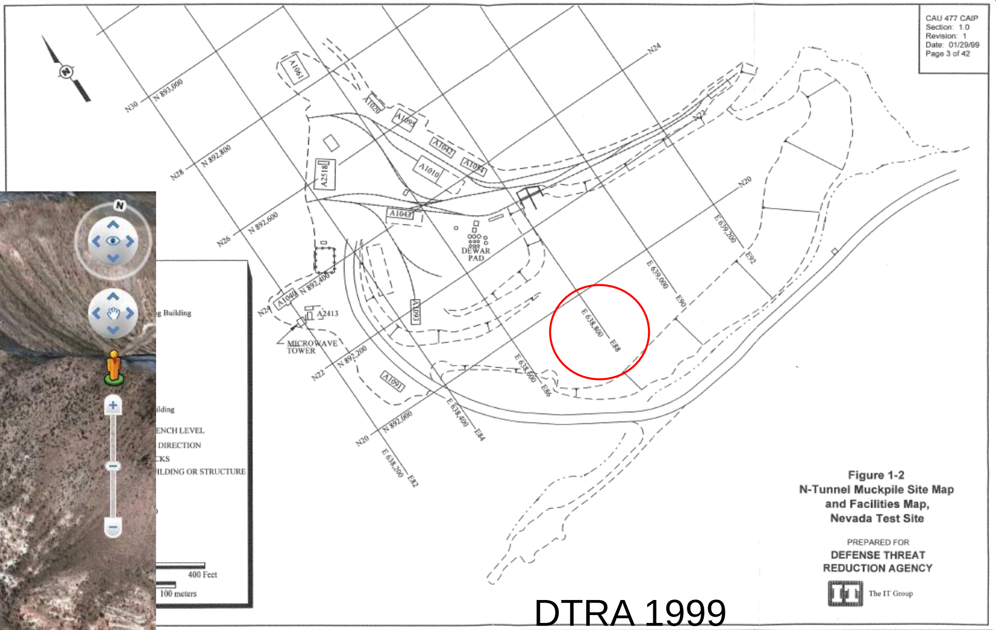


Los Alamos NATIONAL LABORATORY EST. 1943

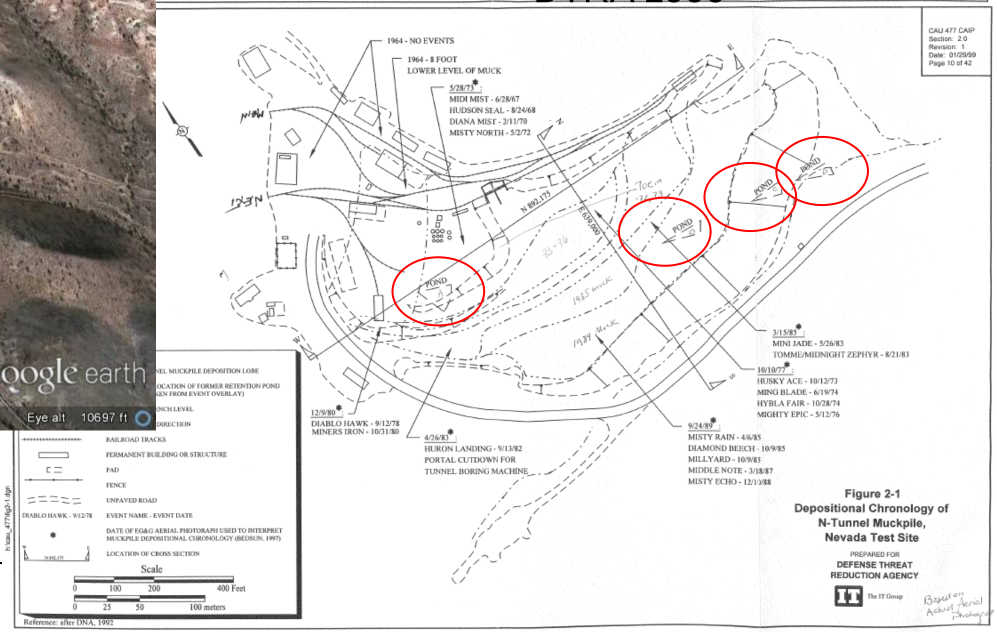
Pond tritium concentration estimates provided by LLNL

NNSA

N-Tunnel Ponds: Pond Locations and Areas



DTRA 1999



Pond areas estimated using Google Earth Pro

Los Alamos NATIONAL LABORATORY EST.1943

N-Tunnel Ponds: Pond Catchments

N-Tunnel Ponds: Geology

- Source: NSTech, 2011

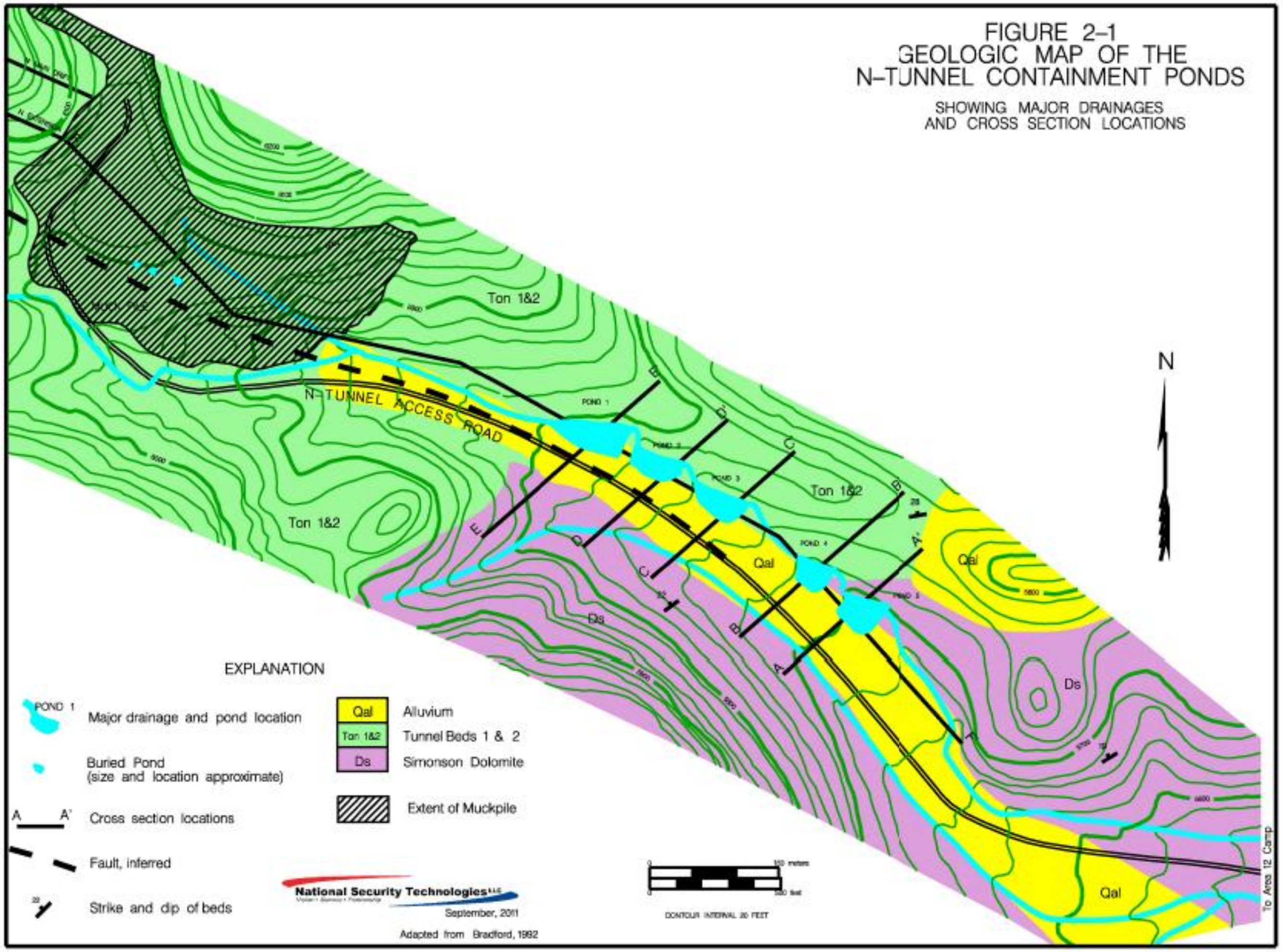
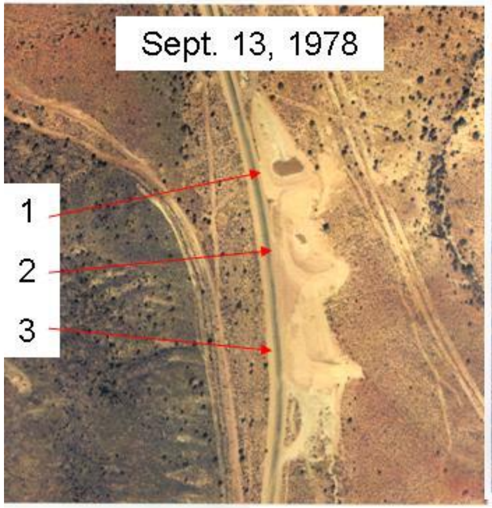
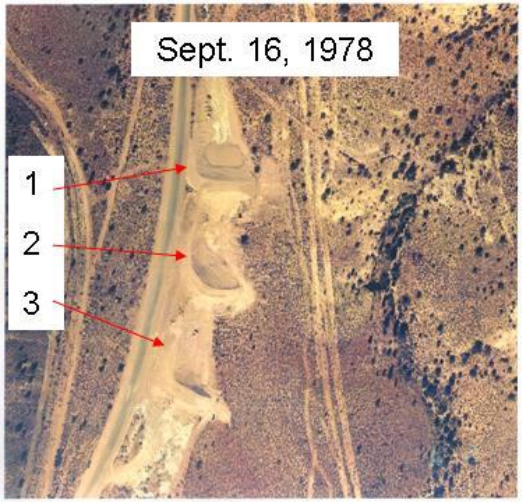


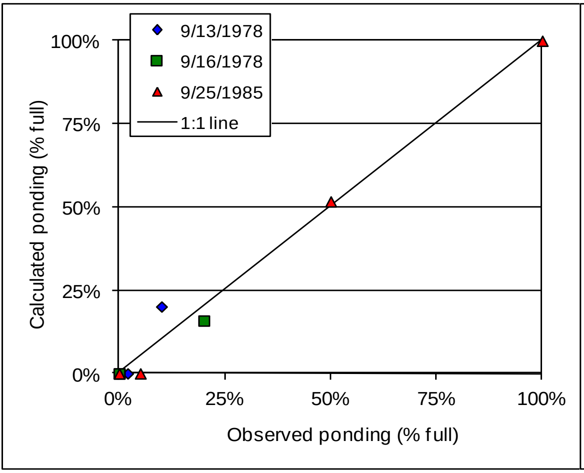
Figure 2-1
Geologic Map of the N-Tunnel Containment Ponds Showing Cross Section Locations

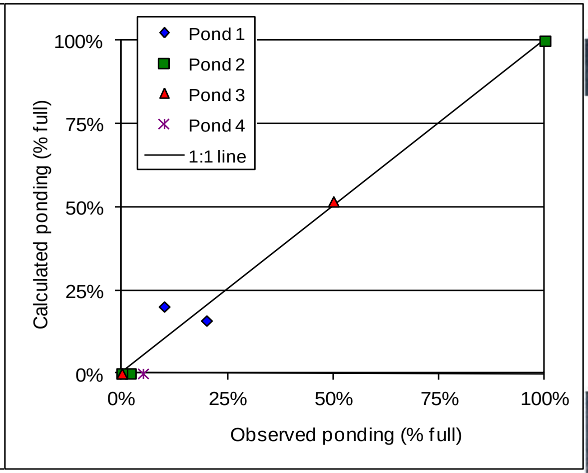
N-Tunnel Ponds: Model Calibration

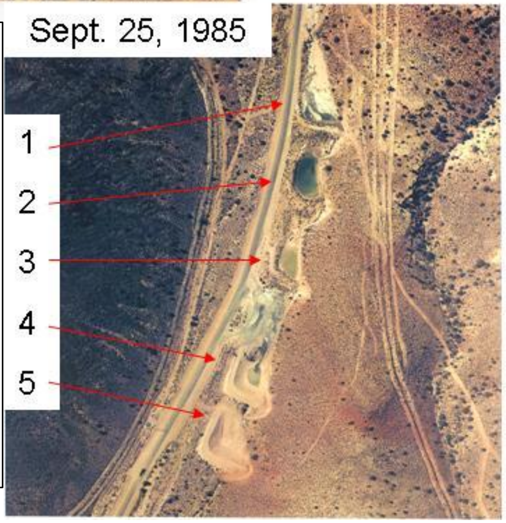
- Calibration: adjustment of soil Ksat until pond volumes best matched photos of ponds taken on 3 dates.
  - Sept 13, 1978
  - Sept 16, 1978
  - Sept 25, 1985







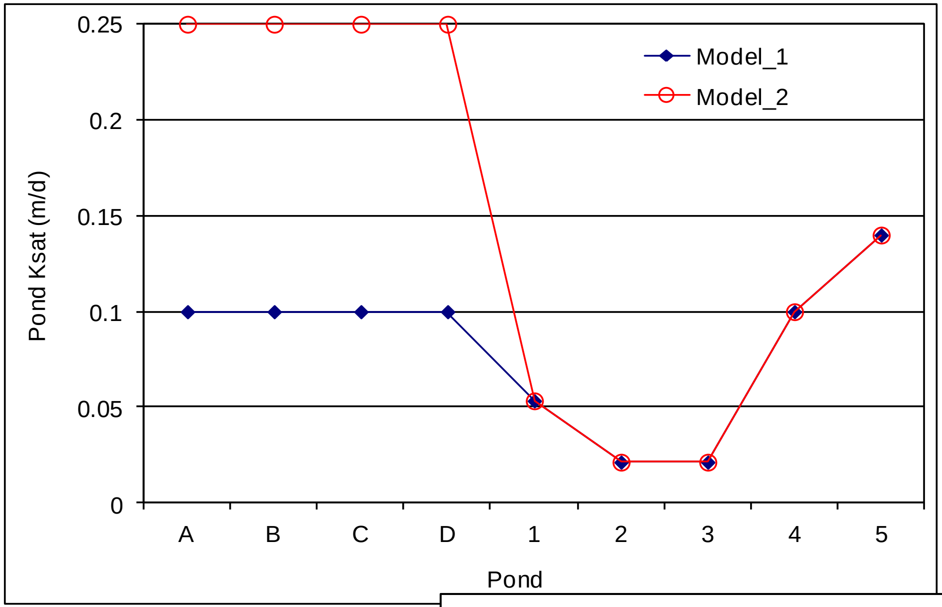




1) Ponds 2 and 3 were mostly full, most of the time
2) Pond 5 was never observed to overflow, although it came close in 1992 and the free-board of ponds 4 and 5 was raised by 2-3 feet in 1992
3) Water was pumped out of pond 4 and into 3 due to concerns about pond 4 failing

N-Tunnel Ponds: Model Calibration

- Calibration results: Ksats =~0.02 to 0.14 m/day (Model_1)
  - Model_2 prevents water from leaving ponds A,B,C,D (out of domain)



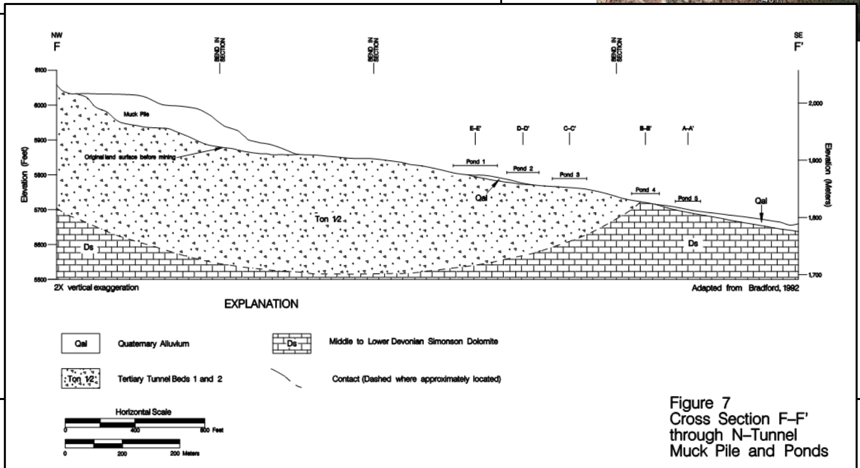
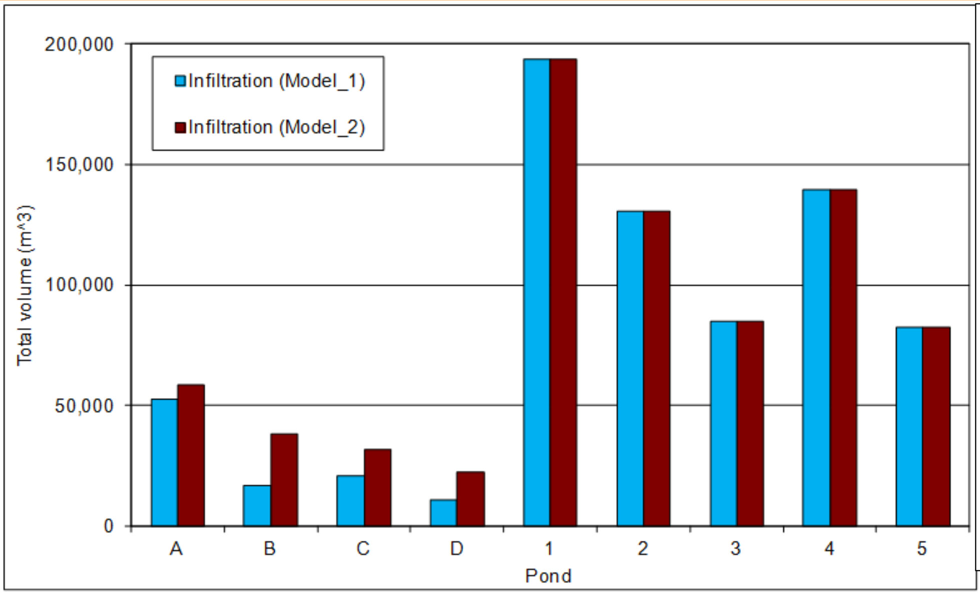
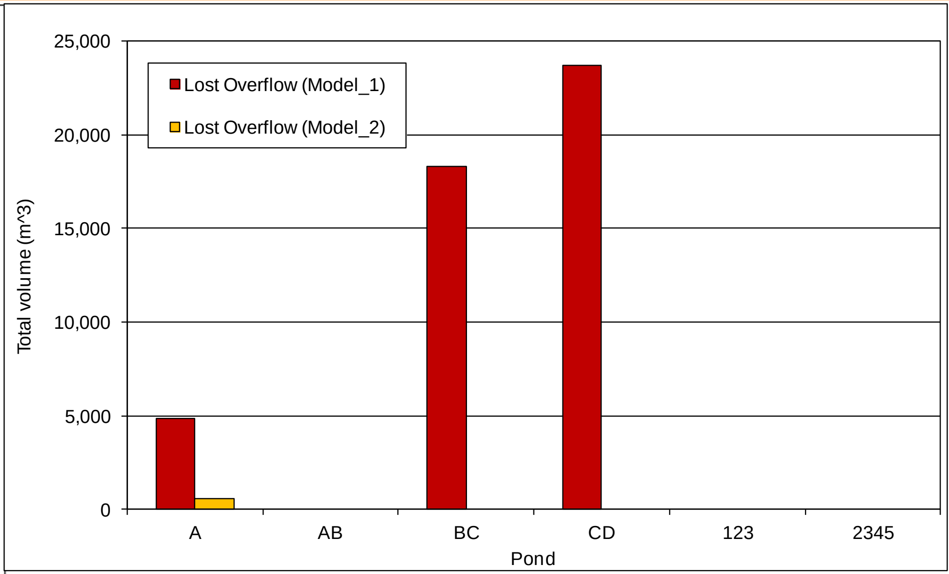
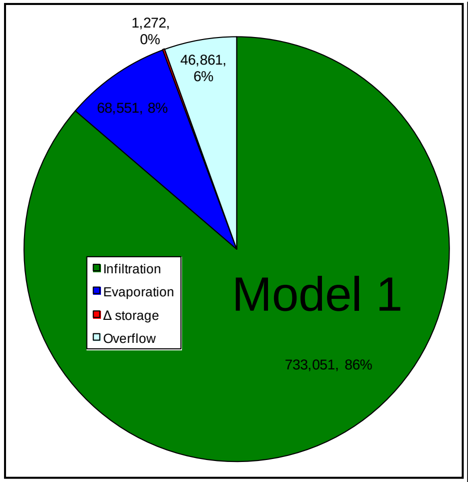


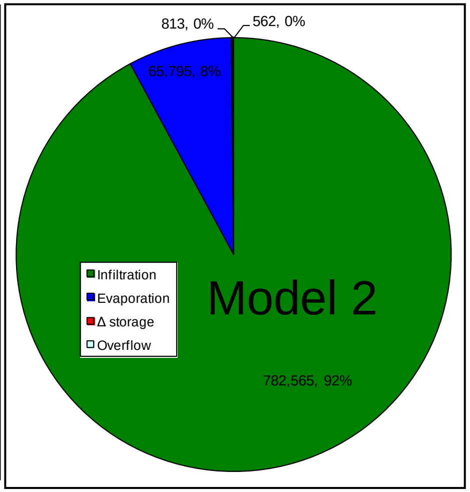
Figure 7
Cross Section F–F'
through N–Tunnel
Muck Pile and Ponds

N-Tunnel Ponds: Model Results









E-Tunnel Ponds: Pond Areas

E-Tunnel Ponds: Geology

- Source: NSTech, 2011

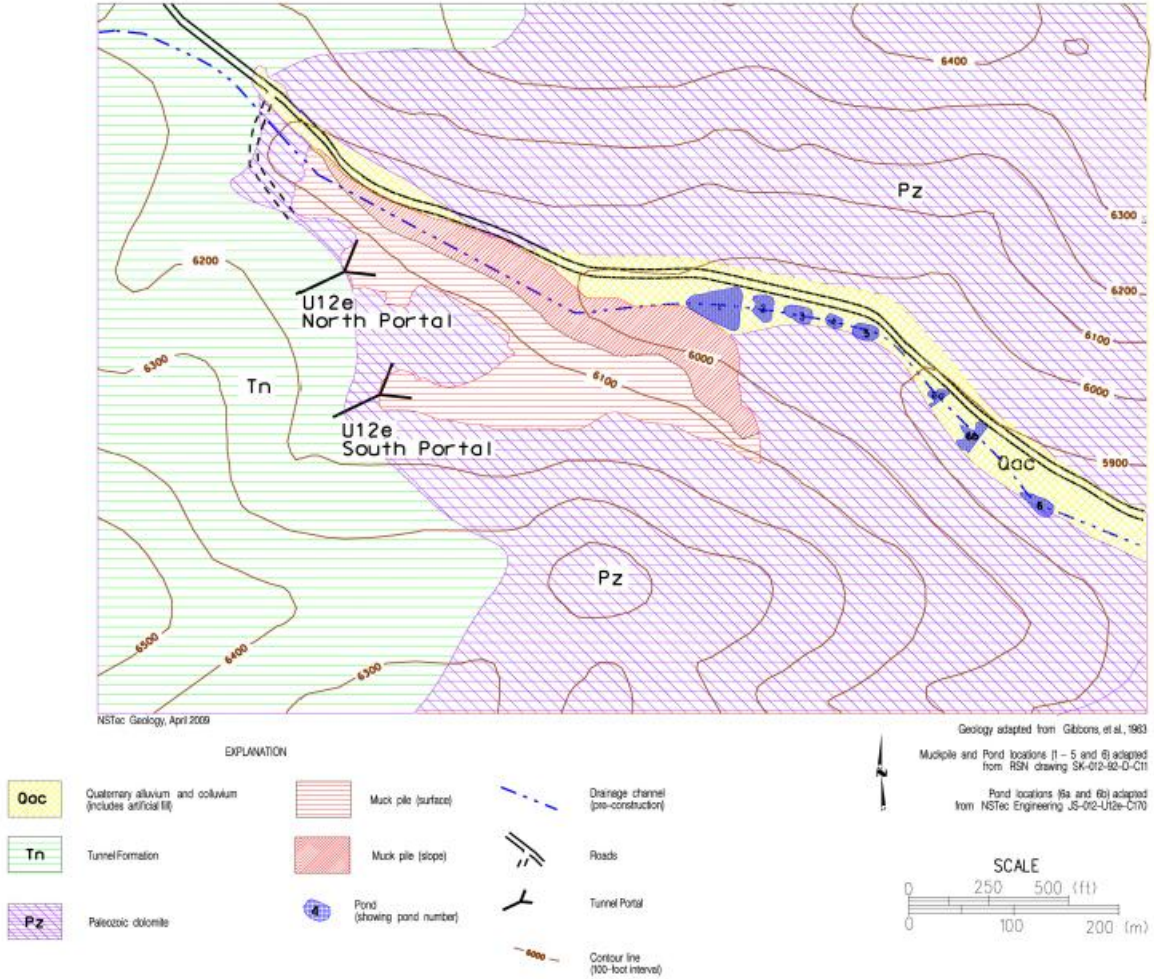
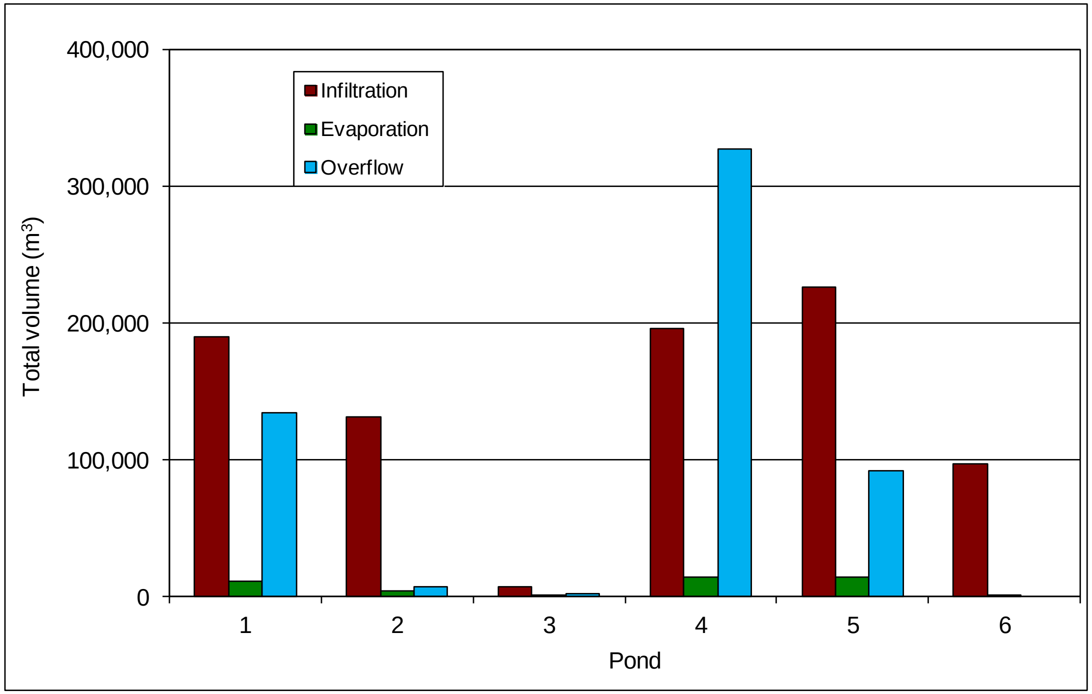
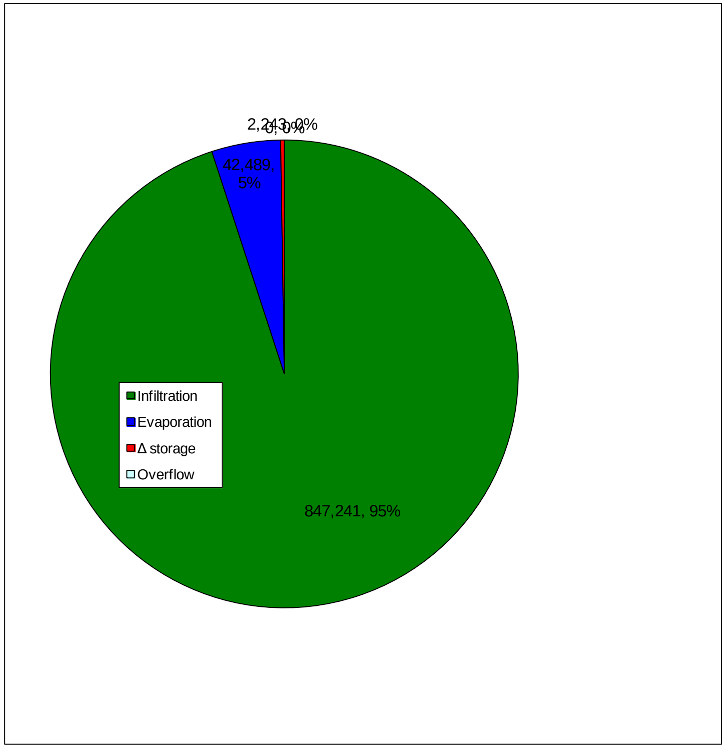


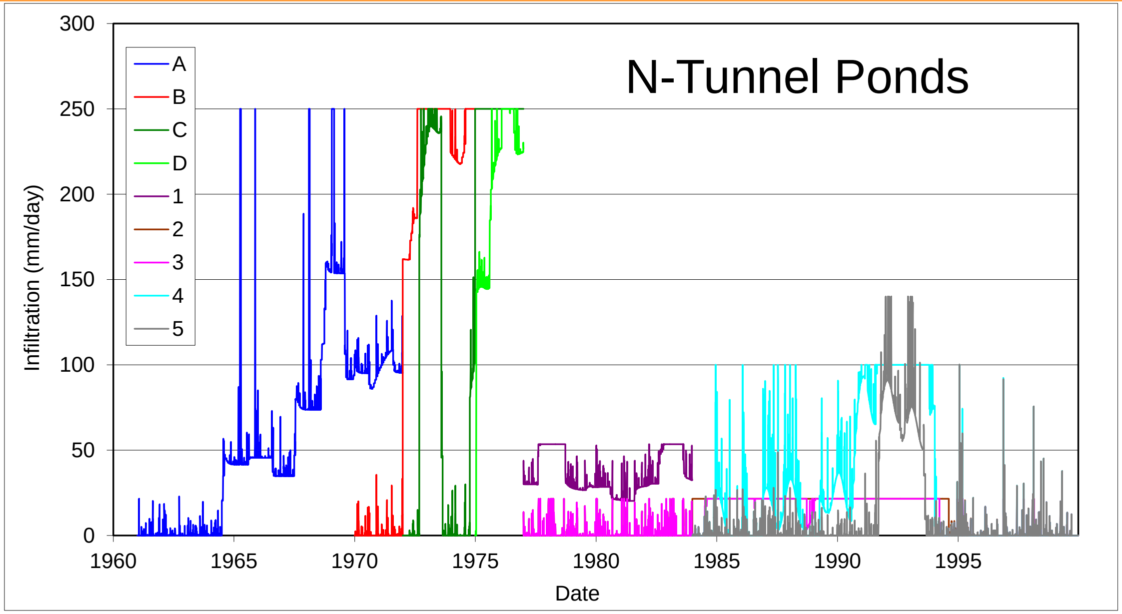
Figure 4-1
Geologic Map of the E-Tunnel Pond Area

E-Tunnel Ponds: Model Results

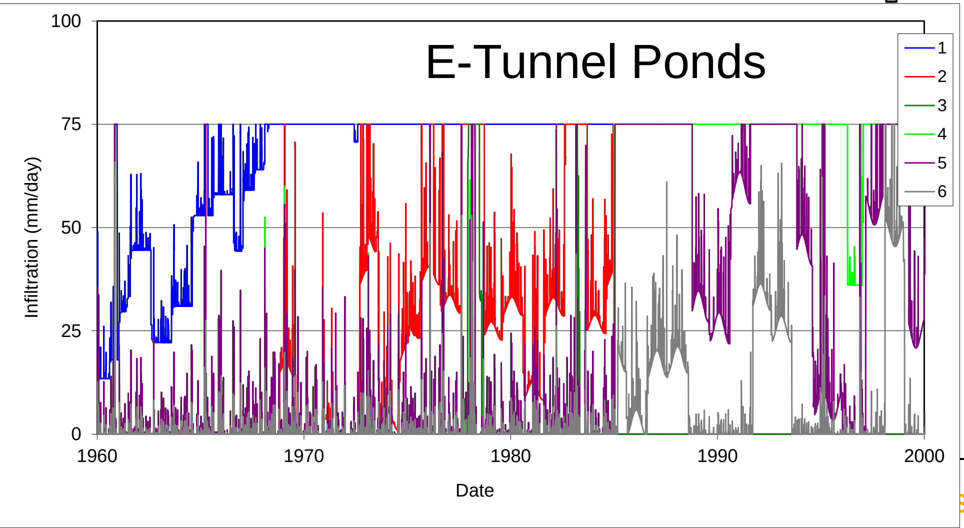


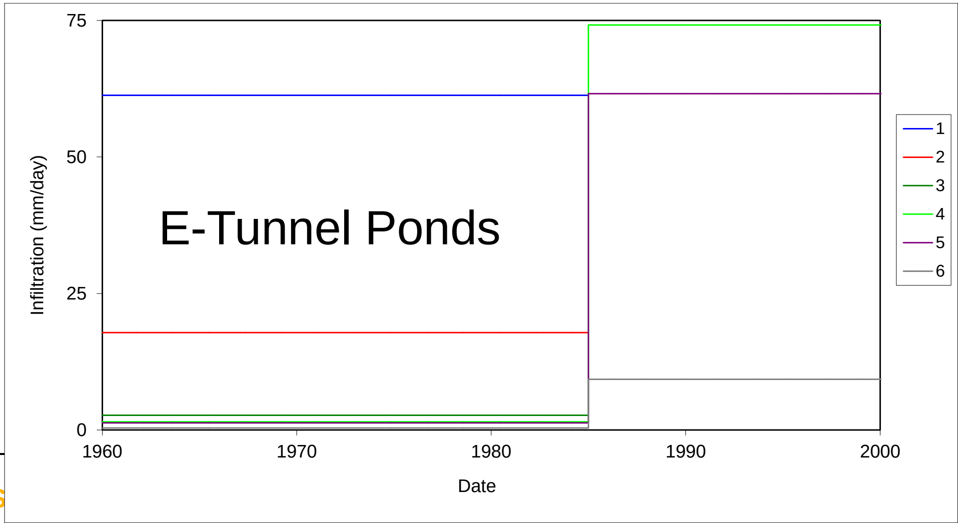


Tunnel Ponds: Model Results



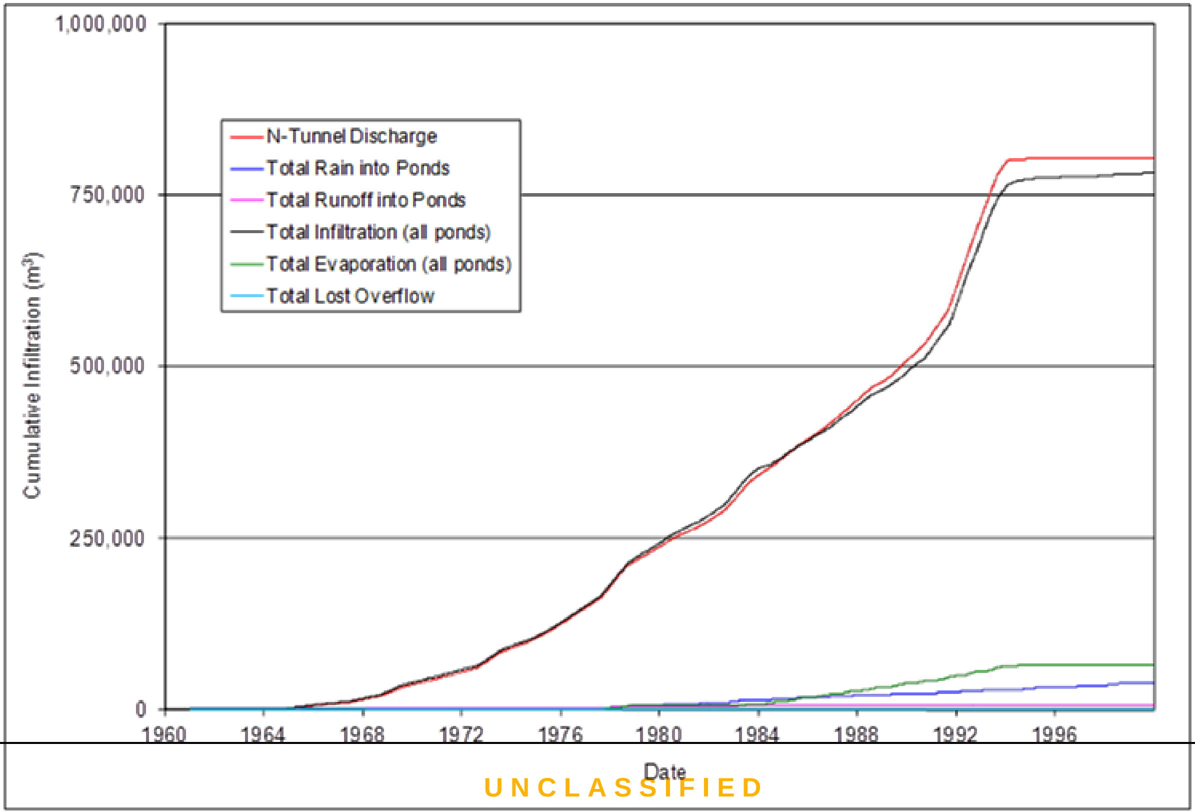
Approximated as:





Tunnel Ponds Infiltration: Conclusions

- 92-95% all the tunnel discharge ends up infiltrating into the ponds
- This is due to the large amount of water (only about 1 cm/day max can evaporate from ponds)
- Infiltration amounts are well-constrained for all the E- or N-Tunnel ponds as a whole; less certain for each pond



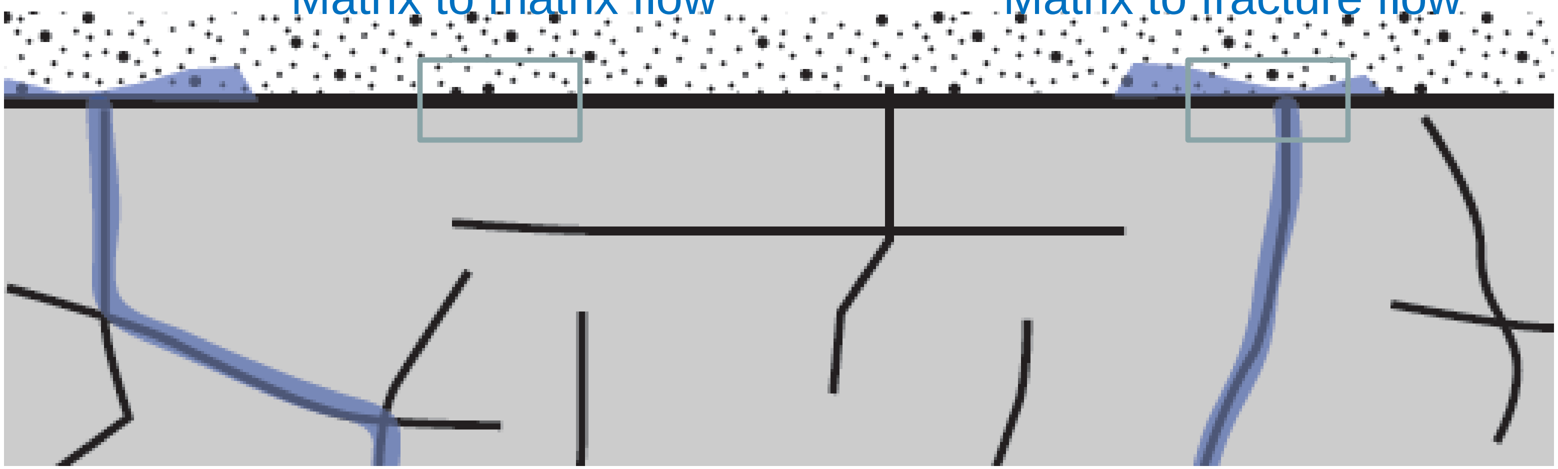
Supplemental slides

Model Pre-processing

- Soil-Bedrock Interface Permeabilities

Interface type 1: Matrix to matrix flow

Interface type 2: Matrix to fracture flow



$$K_{interface} = (1-Ø_f) \times K^1_{interface} + Ø_f \times K^2_{interface} \approx K^1_{interface} + Ø_f \times K^2_{interface}$$

Where

$$K^1_{interface} = (\Delta z_1+\Delta z_2)/(\Delta z_1/K_{soil} + \Delta z_2/k_{matrix})$$

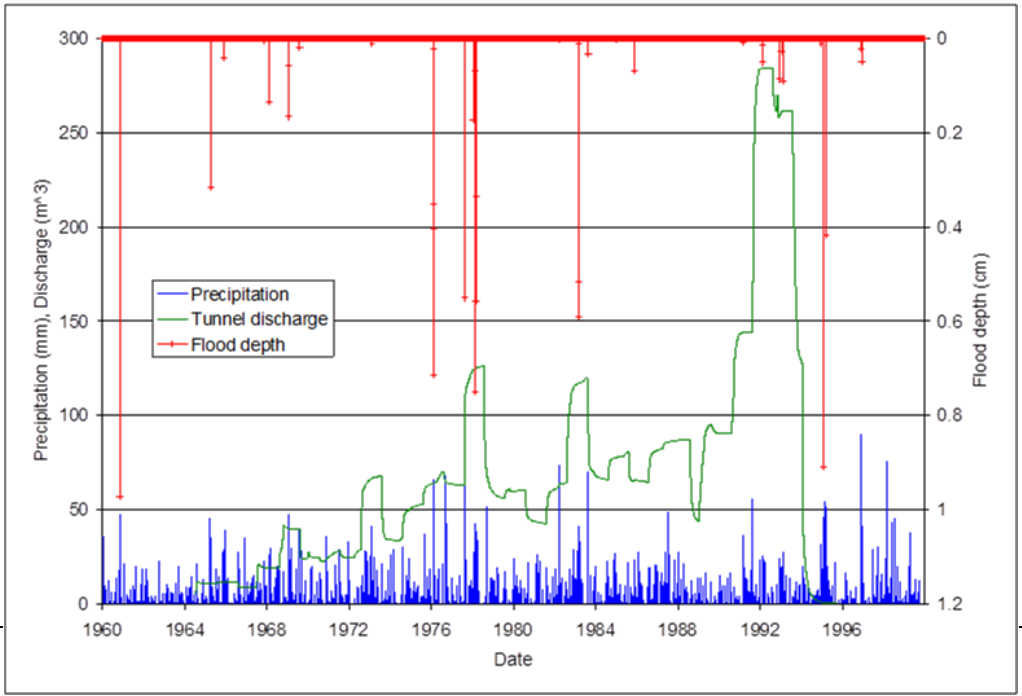
$$K^2_{interface} = (\Delta z_1+\Delta z_2)/(\Delta z_1/K_{soil} + \Delta z_2/k_{fracture})$$

and

$Ø_f$ is fracture porosity in the bedrock

Tunnel Ponds: Runoff into ponds

- Surface water runoff into each of the active ponds were conducted using the U.S. Department of Agriculture (USDA) Soil Conservation Service Curve Number (SCS-CN) method.
- Surface soil water potential was simulated using HYDRUS-1D:
  - Calibrated to weighing lysimeter data
  - Calculate curve number on a daily basis
  - Surface soil water potential thresholds used to separate antecedent runoff conditions (ARCs) I, II, and III



E- and N-Tunnel Ponds Histories

National Security Technologies LLC
Vision • Service • Partnership

DOE/NV/25946--1364

Geology and History of the Water-Containment Ponds at
U12n, U12t, and U12e Tunnels, Rainier Mesa,
Nevada National Security Site

December 2011

Prepared for:

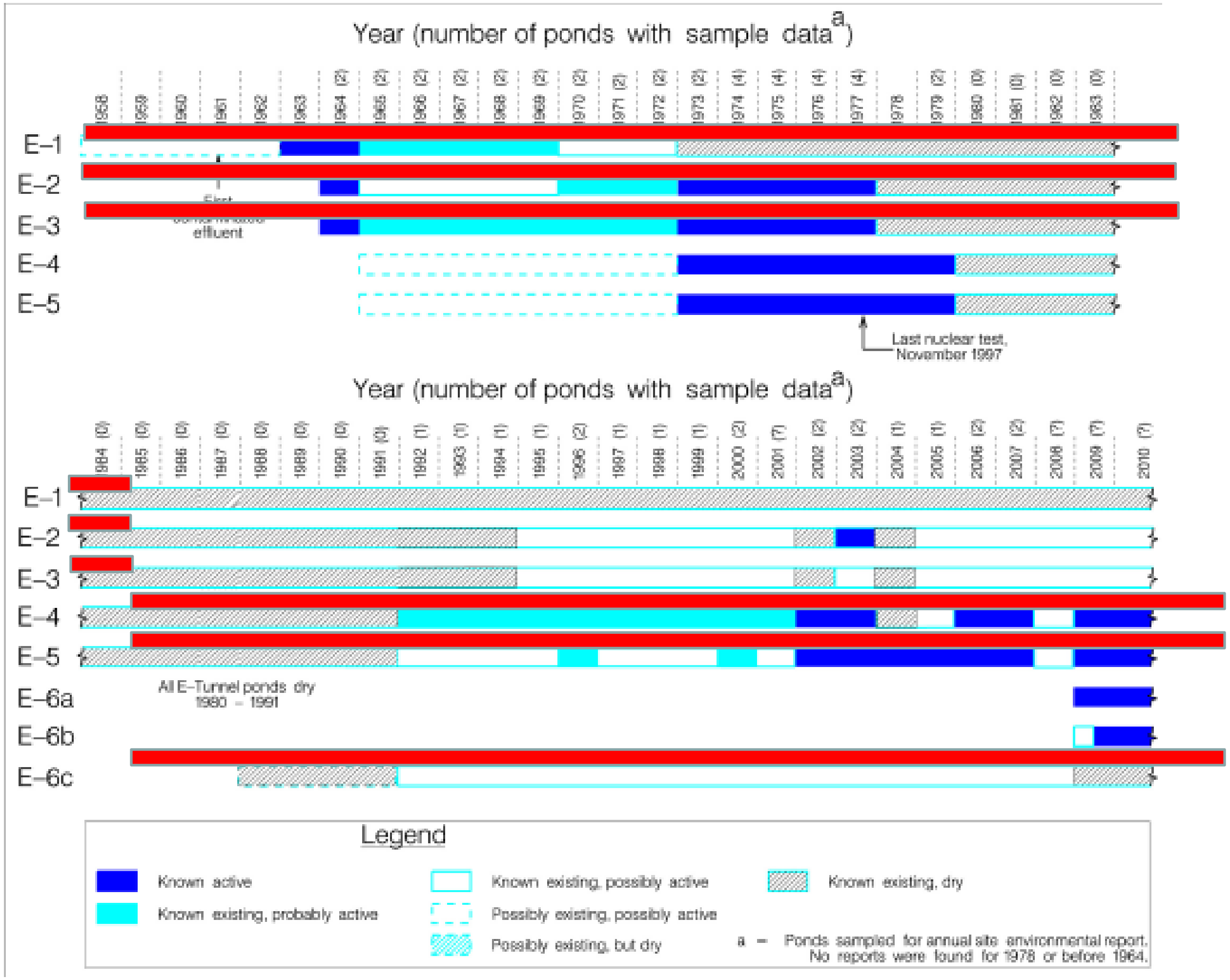
U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office

Prepared by:

Heather E. Huckins-Gang and Margaret J. Townsend

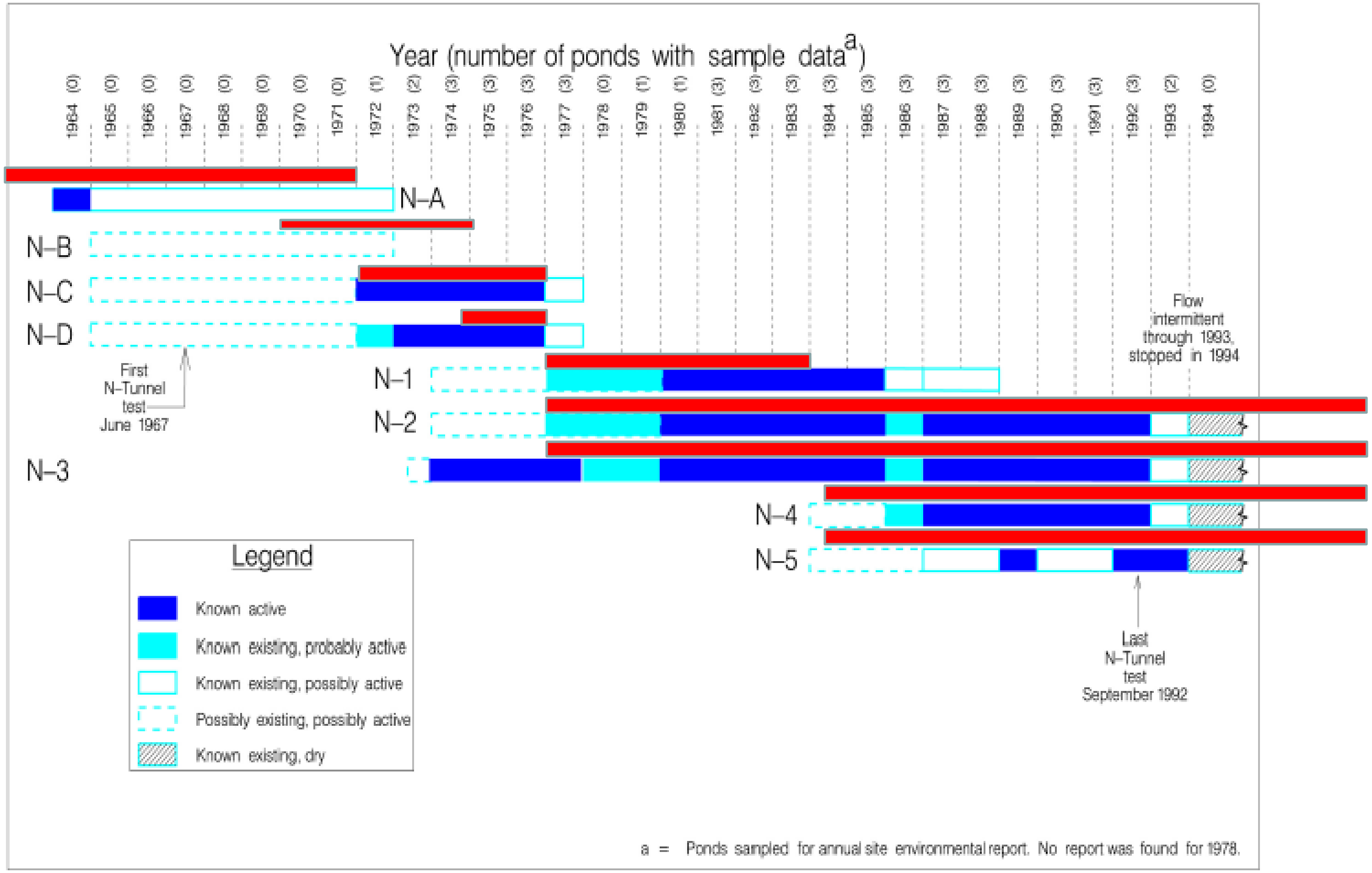
Underground Test Area and Boreholes Programs and Operations
Environmental Restoration
National Security Technologies, LLC
Las Vegas, Nevada

E-Tunnel Ponds Histories



LANL's values in red
NSTec's values in blue

N-Tunnel Ponds Histories



LANL's values in red
NSTec's values in blue