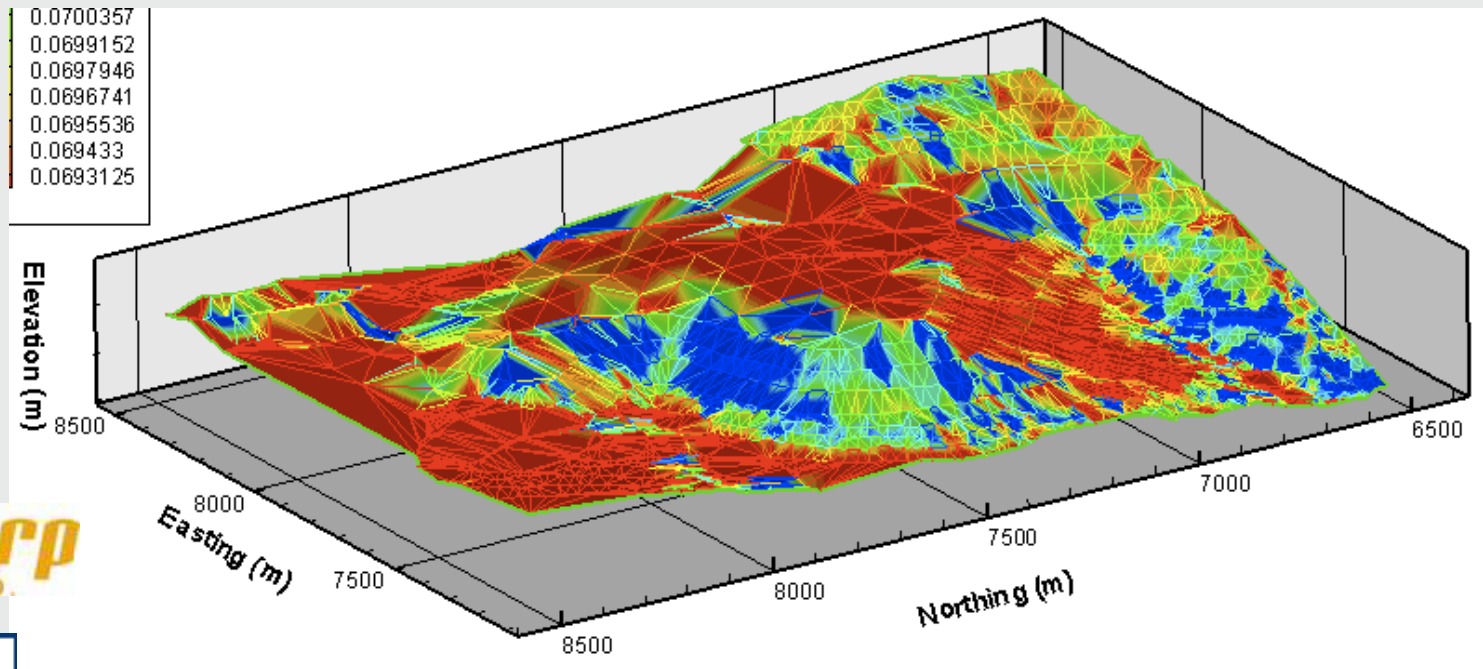


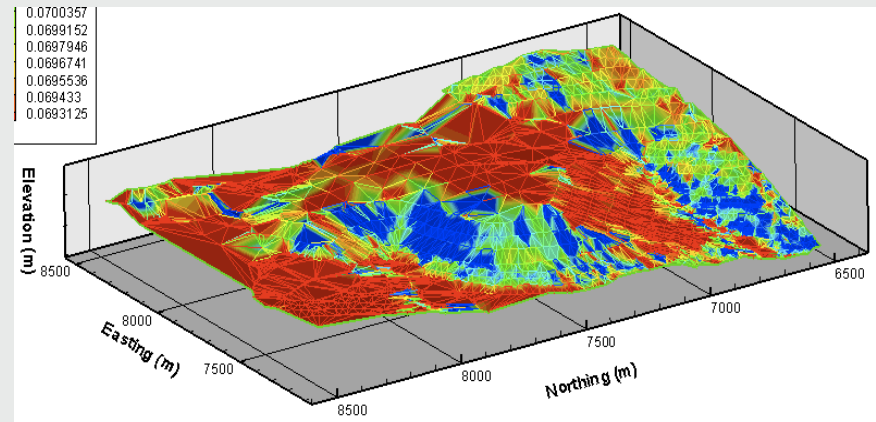
The Influence of Orientation and Aspect on Net Infiltration for the Soil Cover System at Equity Silver Mine



Debbie Lin, Bjorn Weeks,
Mike Aziz, Ward Wilson

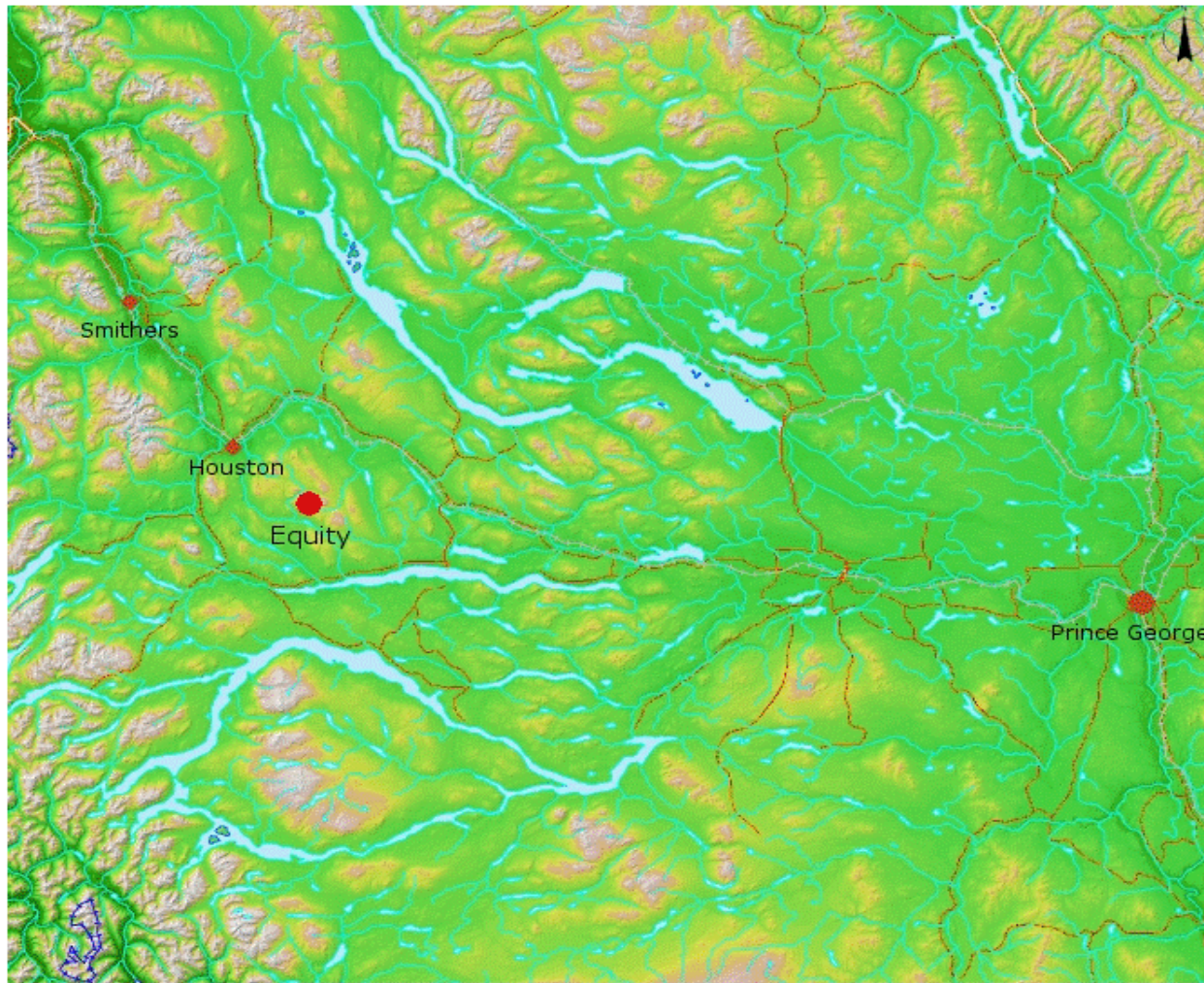
Outline

- Background
- Modeling energy distribution on slopes
- Modeling infiltration on slopes
- Progress & Results
- Conclusions
- Questions

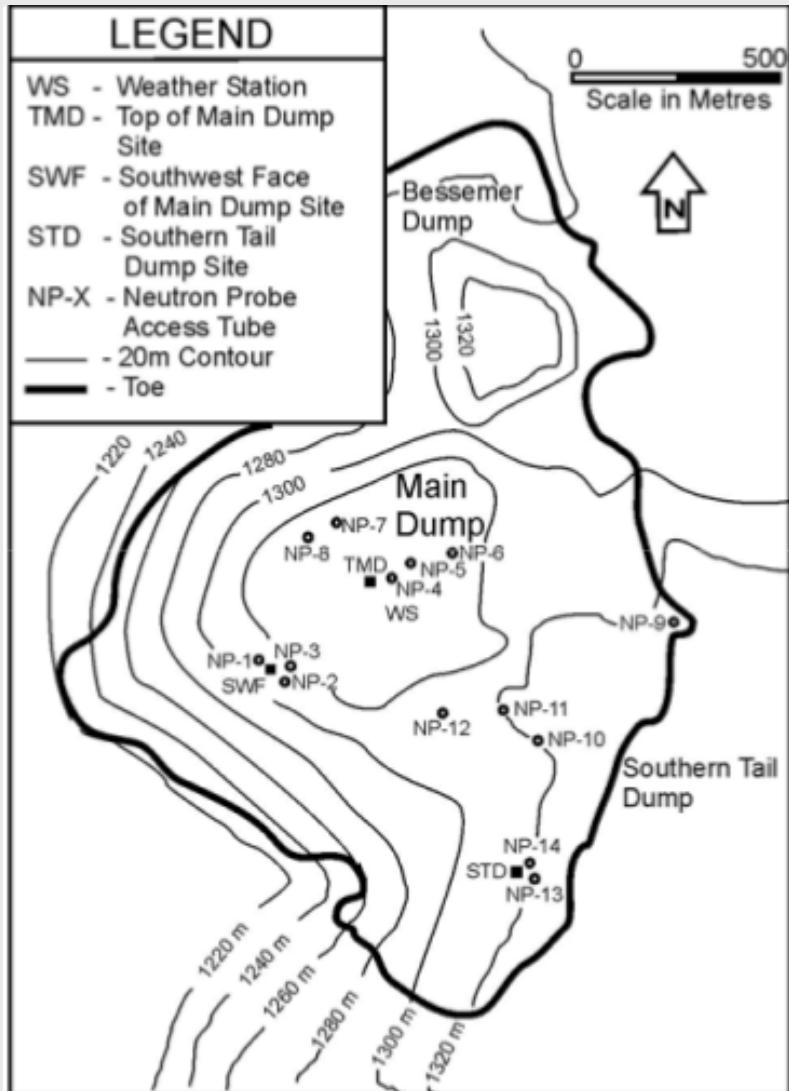


Site Location

Equity Mine Site Location



Equity Silver Waste Dumps



Name of waste dump	Volume of waste rock (Mt)	Area (ha)	Year of cover placement
Bessemer	10	29	1994
Main	52	41	1993-1994
Southern tails	18	31	1991

(Weeks, 2006)

(O'Kane, 1995)

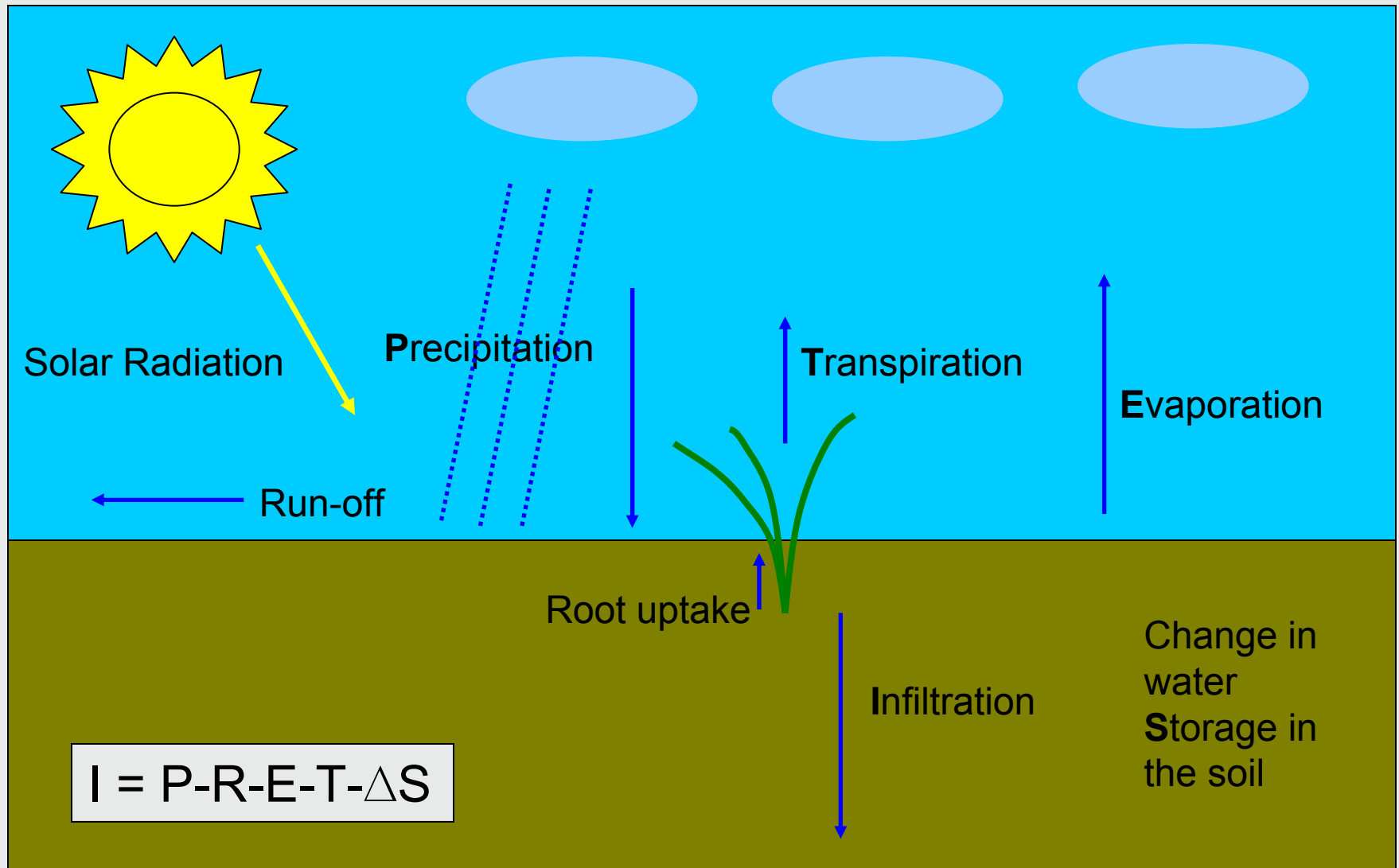
Background

- Long-term ARD problem since 1981
- Soil cover placed on top of entire waste dump starting in 1991
- Discrepancy between 5% predicted net-infiltration and 15% net-infiltration collected in the ARD seepage ditches
- Speculation that the south face of the dump remains relatively dry, while most infiltration is entering through the north face of the dump



(Weeks, 2006)

Soil-atmosphere Moisture Exchange



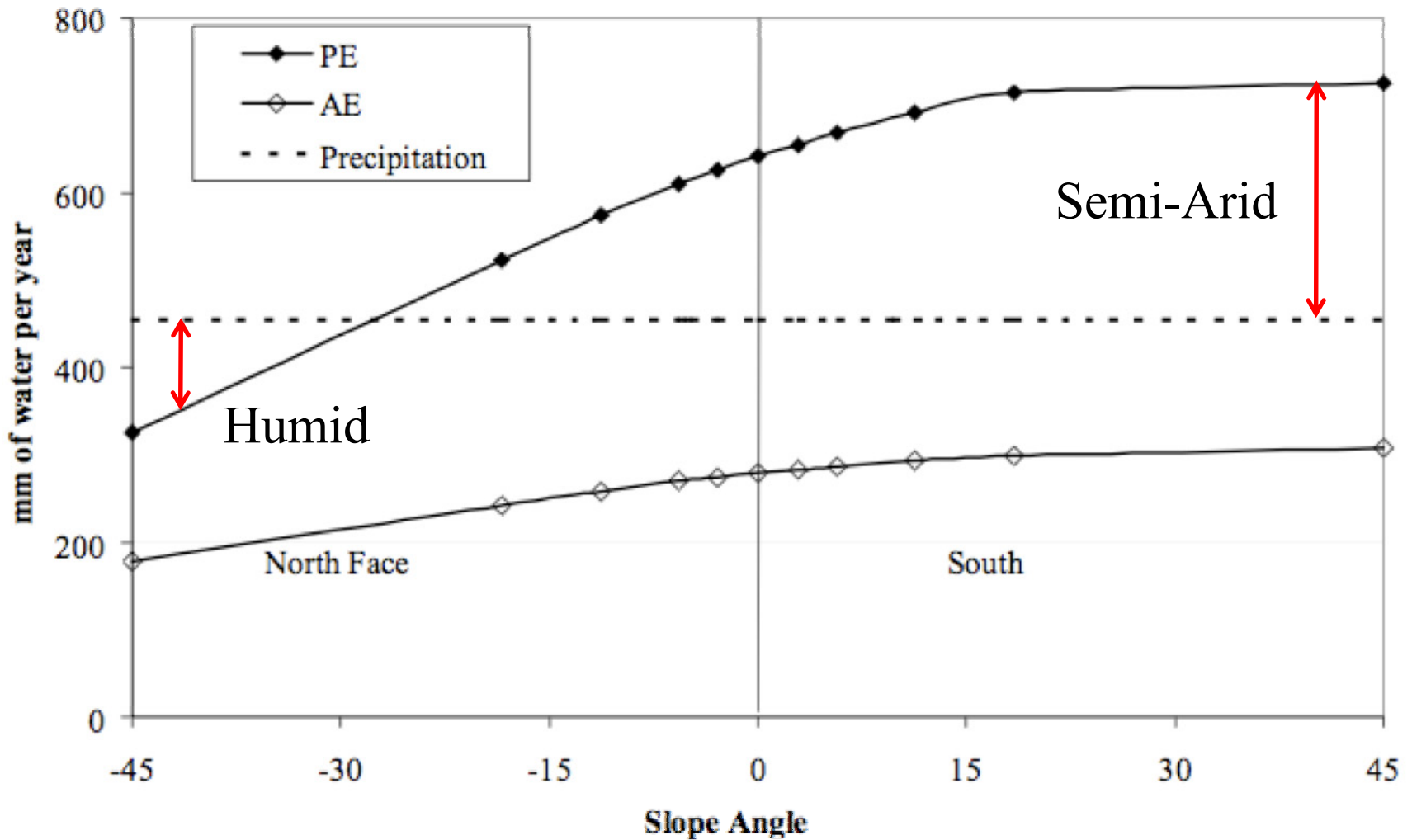
Importance of Net Radiation (Q_{net}) on Evaporation

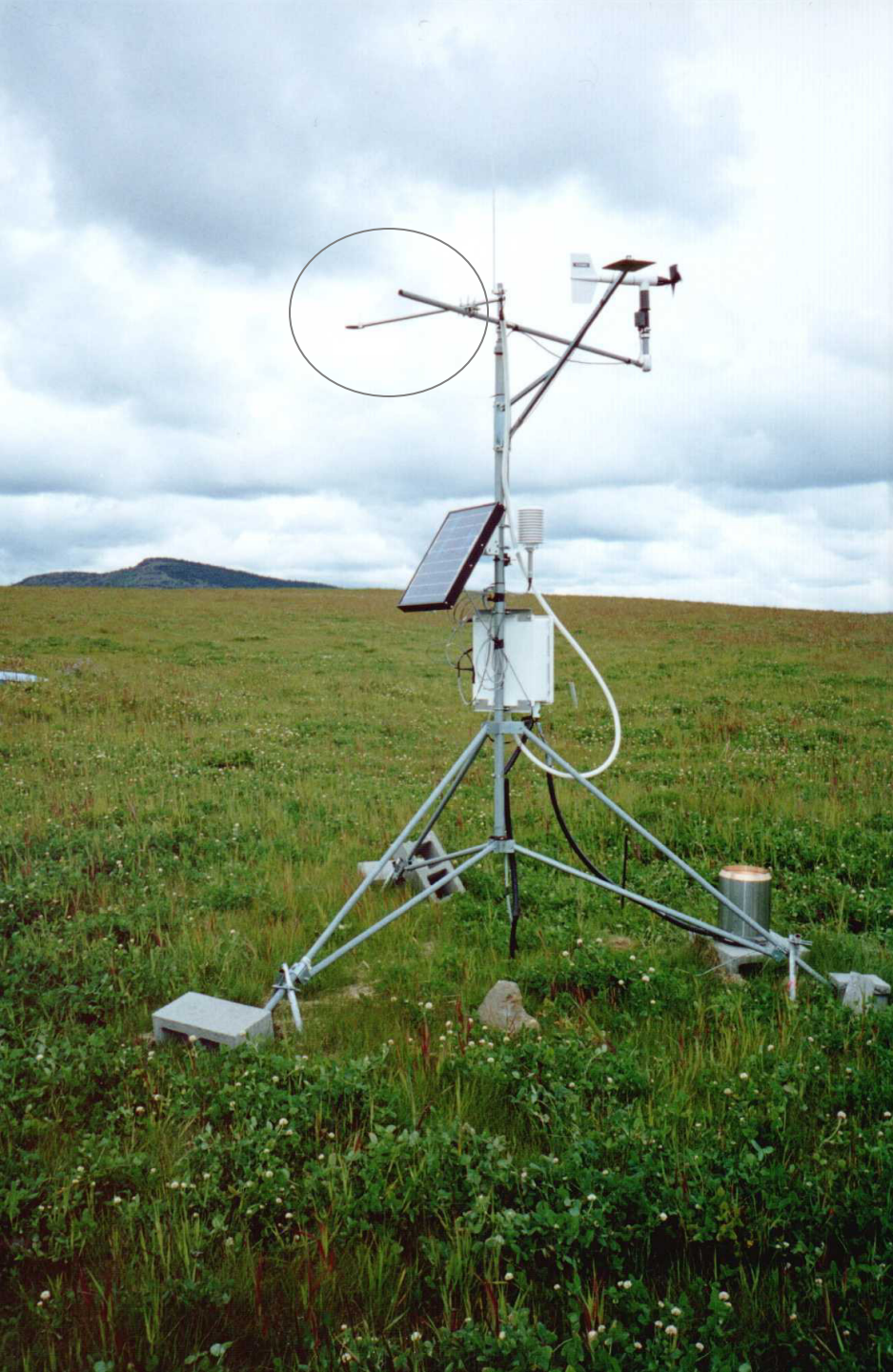
- Both AE and PE are partly functions of net solar radiation

$$AE = \frac{\Gamma Q_{net} + \nu E_a}{\Gamma + A \nu}$$

- The net solar radiation received by a surface will be affected by the orientation of the surface

Impact of Slope on Evaporation





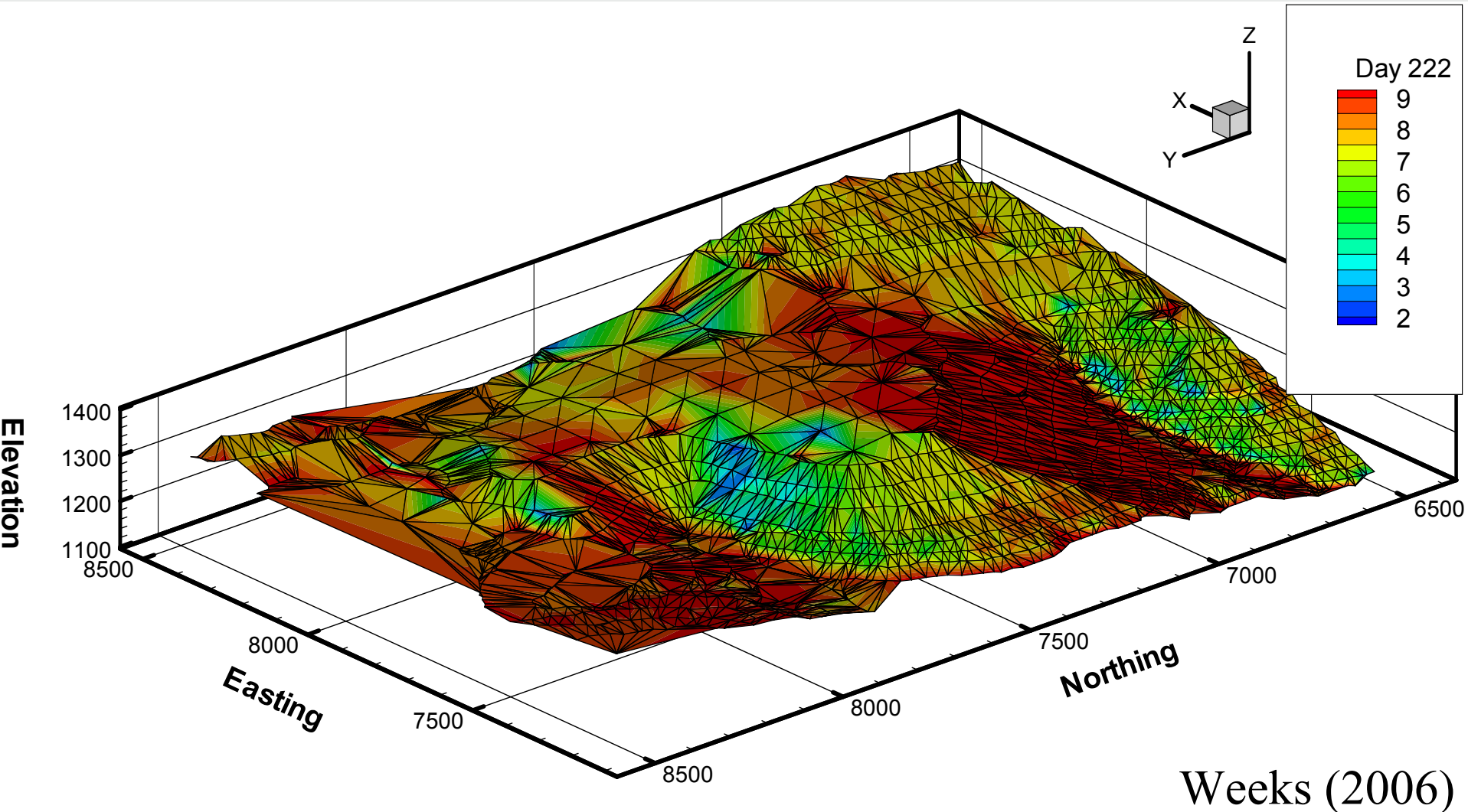
The measurement
of Q_{net} at
Weather Station
on top of the EQ
waste dump

(Weeks, 2006)

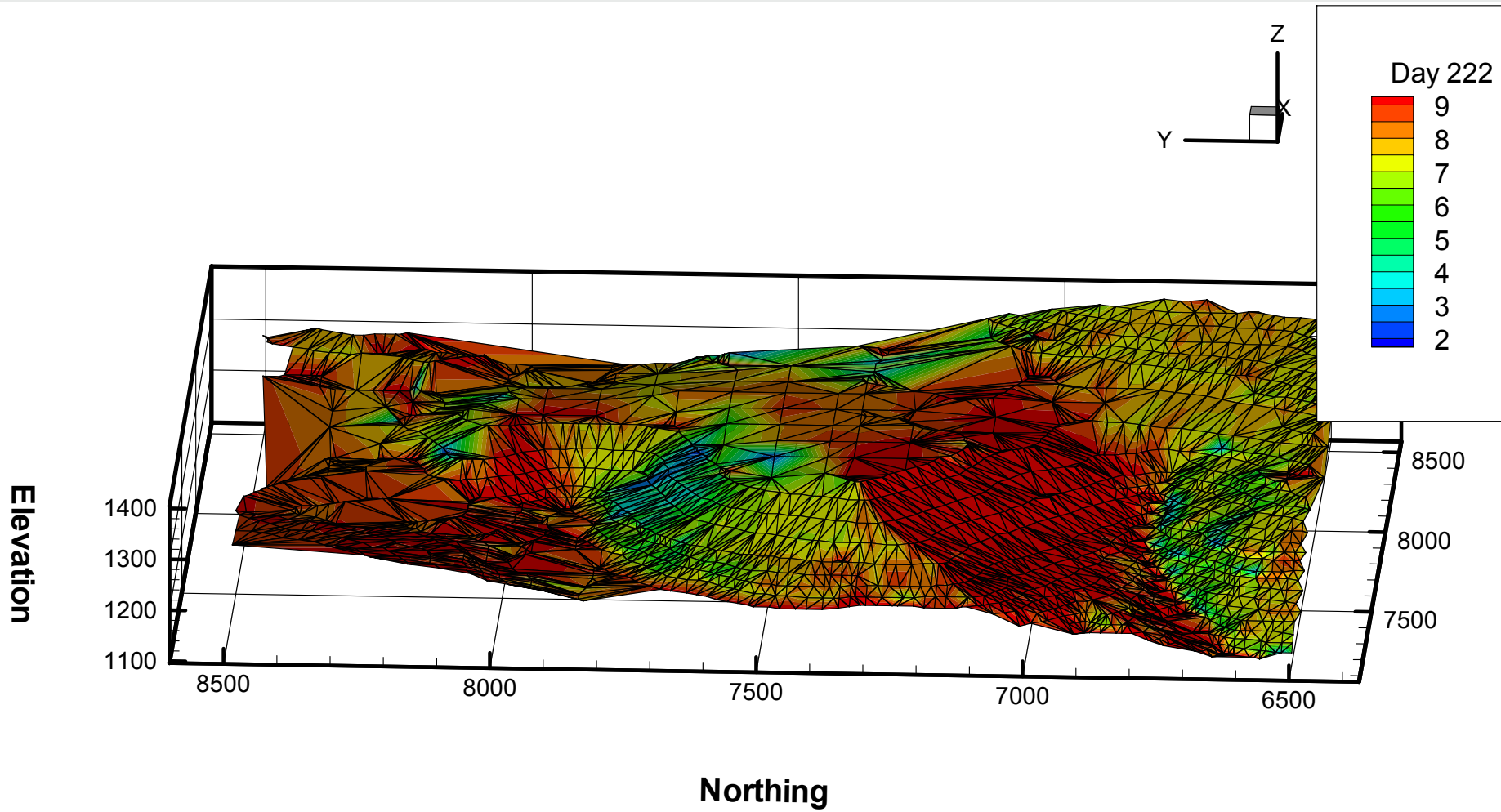
Q_{net} Measurement on slopes



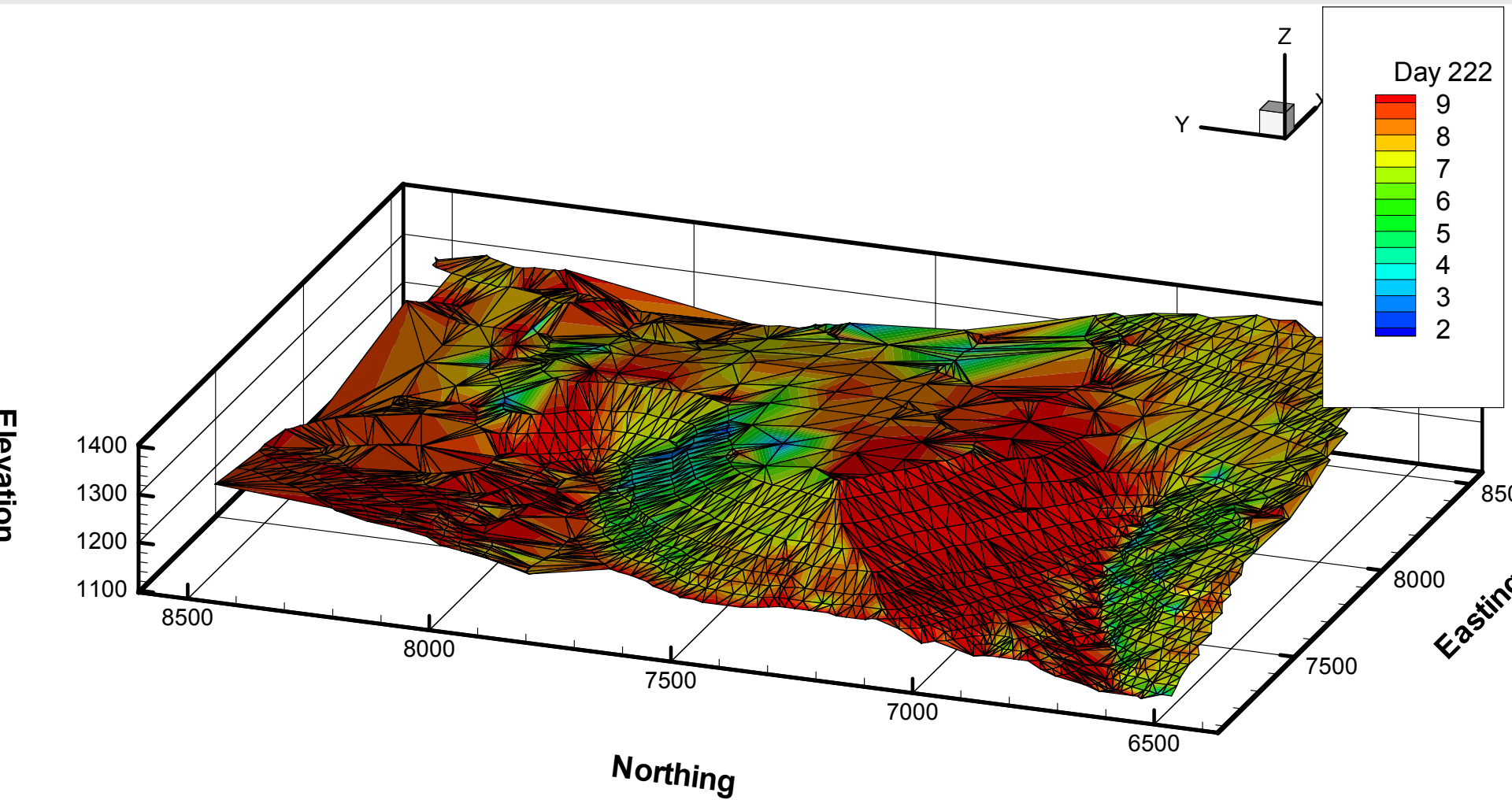
SunModel applied to Equity



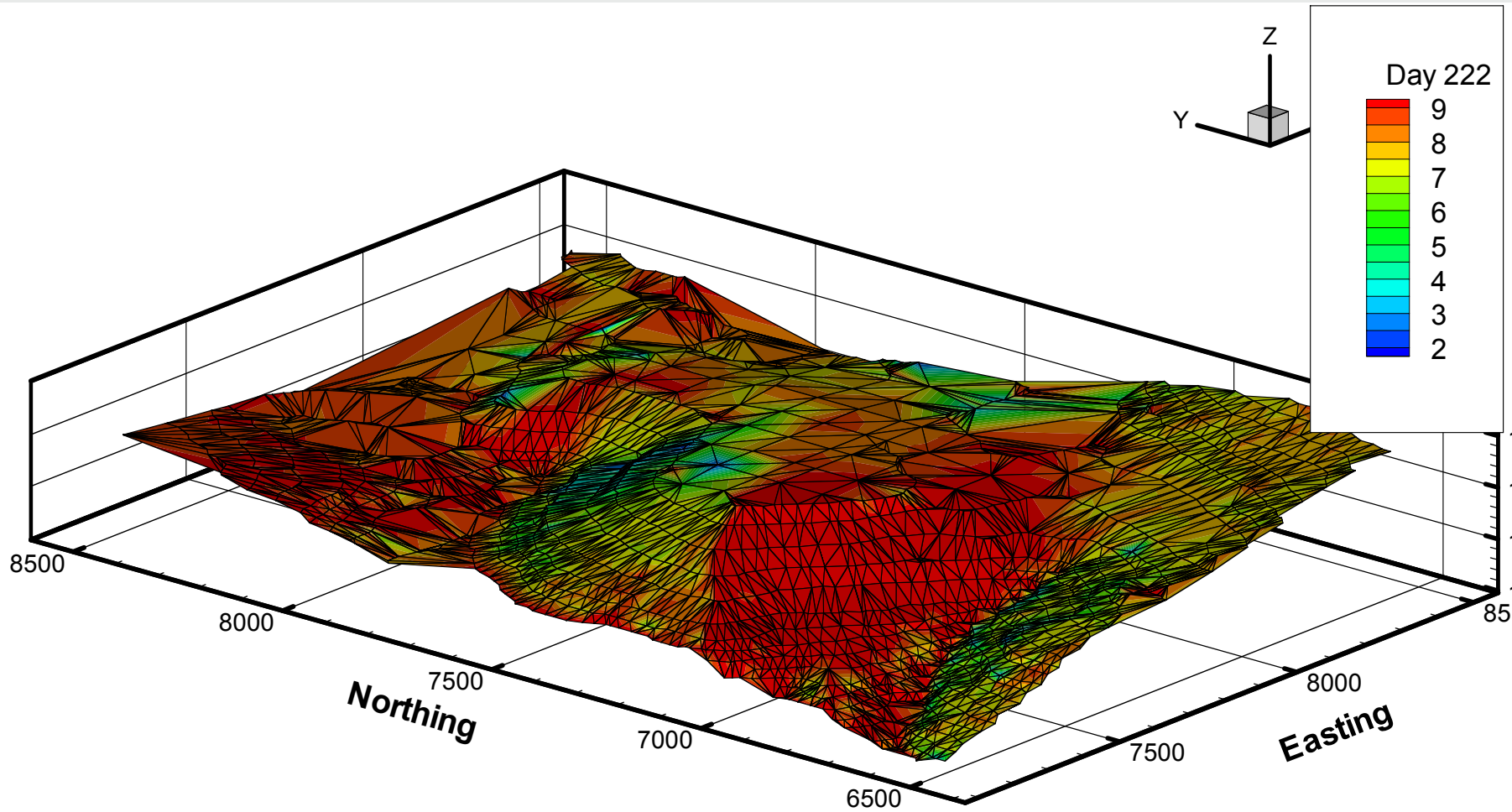
Weeks (2006)



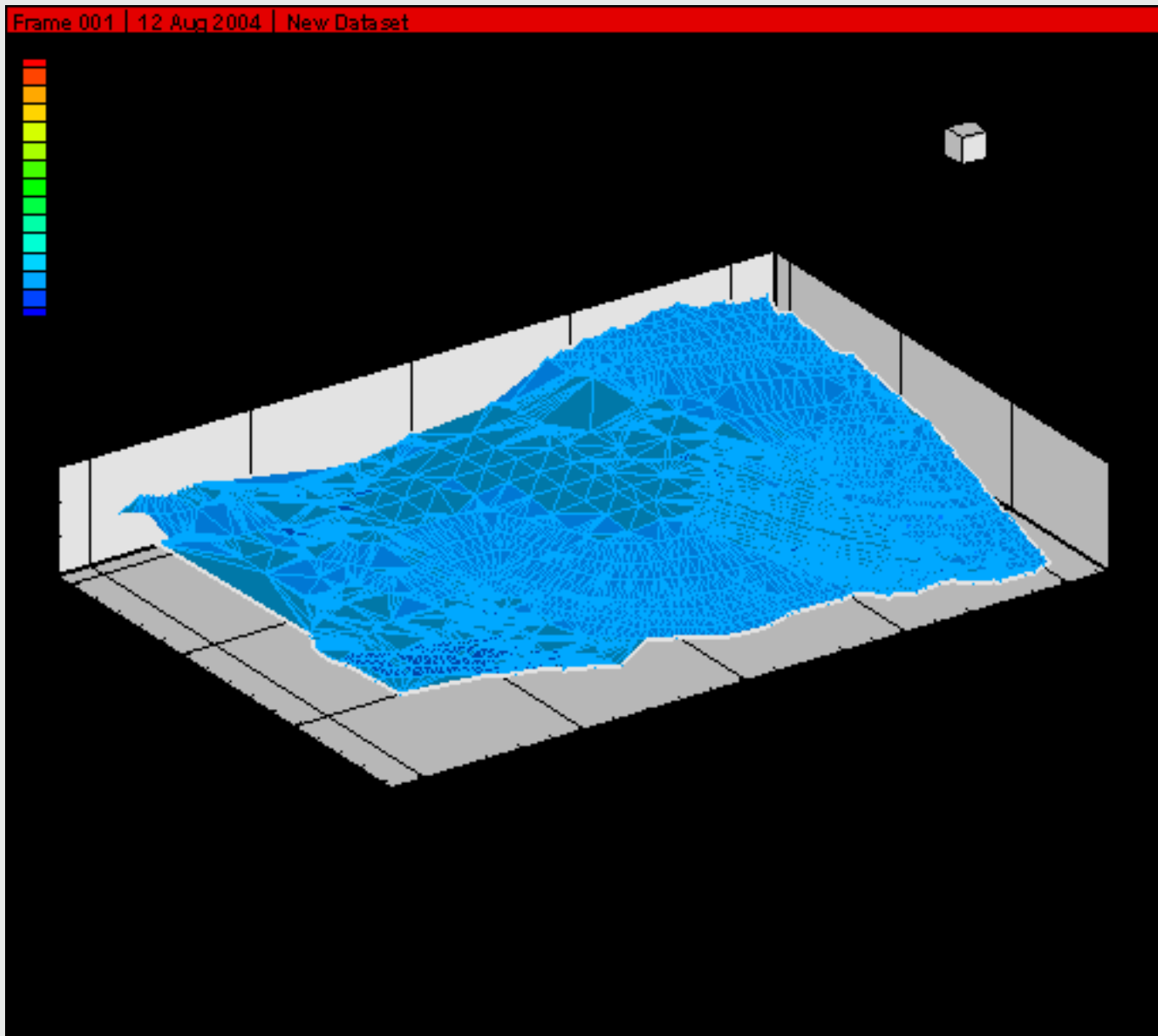
Weeks (2006)



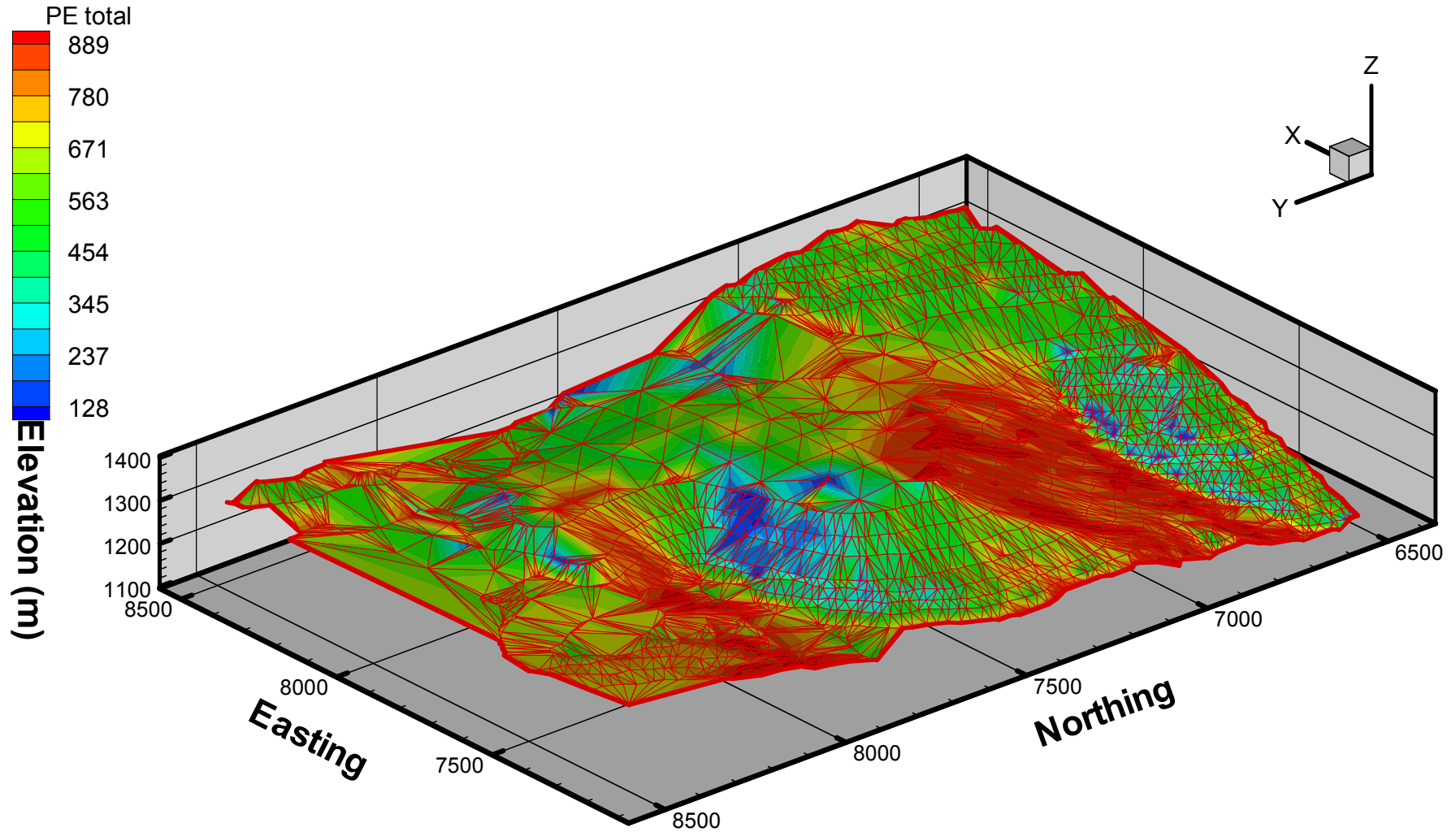
Weeks (2006)

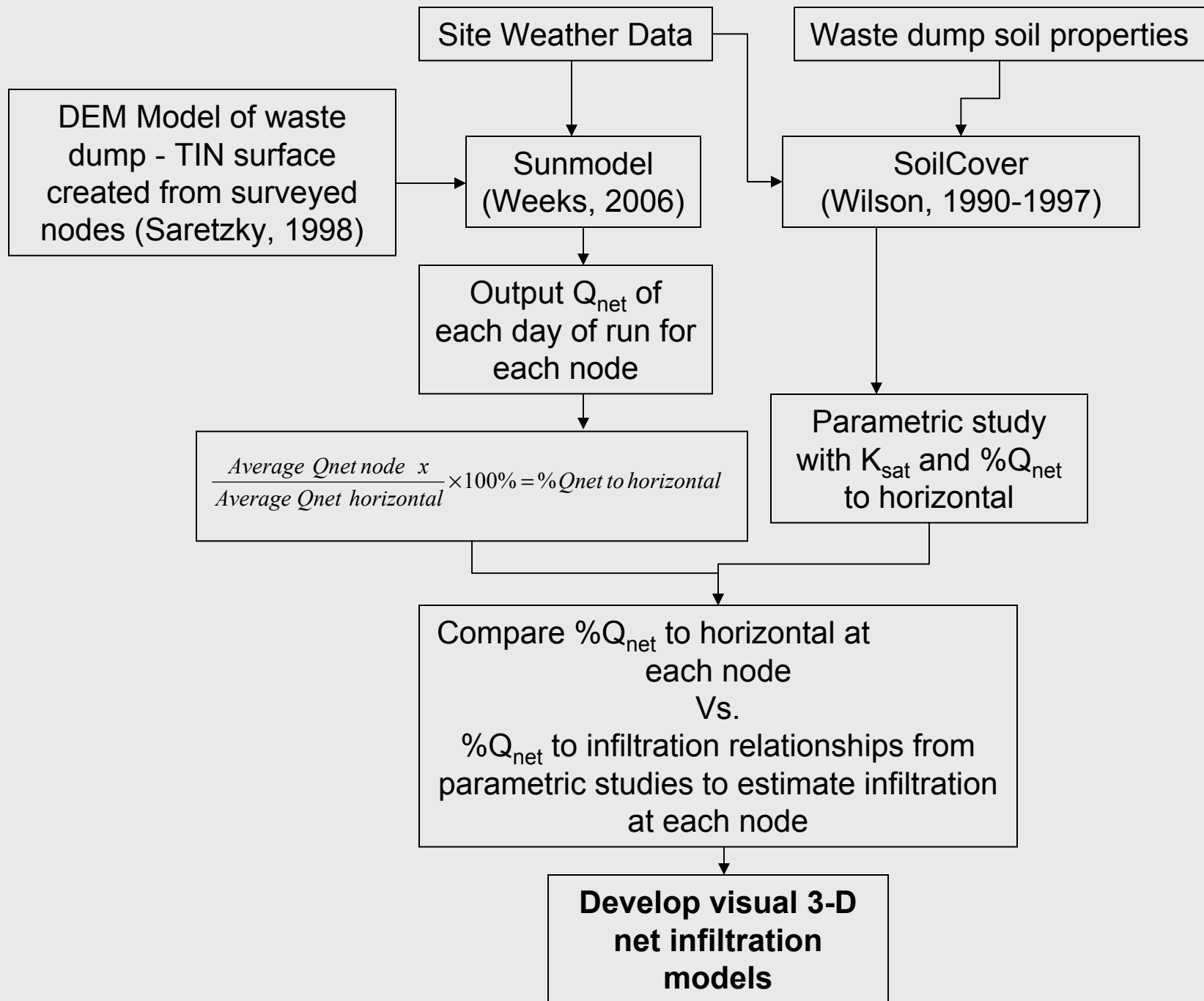


Variation of Q_{net} over Time



Model Applied to site (PE)





Numerical Modeling

- SoilCover Version 4.01:
 - One-dimensional finite element
 - Transient
 - Predict exchange of moisture between atmosphere and soil surface
 - Based on soil properties and daily climatic conditions

- Modified Penman Equation
- Mass and Heat transfer equations

$$AE = \frac{\Gamma Q_{net} + vE_a}{\Gamma + vA}$$

$$\frac{\partial h}{\partial t} = C_w^1 \frac{\partial}{\partial z} \left(k_w \frac{\partial h}{\partial z} \right) + C_w^2 \frac{\partial}{\partial z} \left(D_v \frac{\delta P_v}{\delta z} \right)$$

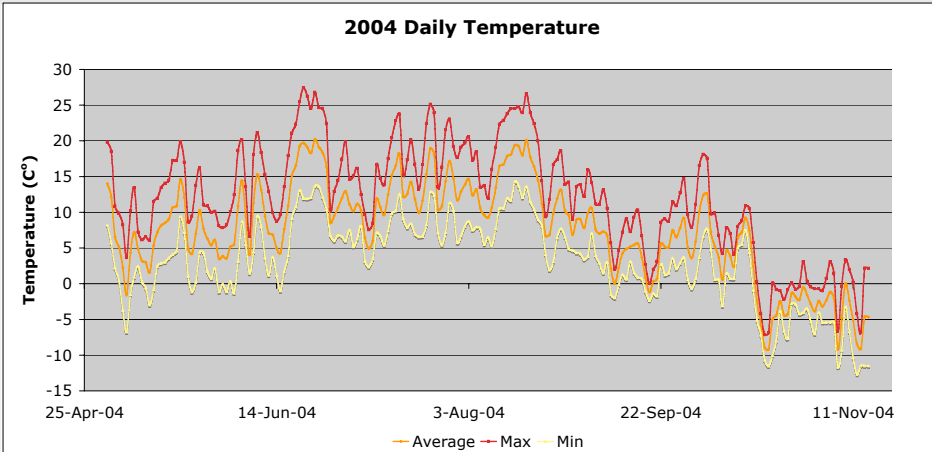
$$C_h \frac{\delta t_e}{\delta t} = \frac{\delta}{\delta z} \left(\lambda \frac{\delta t_e}{\delta z} \right) - L_v \left(\frac{P_t + P_v}{P_t} \right) \frac{\delta}{\delta z} \left(D_v \frac{\delta P_v}{\delta z} \right)$$

Weather Data

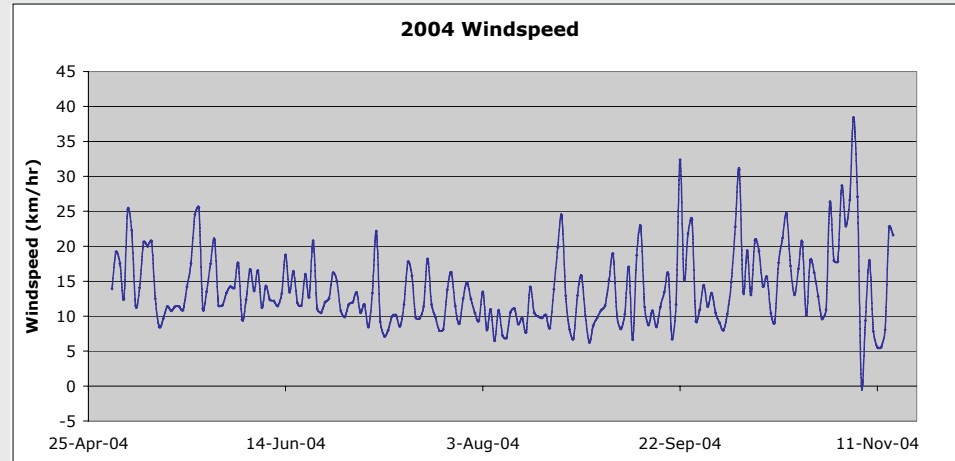
- 2004 Equity Silver Data From Site
- 199 Day run (Non-freezing conditions)
- Snow melt (spring freshet) distributed within first 10 days of simulation

Weather Data

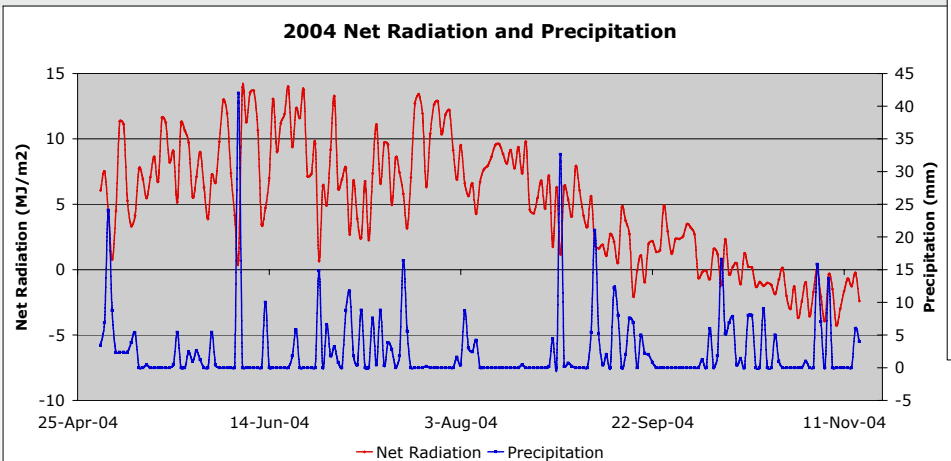
2004 Daily Temperature



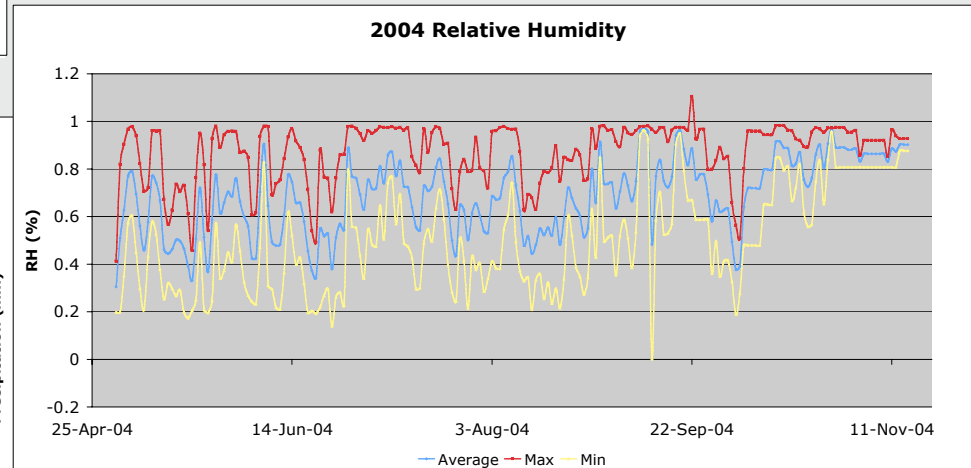
2004 Windspeed



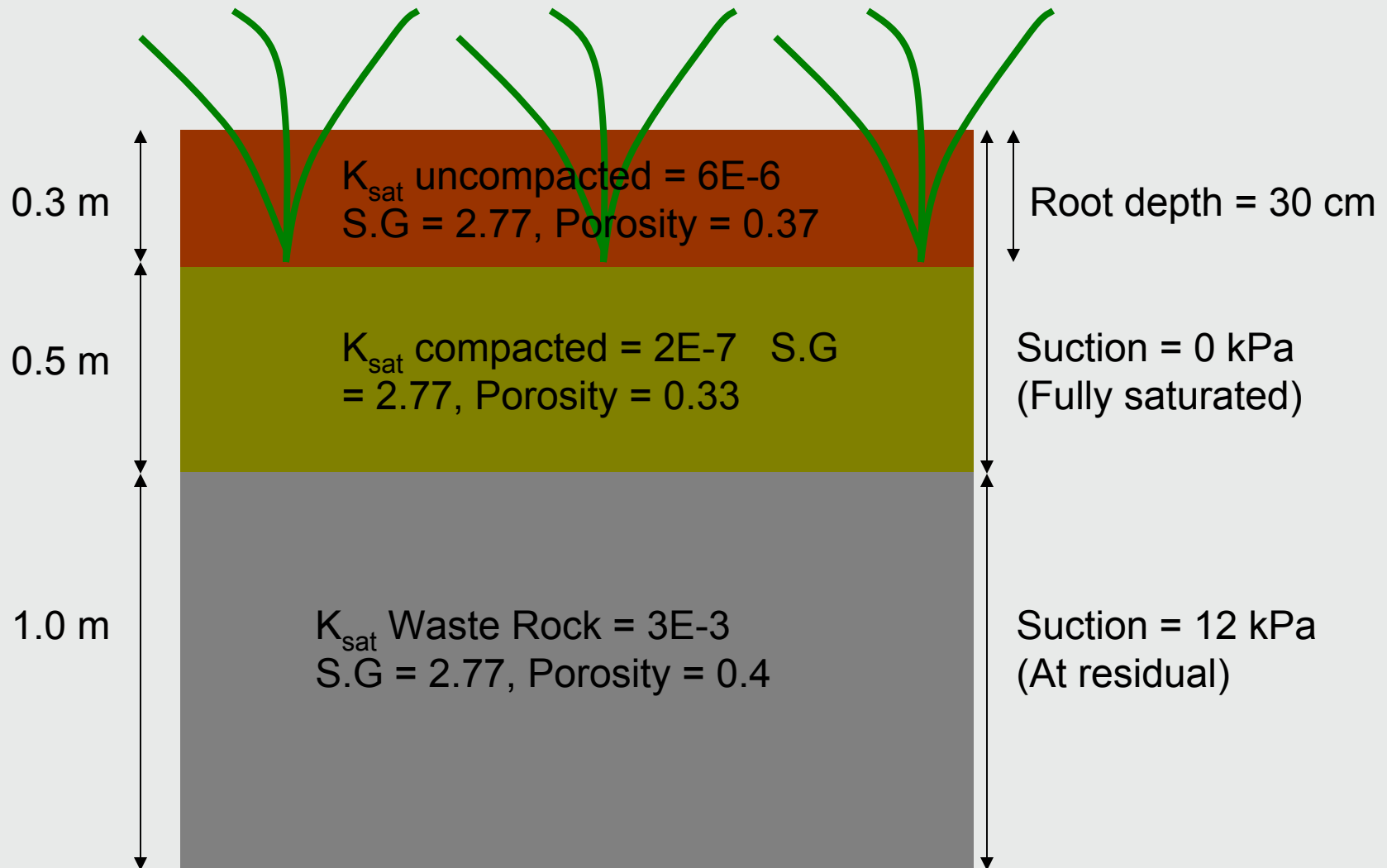
2004 Net Radiation and Precipitation



2004 Relative Humidity

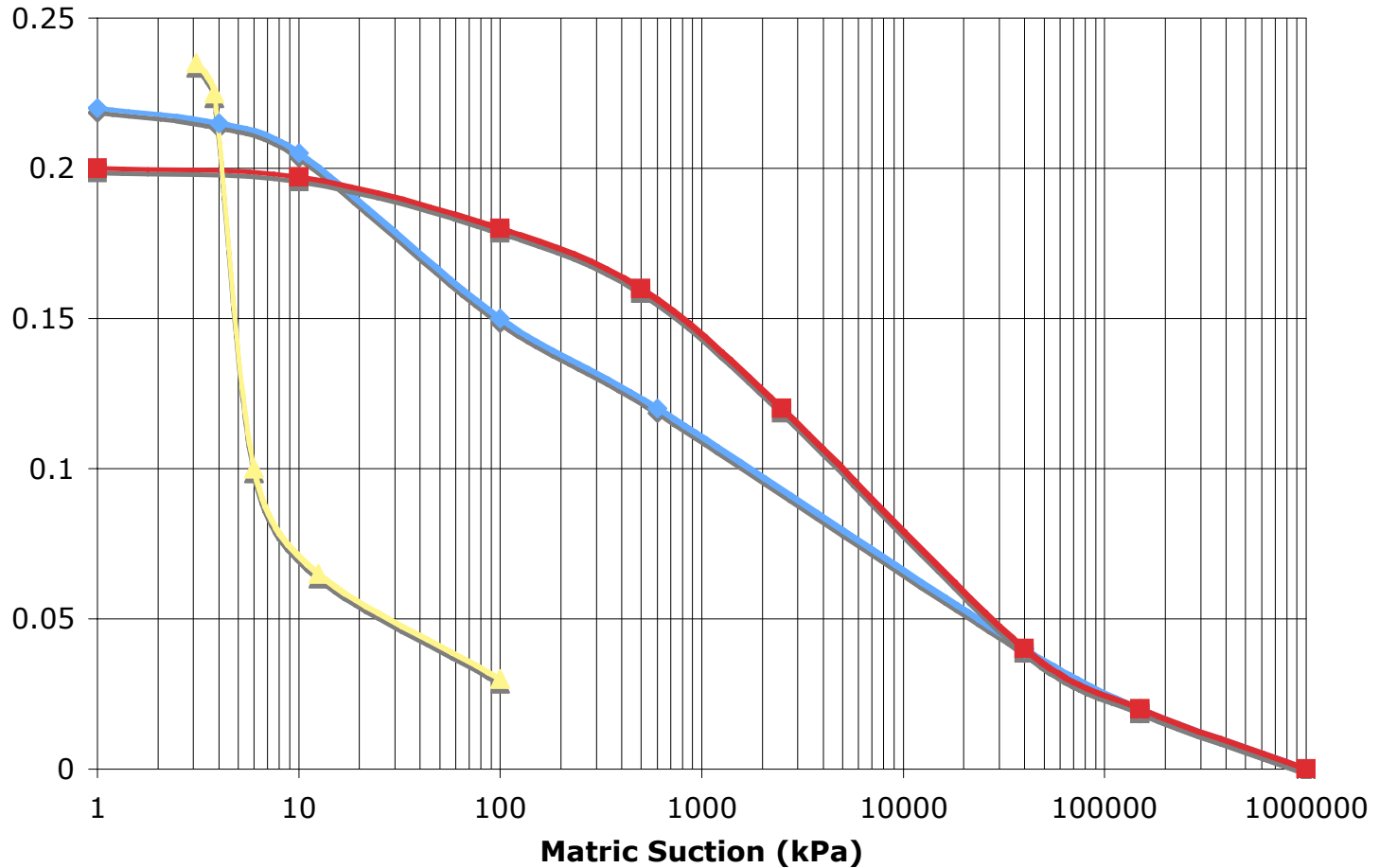


SoilCover Model



Soil Properties

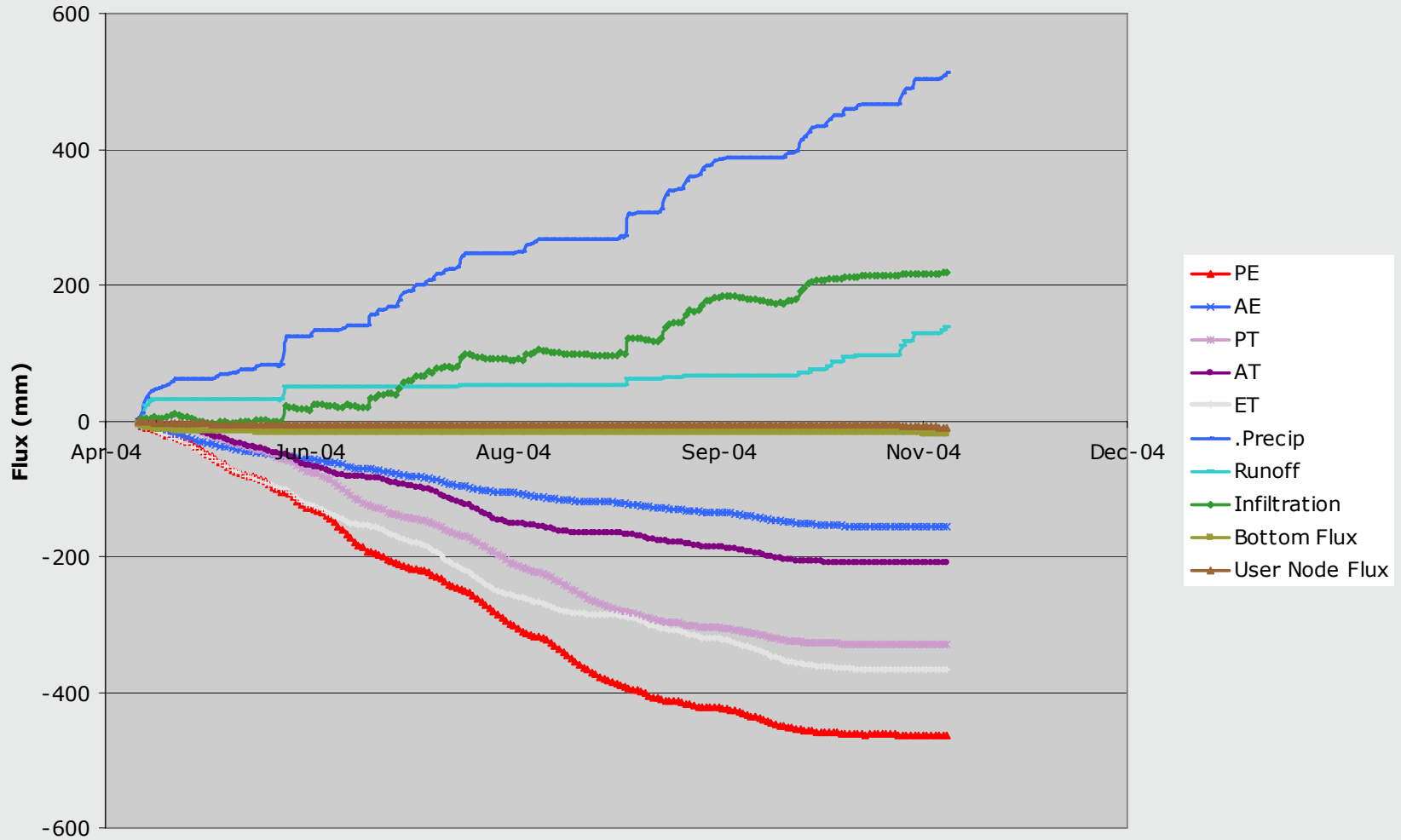
Soil Water Characteristic Curves



(Swansen, 2003) ◆ Uncompacted till ■ Compacted till ▲ Beaver Creek Sand

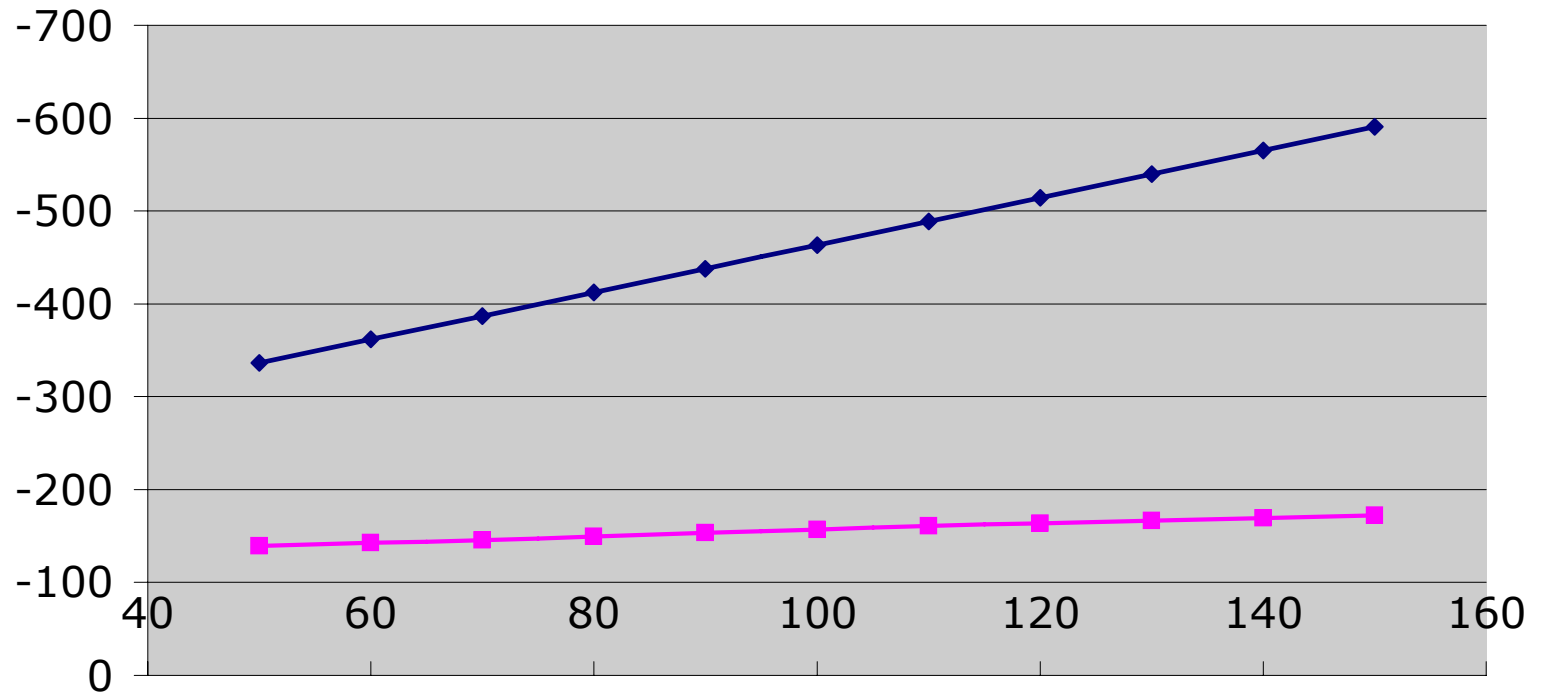
Base Case Results

Cumulative Water Balance For Base Case Model



Base Case Results

Evaporation Vs. %Qnet



%Qnet (of Horizontal Qnet)

—◆— PE —■— AE

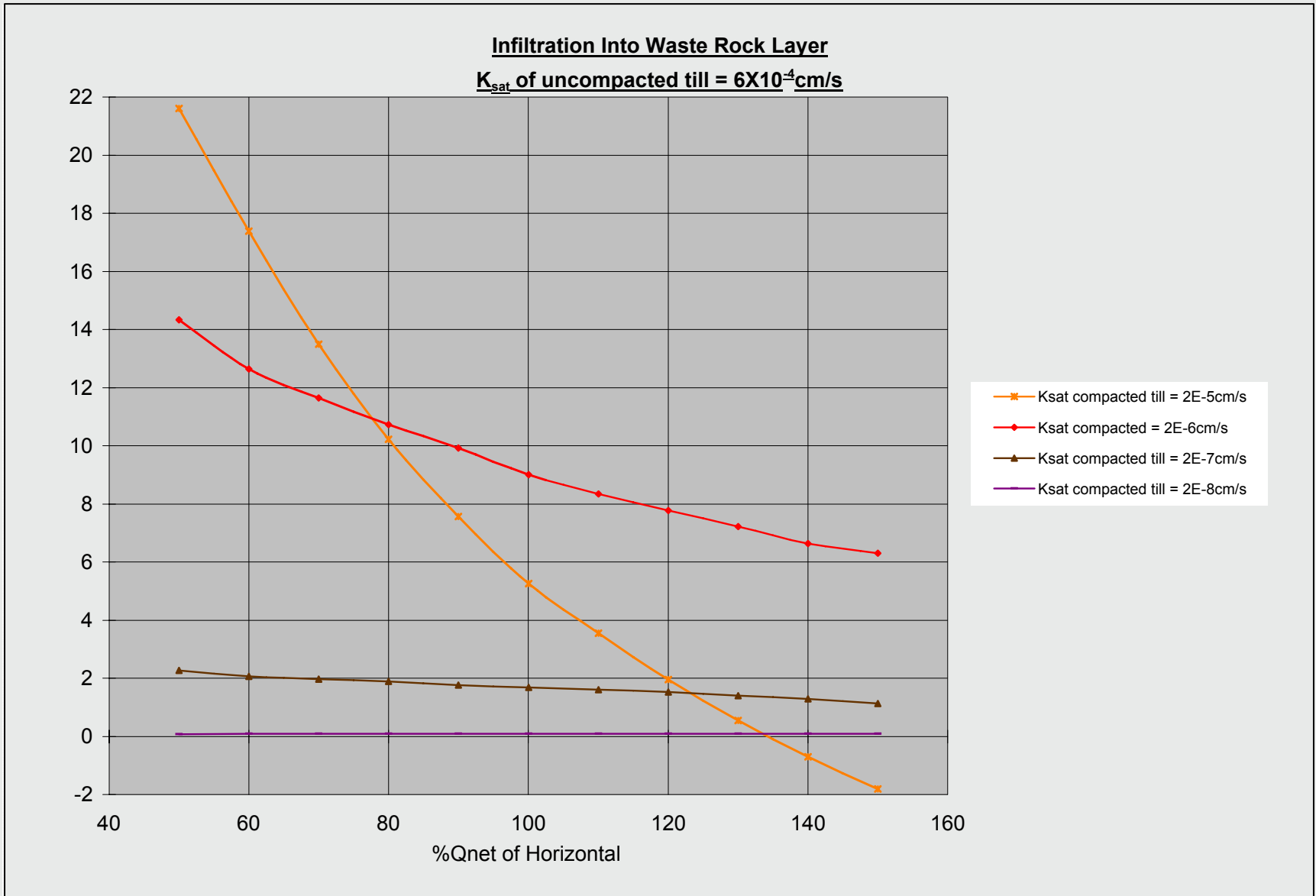
Parametric Study

- Varied Saturated hydraulic conductivity (K_{sat}) of the upper and lower till layers

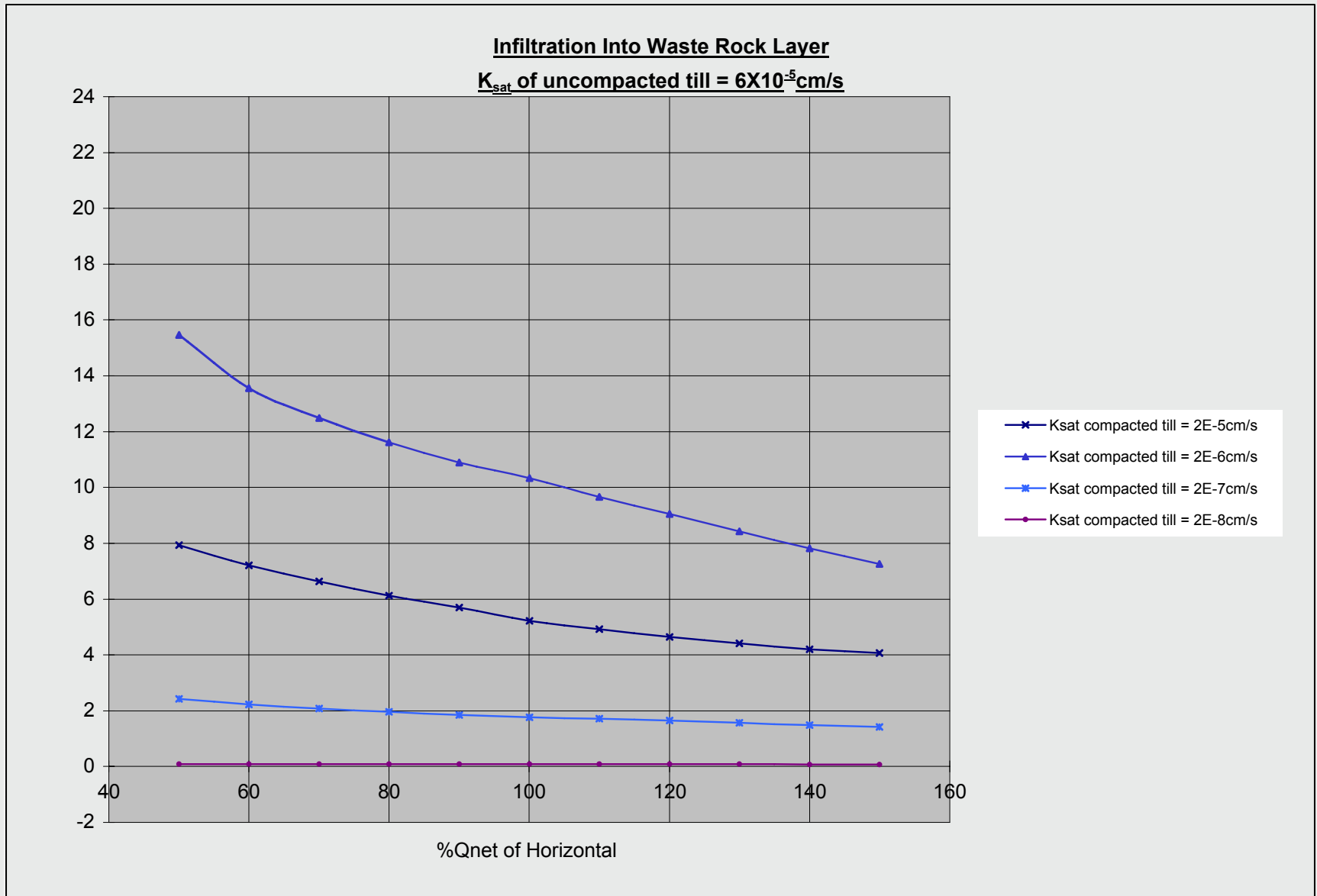
	Uncompacted Till	Compacted Till	Waste Rock
Ksat (cm/s)	6.00E-04	2.00E-05	3.00E-03
		2.00E-06	
		2.00E-07	
		2.00E-08	
	6.00E-05	2.00E-05	
		2.00E-06	
		2.00E-07	
		2.00E-08	

- Q_{net} varied from 50% to 150% of horizontal measurement

Parametric Study Results

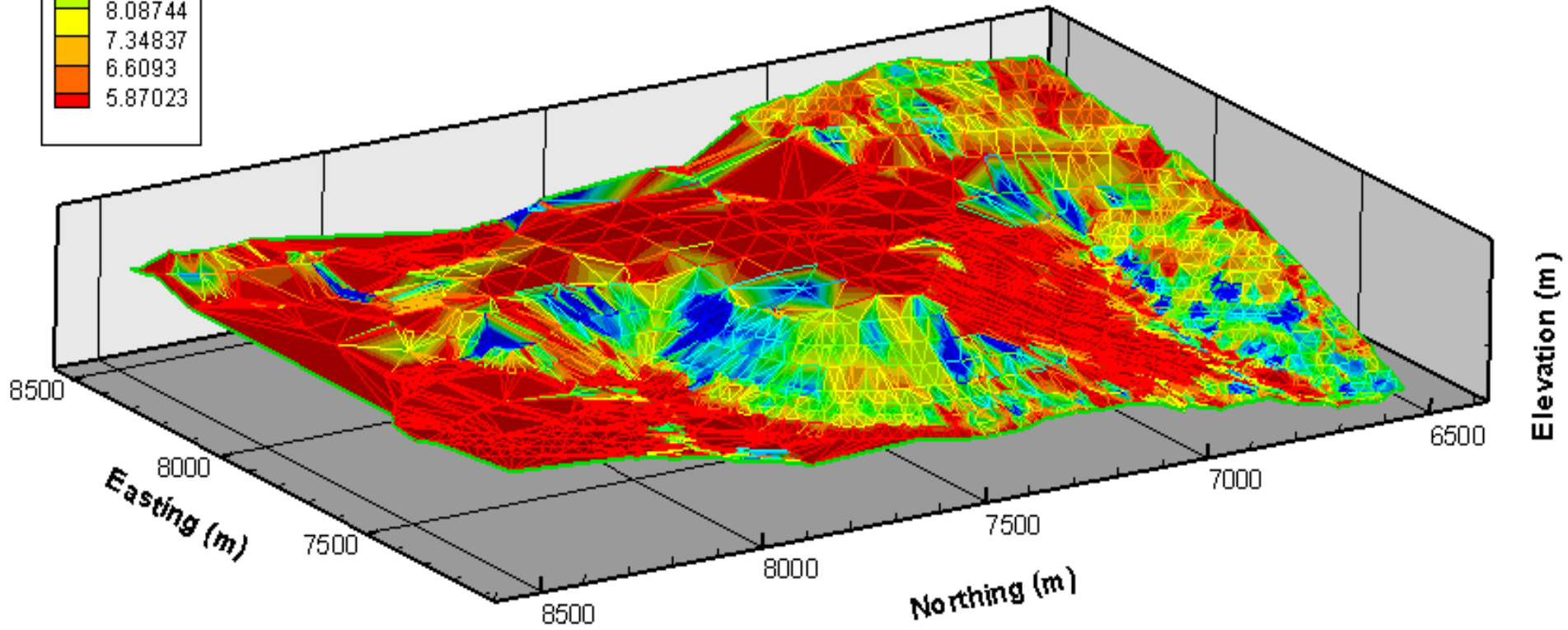
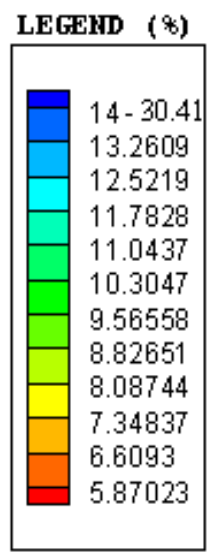


Parametric Study Results



Percent Infiltration (of Total Precip) at Equity Silver Waste Dump

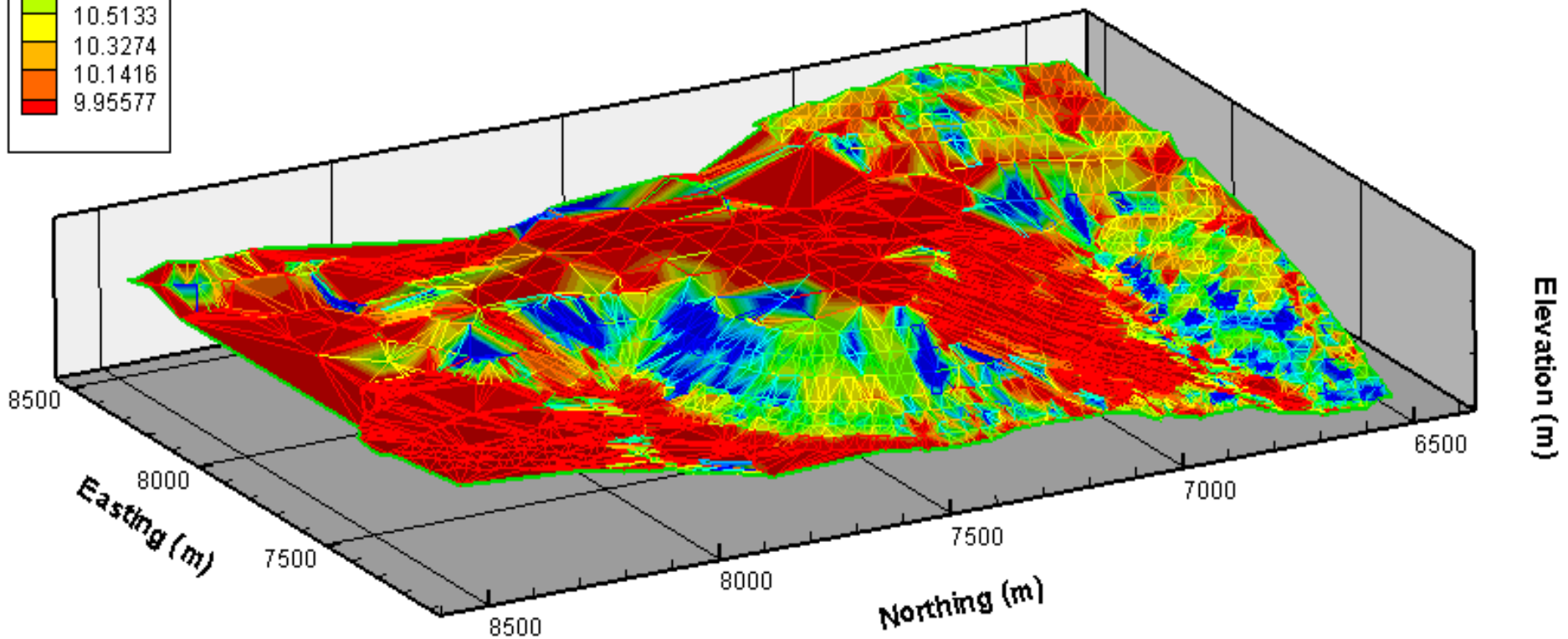
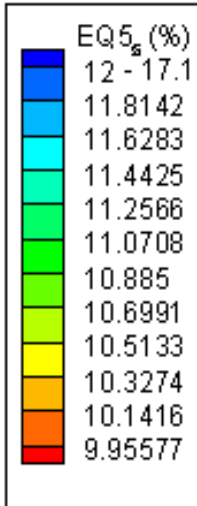
Ksat of uncompacted till = 6.0E-4cm/s
Ksat of compacted till = 2.0E-5cm/s



Percent Infiltration (of Total Precip) at Equity Silver Waste Dump

Ksat of uncompacted till = 6E-5cm/s
Ksat of compacted till = 2E-5cm/s

LEGEND (%)



Conclusions

- Orientation and Aspect have significant influence on net-infiltration
- Infiltration at the Equity Silver waste dump can vary from 6% to 30% for K_{sat} of $6E-4\text{cm/s}$ for the uncompacted layer and $2E-5\text{cm/s}$ for the compacted layer
- Both arid and humid conditions on the same site - calls for different cover designs for different areas of the dump
- Problem areas identified can be focus areas for improvement

Acknowledgments

- Ward Wilson - UBC
- Bjorn Weeks - Golder Associates
- Mike O’Kane, Darren Swansen, David Tratch – Unsaturated Soils Group
- Mike Aziz, Shane MacLeod – Equity Silver Mine
- Many others who have contributed to this research over the past 15 years!

Questions?

