Richmond Hill Mine Heap Leach Pad Soil Cover System Evaluation

Johnny Zhan, Ph.D. – Barrick Gold

November 29, 2018

Presented at: 25th Annual BC-MEND ML/ARD Workshop

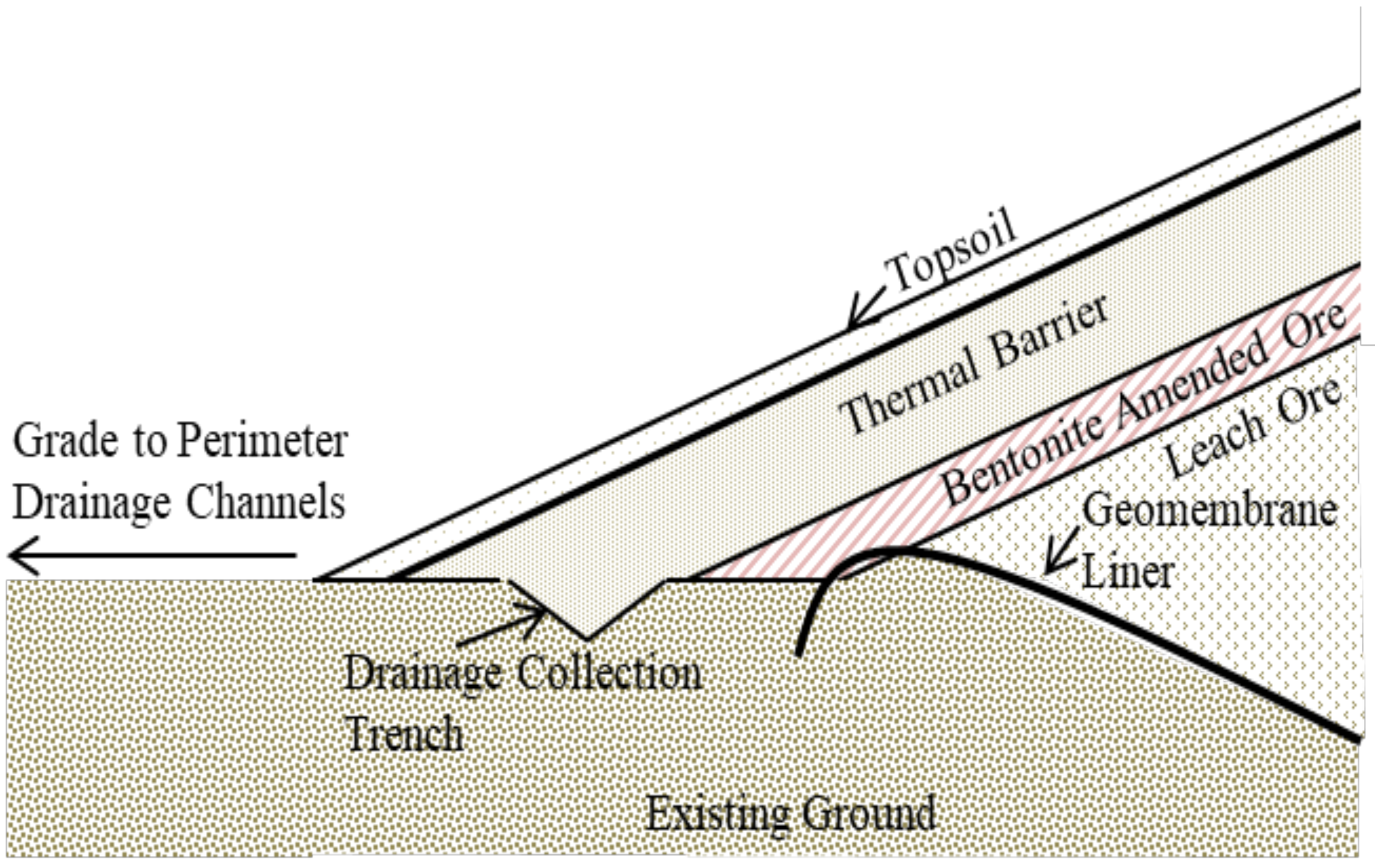
Outlines

- Introduction
- Cover Performance
- Water Balance Model
- Model Calibration
- Discussions
- Conclusions

Introduction: Facility Description

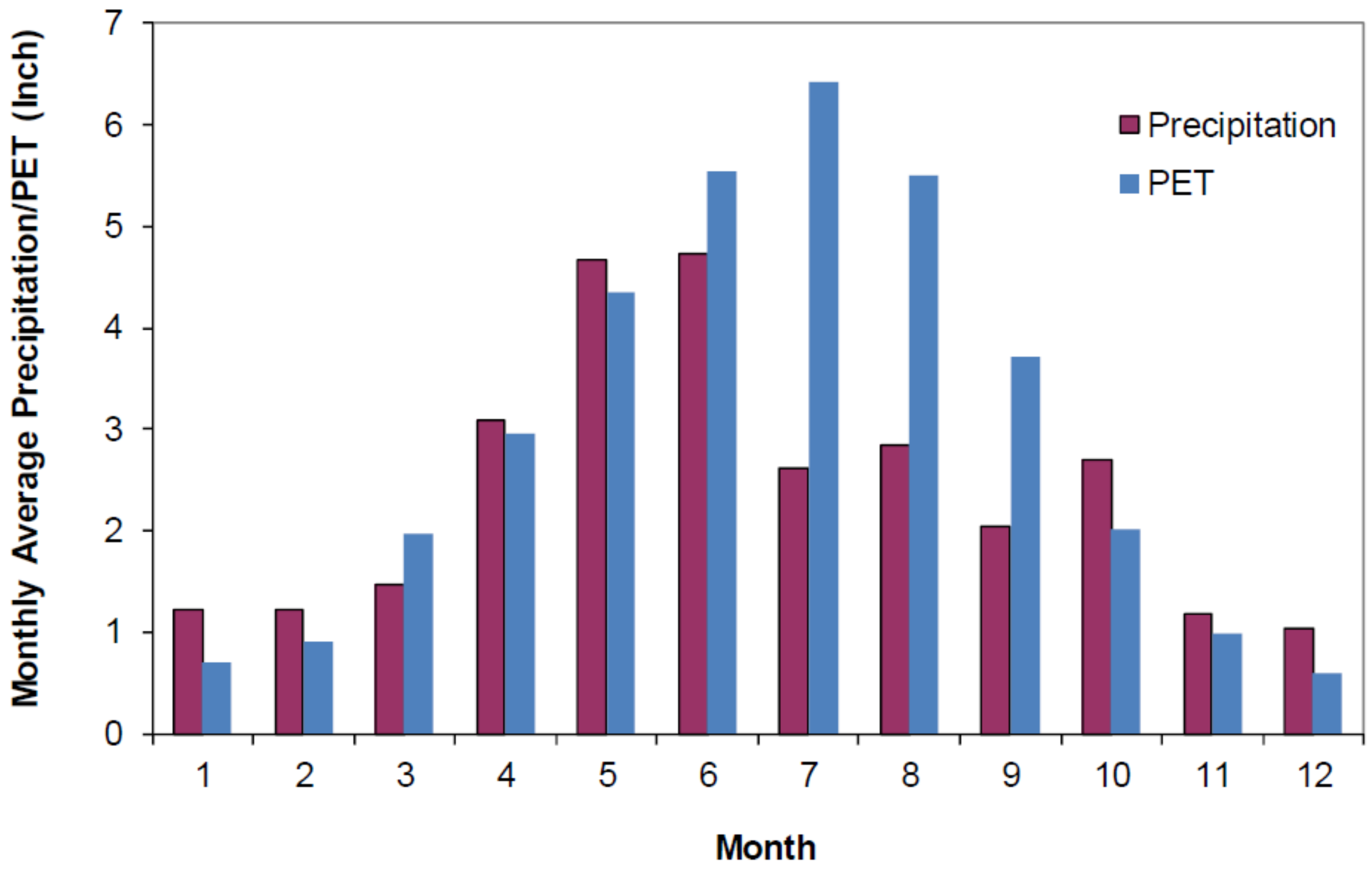
- Located in the northern Black Hills, four miles northwest of Lead, South Dakota
- HLP 1&2 and HLP 3 ET cover areas are nearly identical, about 26 acres each.
- Facility were reclaimed in 1996-1997 with a grass seed mix and deep rooting vegetation

Introduction: Cover Configuration



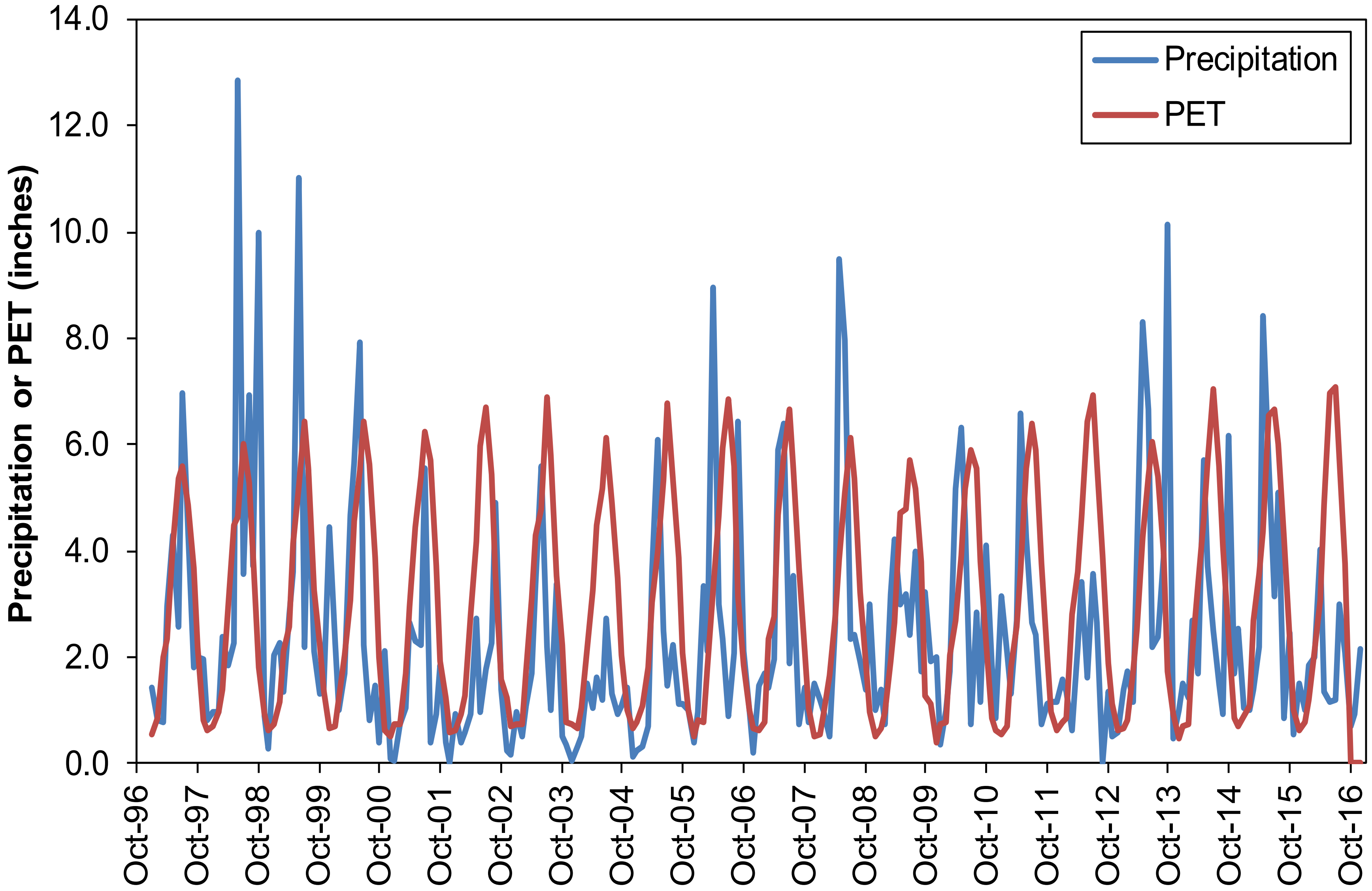
- Side slope is graded at 2.5:1 (H:V)
- Multi-layer ET cover (from bottom up):
  - 1 ft bentonite amended soil liner
  - 4 ft ft thermal barrier/drainage layer
  - 0.5 ft topsoil
- Amended soil liner was extended past the geomembrane liner
- Drainage layer is connected to drainage collection trench

Introduction: Climate Conditions



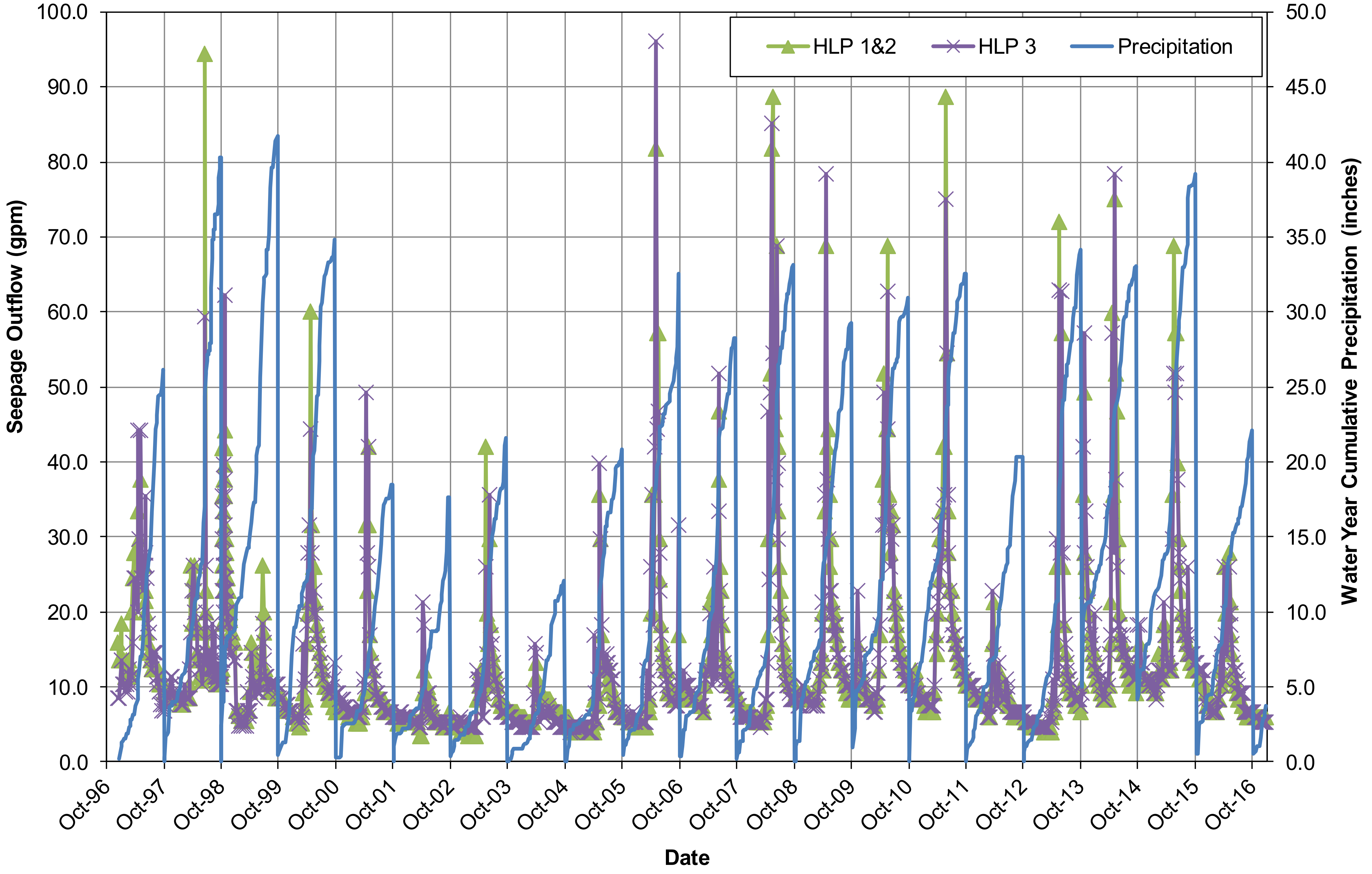
- Precipitation measured at site with a heated rain gauge. Average annual precipitation is 29 inches
- PET is estimated from temperature data using the Hargreaves equation. Average annual PET is 36 inches
- Average monthly precipitation varies from 1.0 to 4.7 inches
- Average monthly PET varies from 0.6 to 6.4 inches
- Snowpack melts in April - June

Cover Performance: Monthly P and PET



- Annual precipitation ranges from 12 - 44 in
- Estimated annual PET ranges from 33 – 40 in

Cover Performance: Seepage



Cover Performance: Seepage

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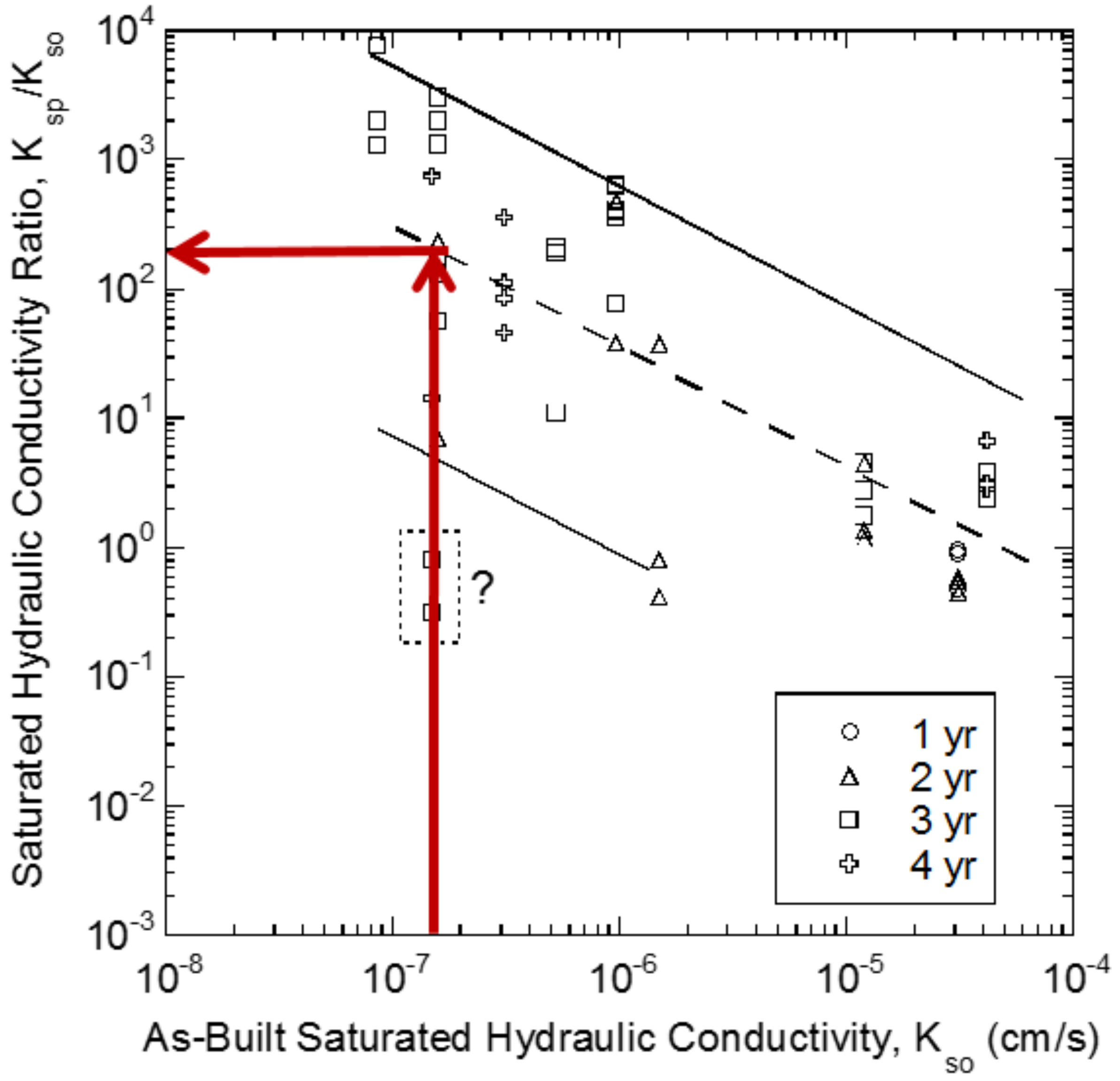
Water year precipitation and seepage outflow as percent of precipitation (WY 1998 to WY 2016)

	Precipitation (in)	Pad 1&2 (%)	Pad 3 (%)
1998	40.29	23	22
1999	44.04	22	20
2000	34.84	25	25
2001	18.50	38	42
2002	17.69	25	26
2003	21.60	29	28
2004	12.12	44	37
2005	20.83	27	29
2006	32.58	30	31
2007	28.30	34	32
2008	33.13	39	34
2009	29.28	39	37
2010	30.99	43	41
2011	32.52	40	38
2012	20.38	31	31
2013	34.19	23	24
2014	33.08	41	42
2015	39.19	33	33
2016	22.13	35	37
Average All	**28.72**	**32**	**31**
Average 1998 - 2000	**39.72**	**23**	**22**
Average 2001 - 2005	**18.15**	**32**	**32**
Average 2006 - 2016	**30.52**	**35**	**34**

Measured heap leach pad average annual seepage outflow rate (gpm)

Water Year	HLP 1&2	HLP 3
1998-2000	13.7	13.0
2001-2005	8.2	8.3
2006-2016	15.3	15.0
All	13.2	12.9

Cover Performance: Pedogenesis - Ks



From lab, $K_s = 1.5\text{x}10^{-7}$ cm/s

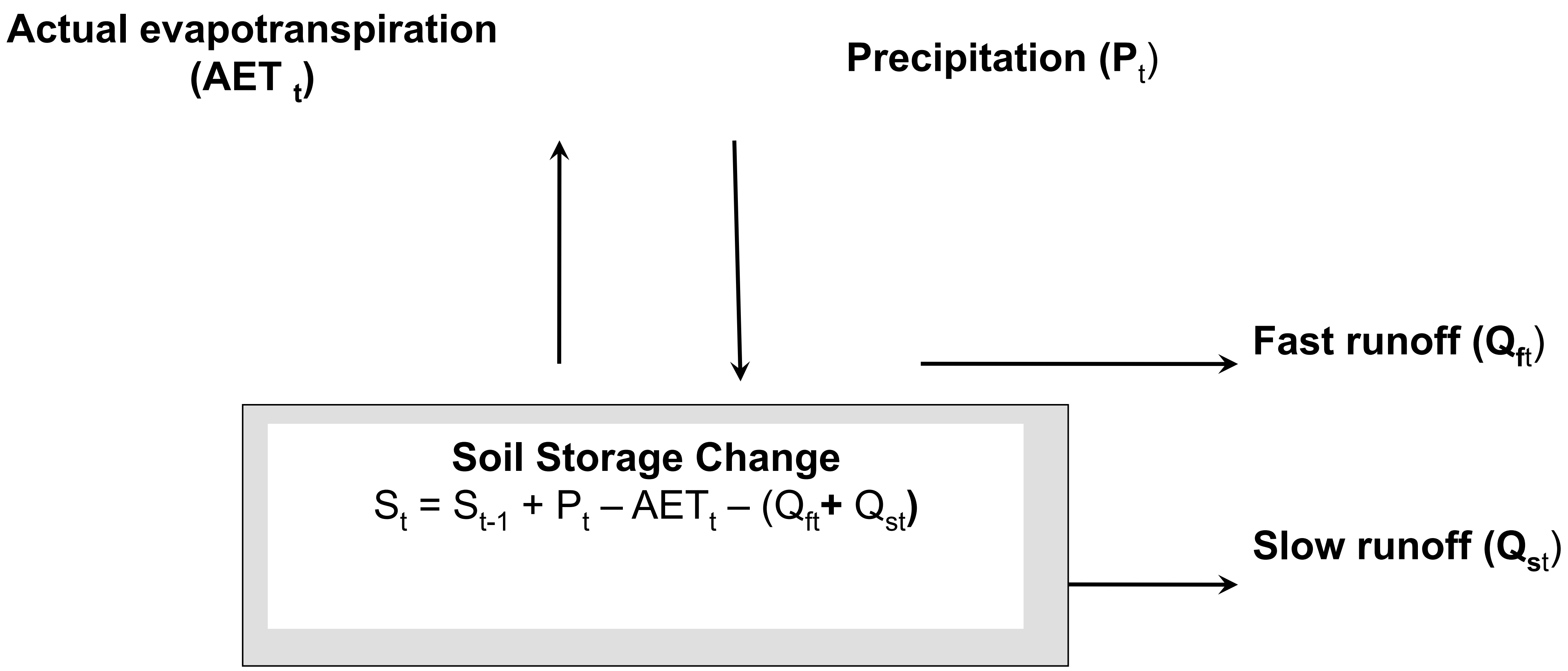
$K_{sp}/K_{so} = 200$

$K_{sp} = 200 \text{ x } 1.5\text{x}10^{-7}$

$= 3.0\text{x}10^{-5}$ cm/s

Benson CH, Sawangsuriya A, Trzebiatowski B, Albright WH. 2007. Pedogenic Effects on the Hydraulic Properties of Water Balance Cover Soils. *J. Geotech. and Geoenvironmental Eng*. 133(4): 349-359.

Water Balance Model (Vandewiele et al. , 1992)



$$S_t = S_{t-1} + P_t - AET_t - (Q_{ft} + Q_{st})$$

Vandewiele, G.L., Xu, C.-Y., and Win, N.-L., 1992, Methodology and comparative study of monthly water balance models in Belgium, China and Burma. Journal of Hydrology 134: pp 315-347

Water Balance Model (Vandewiele et al. , 1992)

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- Monthly actual evapotranspiration (AET):

$$AET_t = \min[E_t \times (1 - a_1^{W_t/E_t}), W_t]$$

Where E is PET and W is water available

- Available water (W):

$$W_t = P_t + S_{t-1}$$

- Slow (Q_{st}) and fast (Q_{ft}) Seepages:

$$Q_{slow} = [a_2 \times (S_{t-1})^{b_1}]$$

$$Q_{fast} = [a_3 \times S_{t-1} \times (P_t - E_t \times (1 - \exp(-P_t/E_t)))]$$

Model Calibration: 4 Model Parameters

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Parameter	Calibrated Value
a_1	0.70
a_2	0.10
a_3	0.0032
b_1	1

- The model predicted seepage outflow from HLP 1&2 and HLP 3 during the simulated period (January 2001 through December 2016) is 34% of precipitation, identical to the measured values
- The remaining 66% of precipitation is predicted to be lost to evapotranspiration or subsurface runoff

Model Calibration: Sim. vs. Mea. Seepage (Pad 1&2)

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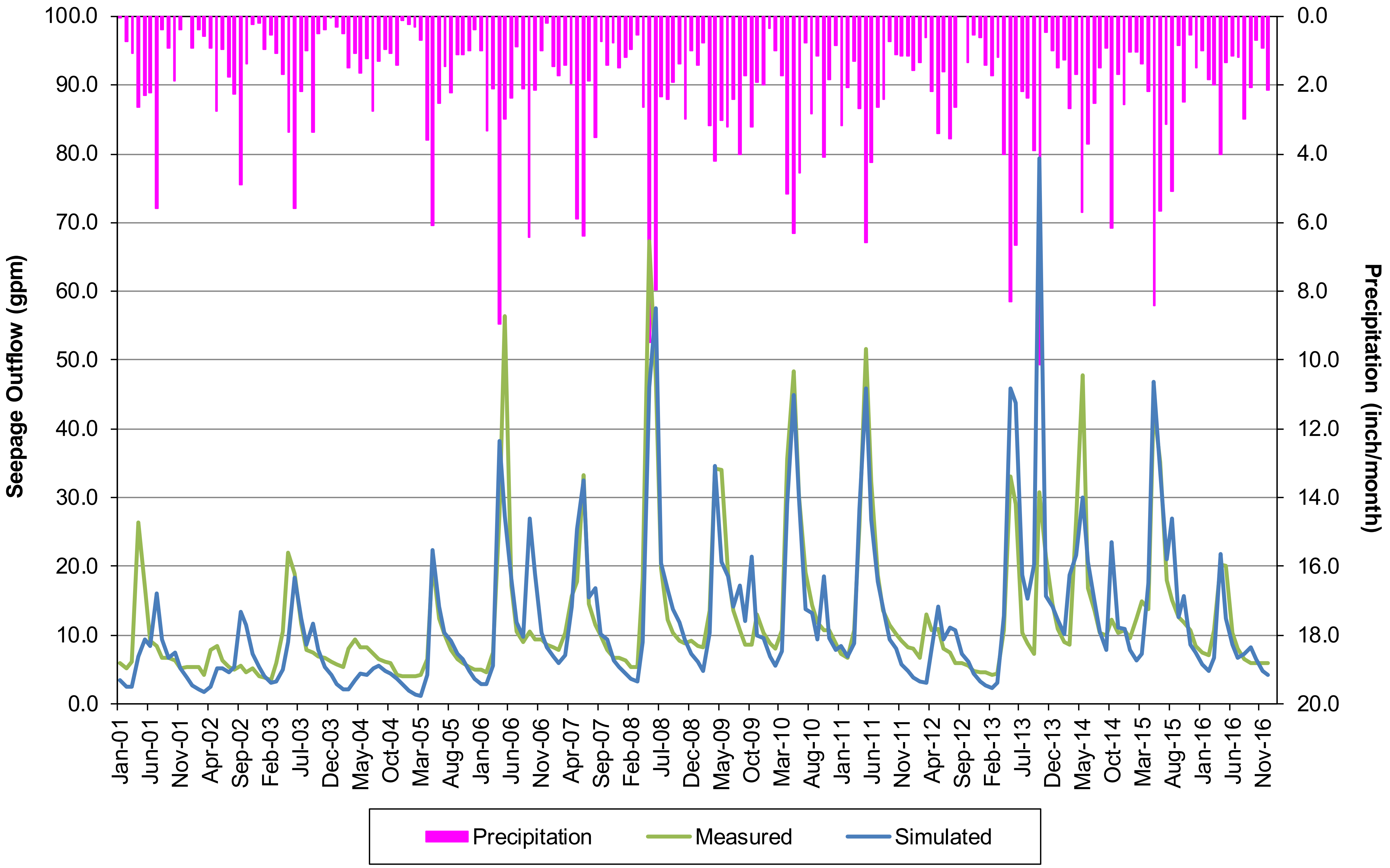

Model Calibration: Sim. vs. Mea. Seepage (Pad 3)

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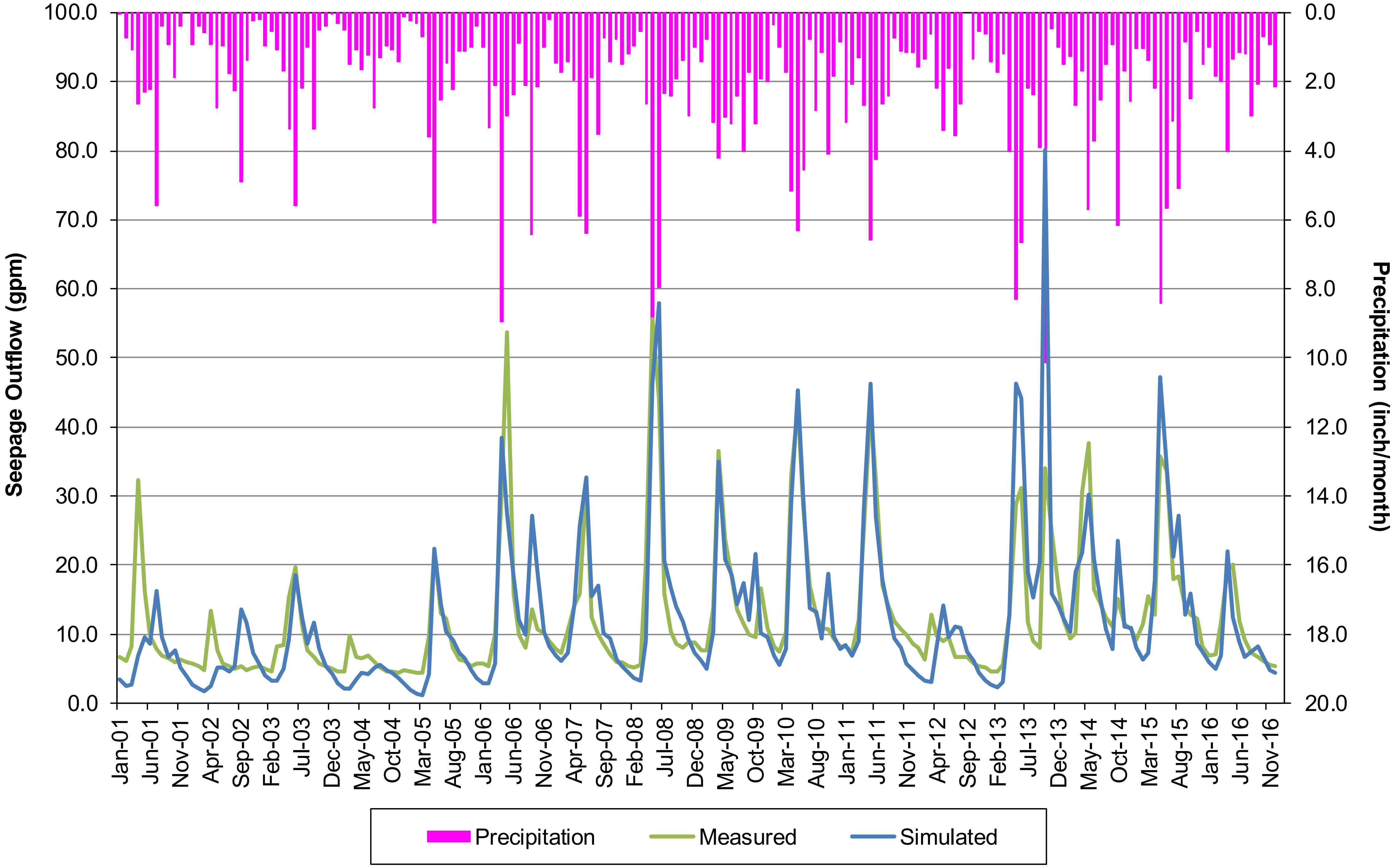

Discussions

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- The site is located at a relative wet area with a P/PET ratio of 0.80 (29/36)
- In some water years, P is even higher than PET
- Peak seepage rates generally occur in May, corresponding peak snowmelt season when PET is low
- At such an area, high seepage rates are expected

Discussion (after Apiwantragoon et al.. 2015)

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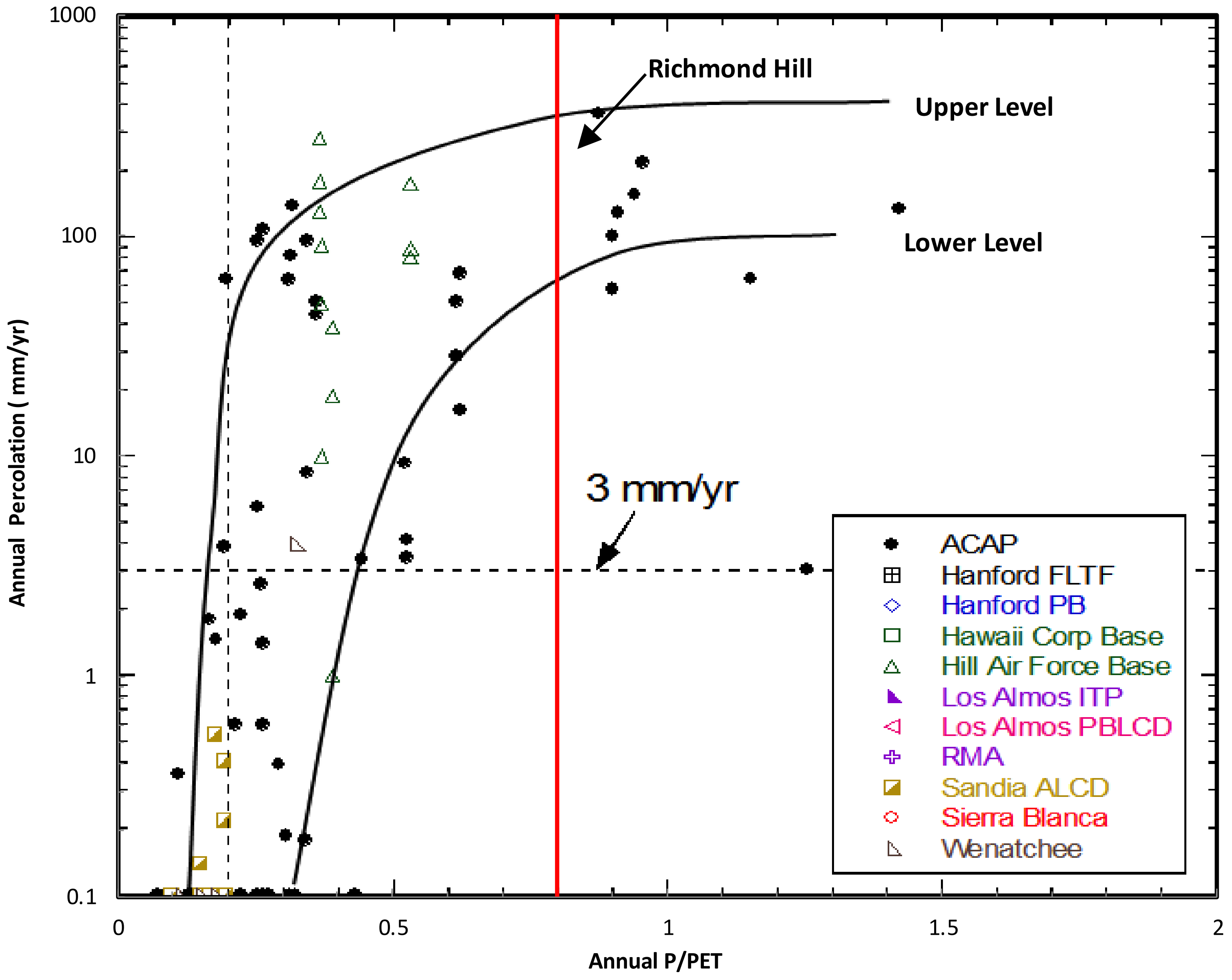
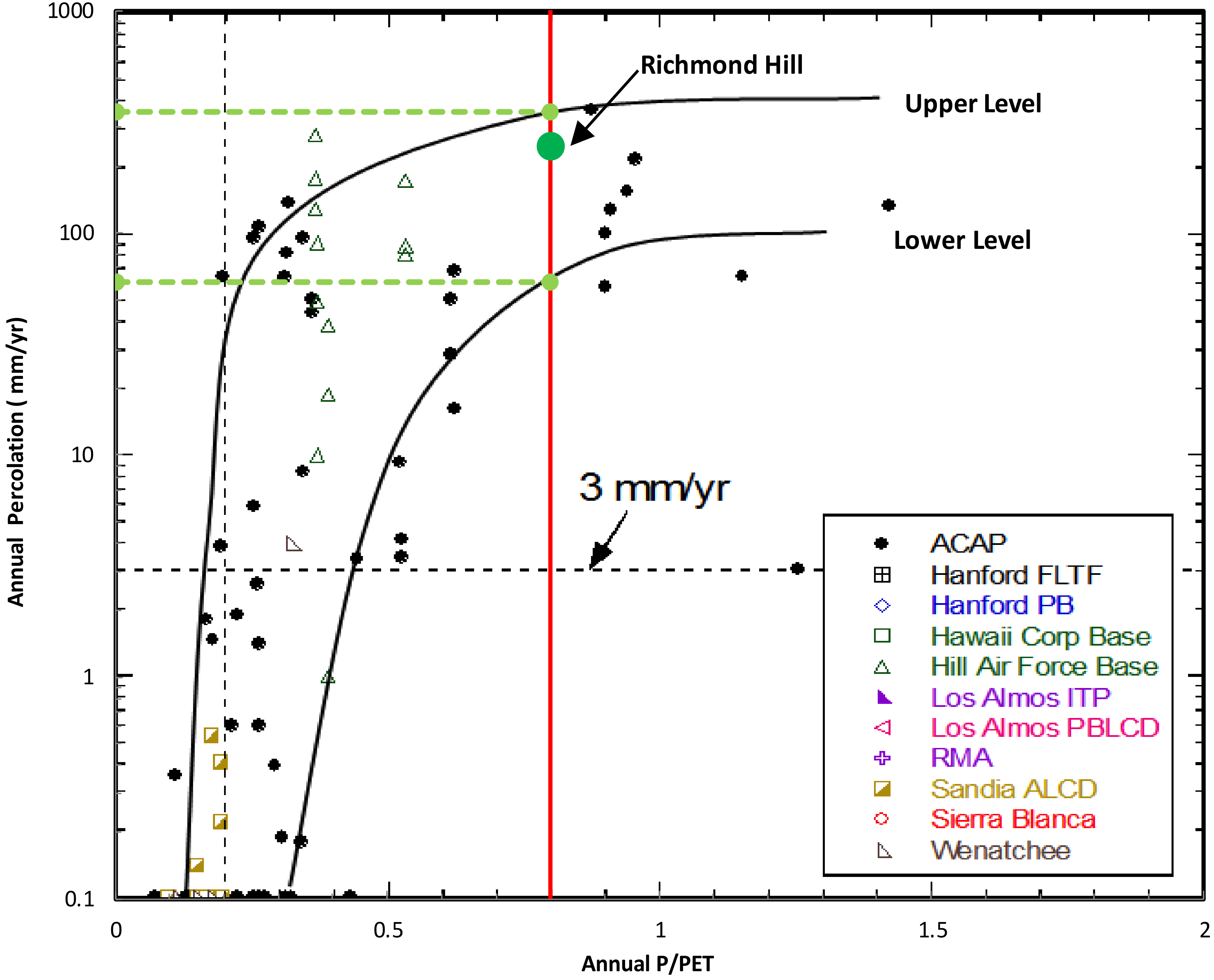


- For a ET cover with low percolation rate (3 mm/yr), the P/PET < 0.4
- For a ET cover with P/PET of 0.8, high percolation rate is expected

Apiwantragoon P, Benson CH, Albright WH. 2015. Field Hydrology of Water Balance Covers for Waste Containment. J. Geotech. and Geoenvironmental Eng. 141 (2): 04014101-1-20. DOI: 10.1061/(ASCE)GT.1943-5606.0001195

Discussion



- When the P/PET ratio is 0.80, the expected net percolation is in the range of 60 – 350 mm per year
- simulated and measured Richmond Hill's net percolation is 248 mm (730 mm x 34%)
- Richmond data is well within this range

Conclusions

- A review of the 20 year monitoring data indicates that K_{sat} of the amended soil liner most likely increased in the early time between 1996–2000 in response to pedogenic processes
- Net percolation rates at HLP 1&2 and HLP 3 were accurately simulated by a monthly water balance model. Observed and simulated percolation rates are about 34% of precipitation
- At subhumid and humid sites, an ET cover system can reduce, but not eliminate, net percolation. Thus, the cover system at Richmond Hill HLP is considered to be functional and has met the design objective

Conclusions

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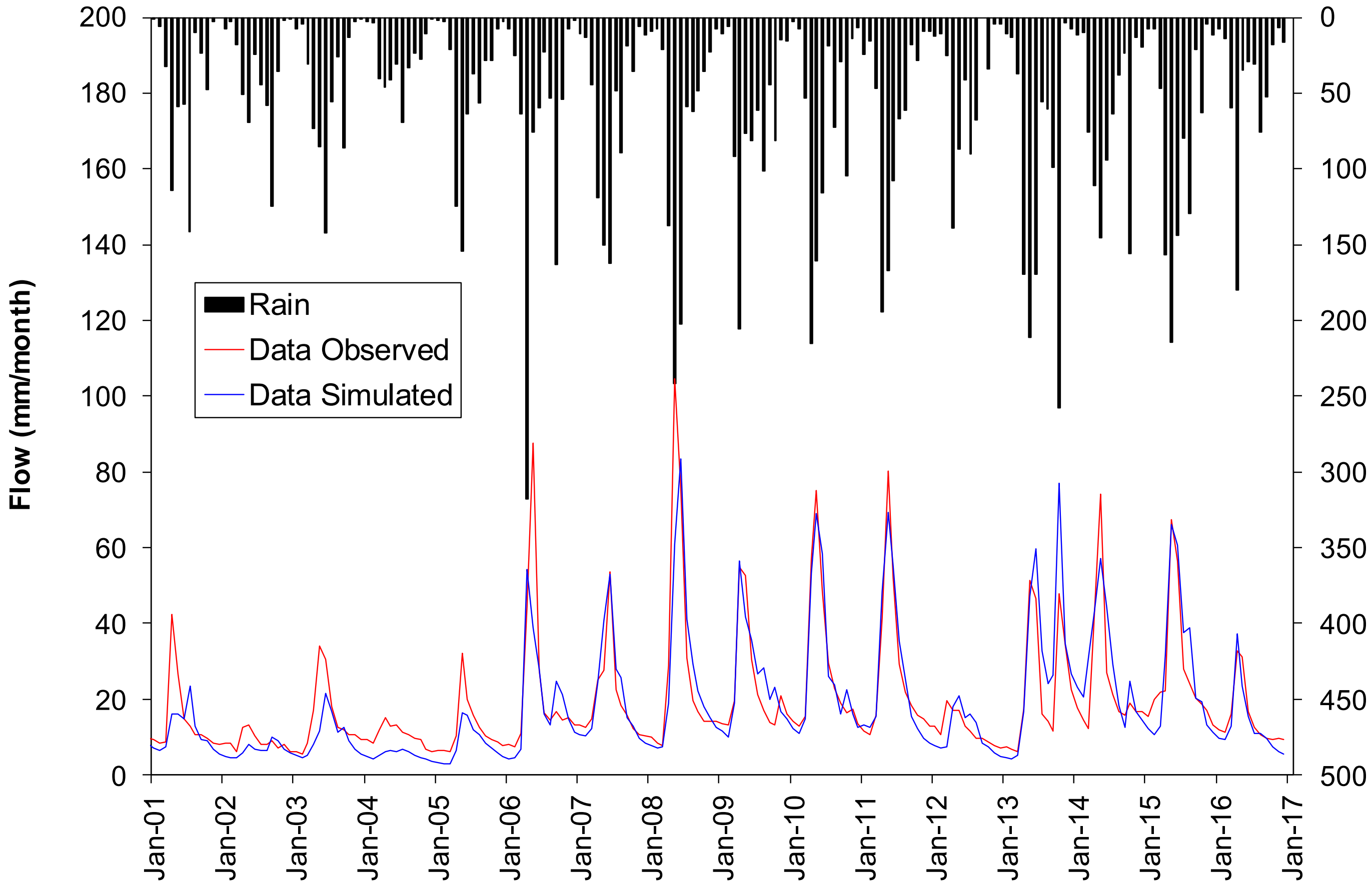
- When a site is located at a relative wet area (P/PET ratio > 0.40), Seepage could be well simulated using a water balance (WB) approach, rather than a unsaturated flow model
- In addition to the Vandewiele WB model presented earlier, another WB modeling approach (GR2M) is also tested with equal success



https://webgr.irstea.fr/en/modeles/mensuel-gr2m/