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Post Closure Cover Performance Evaluation and Improvement at Rain Mine in Nevada

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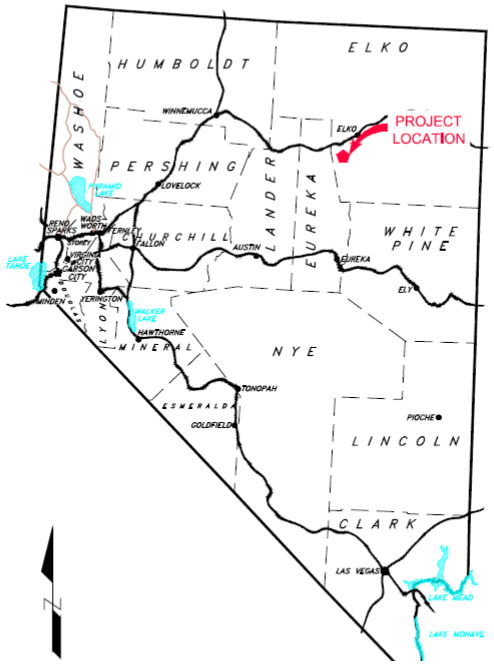
Outlines

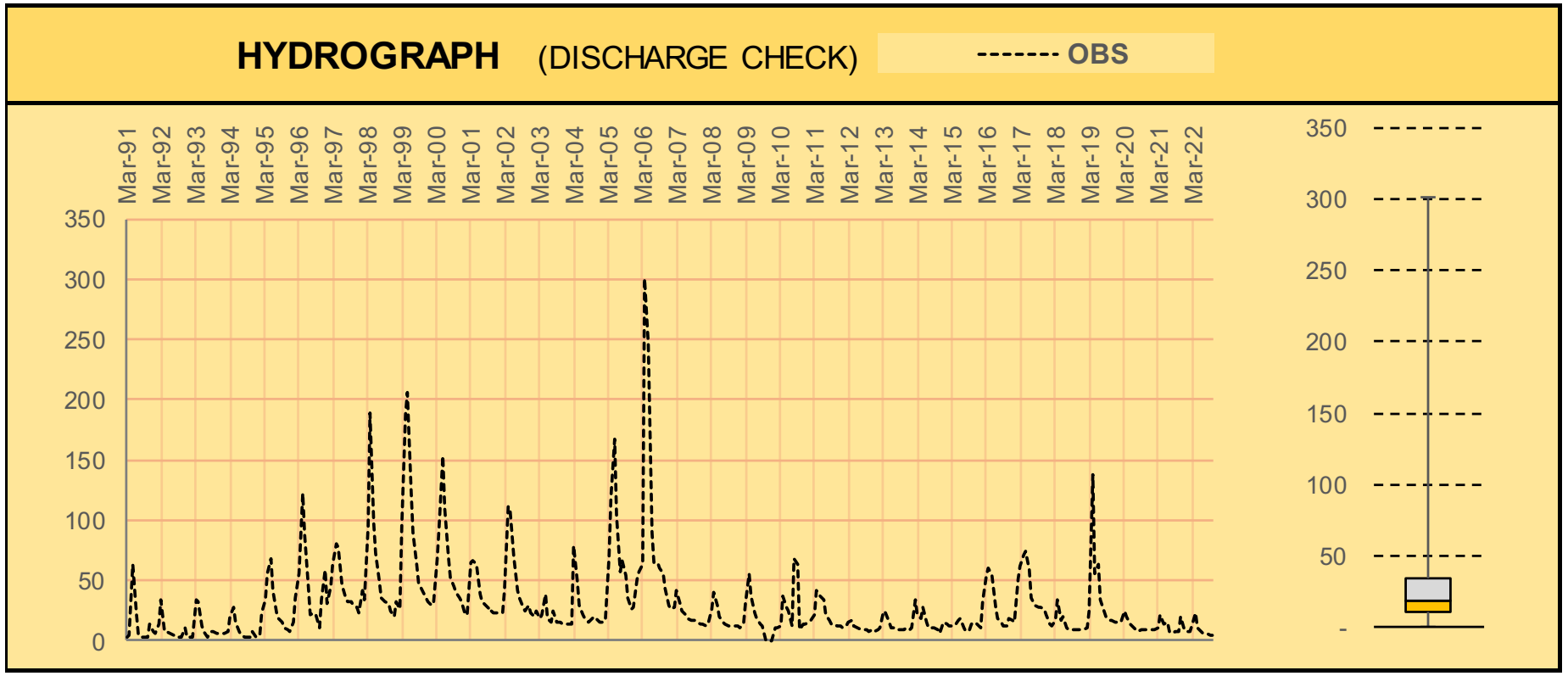
1. Project Background
2. Meteoric Conditions
3. ET Cover
4. Seepage Model
5. Performance Evaluation
6. Synthetic Cover
7. Conclusions

1. Project Background: Facility

- Located in Elko County, Nevada at an elevation of 6,600 feet ft amsl
- From 1988-2002, approximately 70 million tons of waste rock from pits and underground facilities placed with a footprint of 180 acres
- Seepage collected by underdrain systems and managed at the mine (zero discharge)
- In 2002, reclamation completed with construction of a 4-ft Evapotranspiration (ET) cover



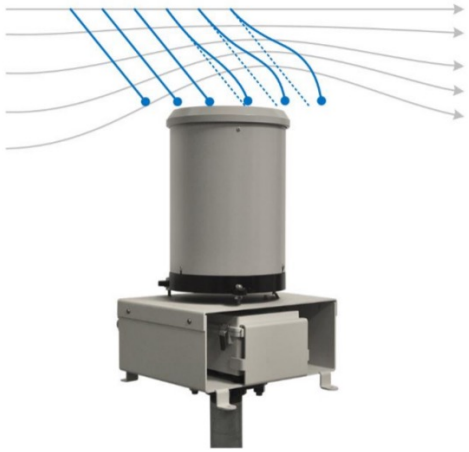
1. Project Background: Seepage



GRAPH STATISTICS	
(gpm)	
Average	30
Median	19
Max	301
Min	2
Range	301
STDEV	35

2. Meteoric Conditions: Precip. Undercut

- Site recorded precipitation (12 in/yr) is underreported

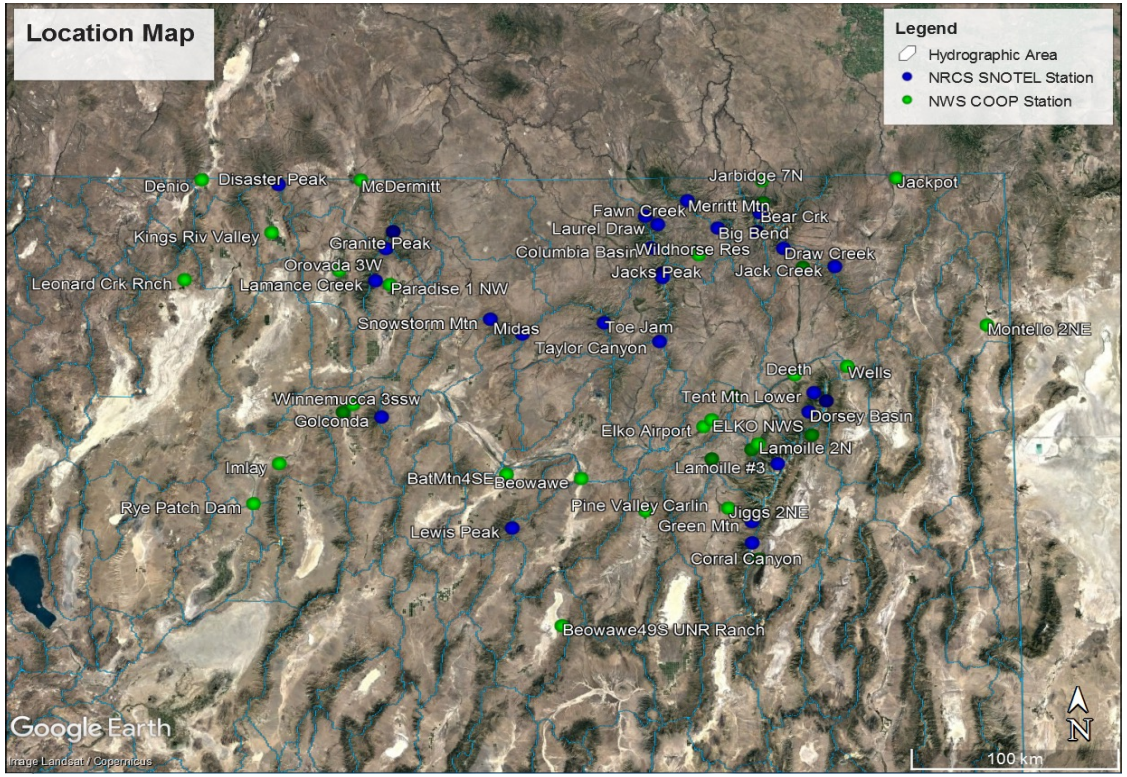


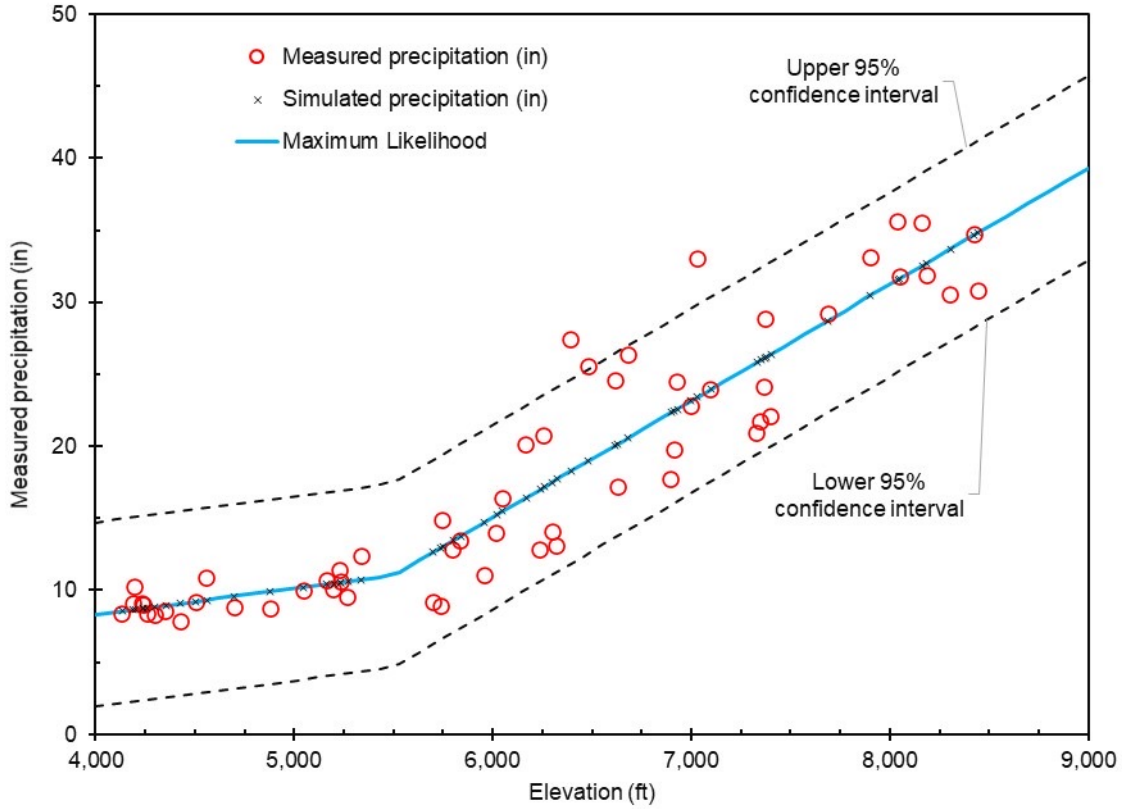
Wind speed at gauge height (Ws)

Yang et al. (1998)

	Wind Speed (m/s)	Unshielded (%)		Alter-Shielded (%)	
Snow	3	53	=EXP(4.606-0.157*Ws^1.28)	78	=EXP(4.606-0.036*$Ws^1.75)
Mixed Precip	3	76	=100.77-8.34*Ws	84	=101.04-5.62*Ws
Rain	3	89	=EXP(4.605-0.062*Ws^0.58)	92	=EXP(4.606-0.041*Ws^0.69)

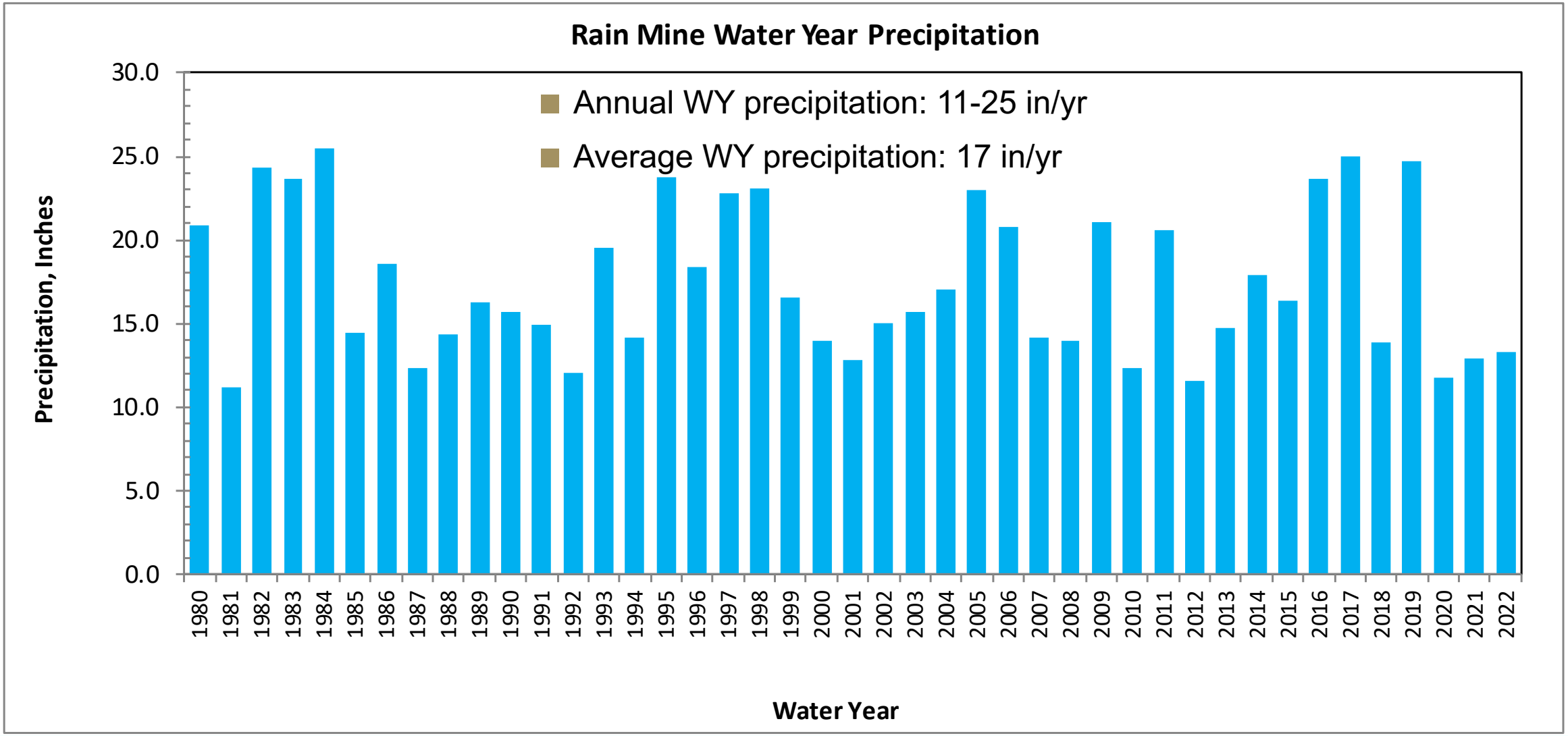
2. Precipitation Pattern in Northeast NV



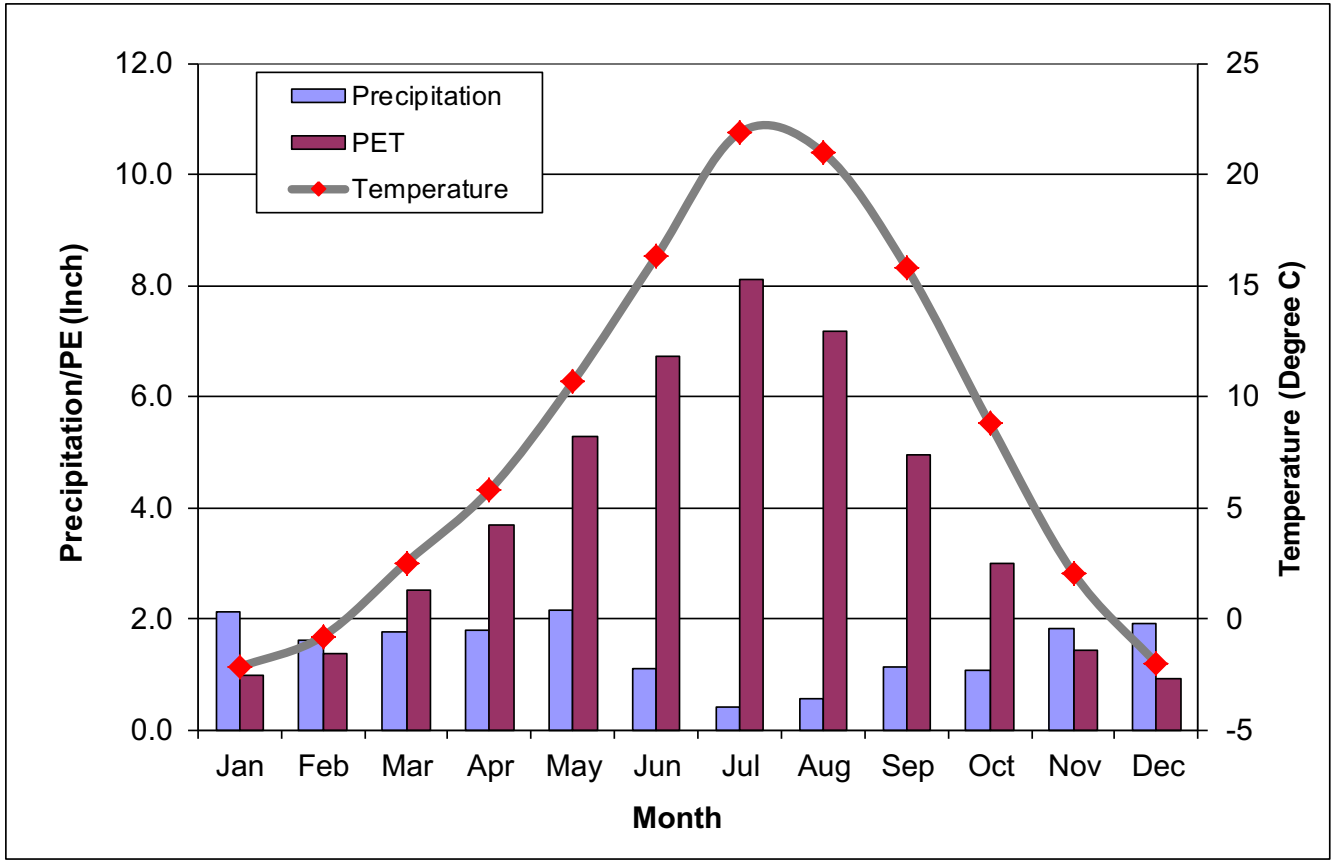


- When elevation is at or below 5,500 ft amsl: P (in/yr) = 0.0019 E (ft) + 0.41
- When elevation is above 5,500 ft amsl: P (in/yr) = 0.0082 E (ft) – 34.55

2. Corrected Precip. (Climate Engine)

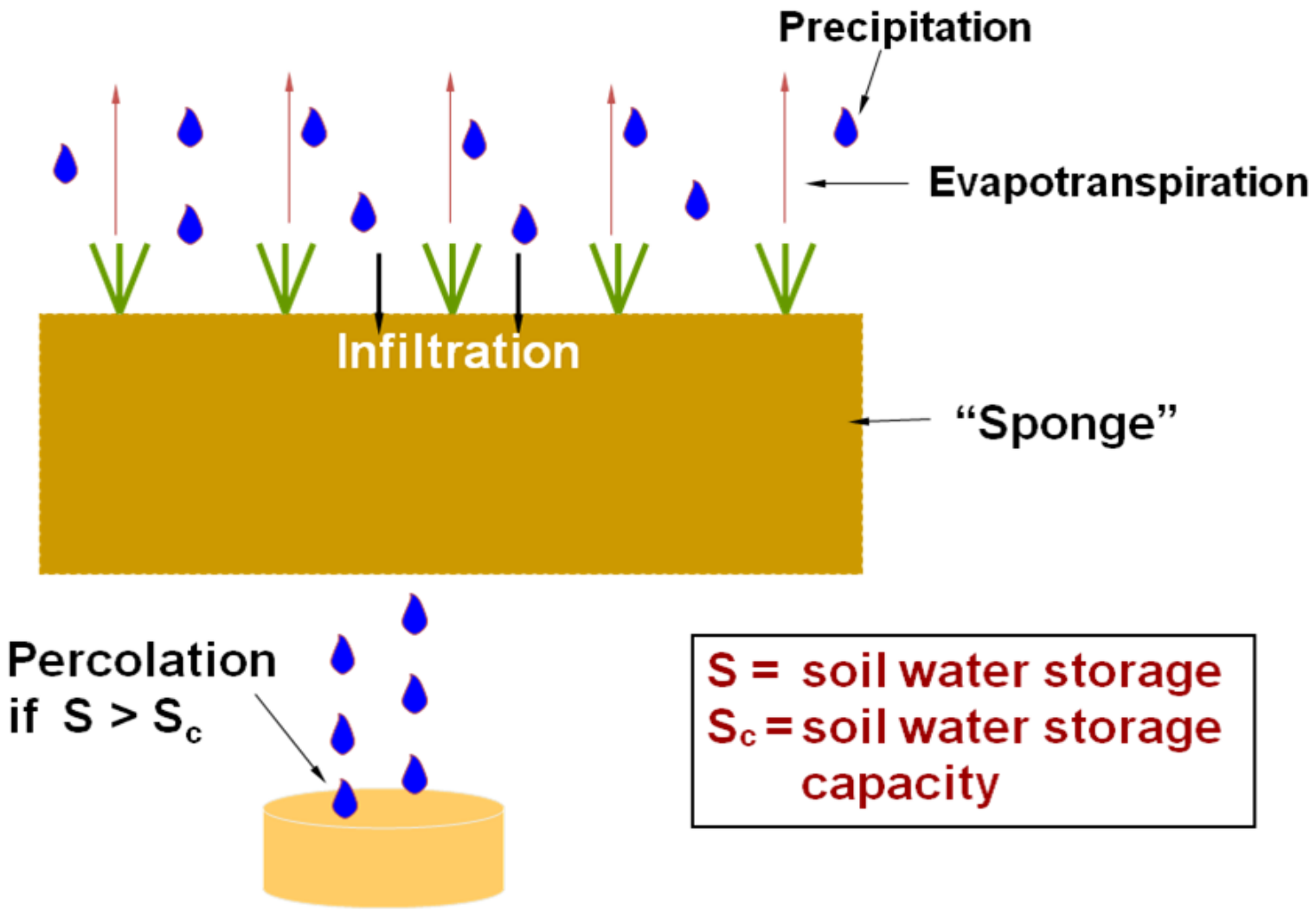


2. Average Climate Conditions



Month	Precipitation (Inch)	Average Temperature (Degree C)	PET (Inch)
Jan	2.1	-2.2	1.0
Feb	1.6	-0.8	1.4
Mar	1.8	2.5	2.5
Apr	1.8	5.8	3.7
May	2.1	10.7	5.3
Jun	1.1	16.3	6.7
Jul	0.4	21.9	8.1
Aug	0.6	21.0	7.2
Sep	1.1	15.8	4.9
Oct	1.1	8.8	3.0
Nov	1.8	2.1	1.4
Dec	1.9	-2.0	0.9
Total /Average	17.4	8.3	46.2

3. ET Cover: Concept



3. Required Cover Water Storage

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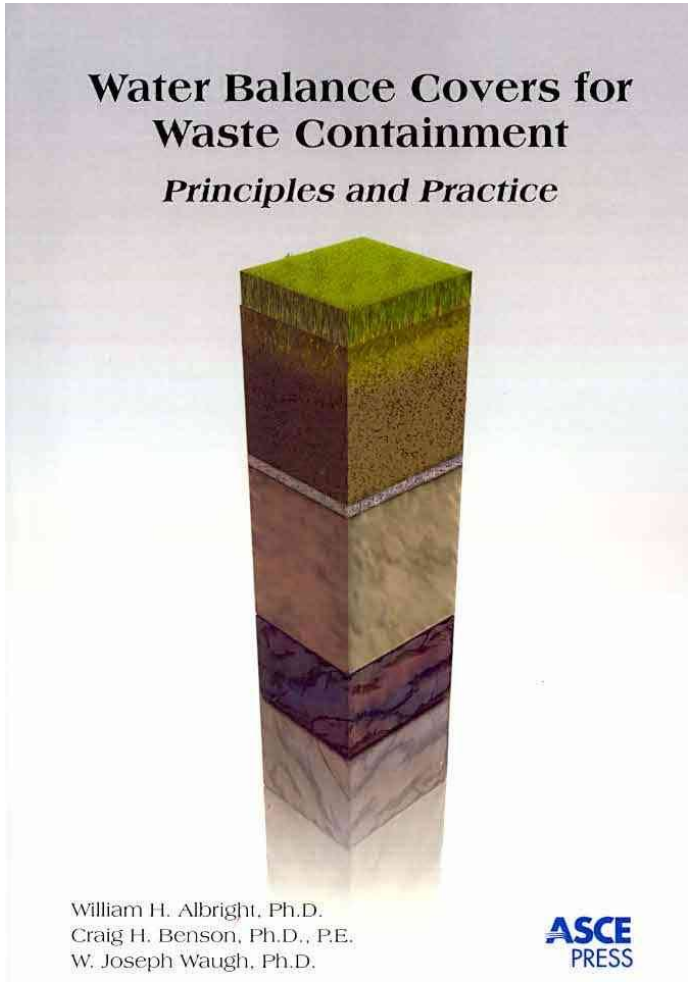
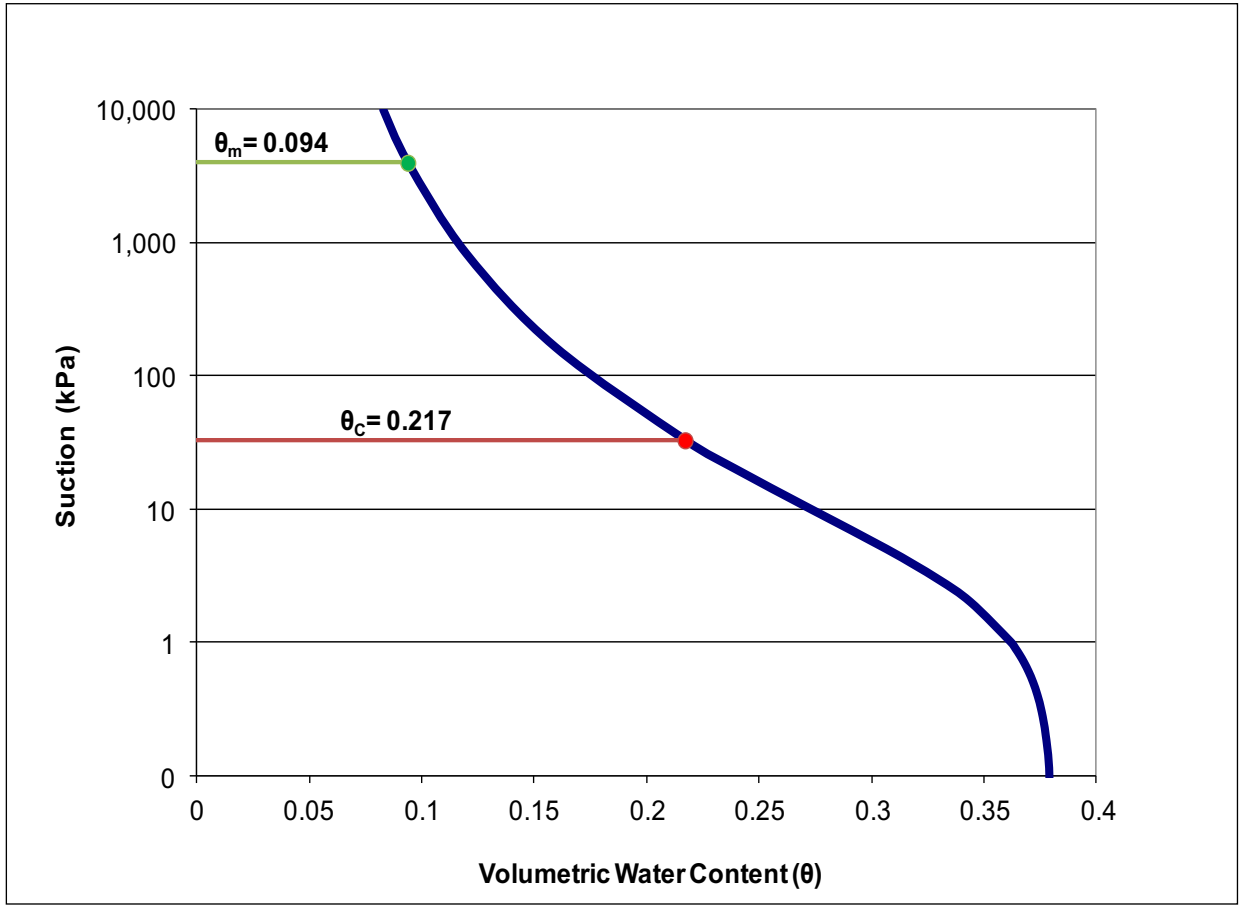
	Precip	PET	Snow/Frozen	Season	P/PET	Threshold	Threshold	Beta	Lambda	Δ S
Month	(mm)	(mm)	Ground?			(P/PET)	Exceeded?	β (-)	Λ (mm)	(mm)
Jan	54.3	25.0	Y	Fall/Winter	2.17	0.51	Y	0.37	0	45.0
Feb	40.7	34.6	Y	Fall/Winter	1.18	0.51	Y	0.37	0	27.9
Mar	44.8	63.9	Y	Fall/Winter	0.70	0.51	Y	0.37	0	21.2
Apr	45.2	93.4	N	Spring/Summer	0.48	0.97	N	1.00	167.8	0.0
May	54.2	133.8	N	Spring/Summer	0.41	0.97	N	1.00	167.8	0.0
Jun	27.7	171.2	N	Spring/Summer	0.16	0.97	N	1.00	167.8	0.0
Jul	10.4	206.2	N	Spring/Summer	0.05	0.97	N	1.00	167.8	0.0
Aug	14.9	182.6	N	Spring/Summer	0.08	0.97	N	1.00	167.8	0.0
Sep	28.4	125.6	N	Spring/Summer	0.23	0.97	N	1.00	167.8	0.0
Oct	26.7	76.2	N	Fall/Winter	0.35	0.34	Y	0.30	27.1	0.0
Nov	45.9	36.6	Y	Fall/Winter	1.25	0.51	Y	0.37	0	32.3
Dec	48.6	23.3	Y	Fall/Winter	2.08	0.51	Y	0.37	0	40.0
Total (mm)	441.8	1,172.2						Total Required Storage =		166.5



3. Available Water Capacity (AWS)

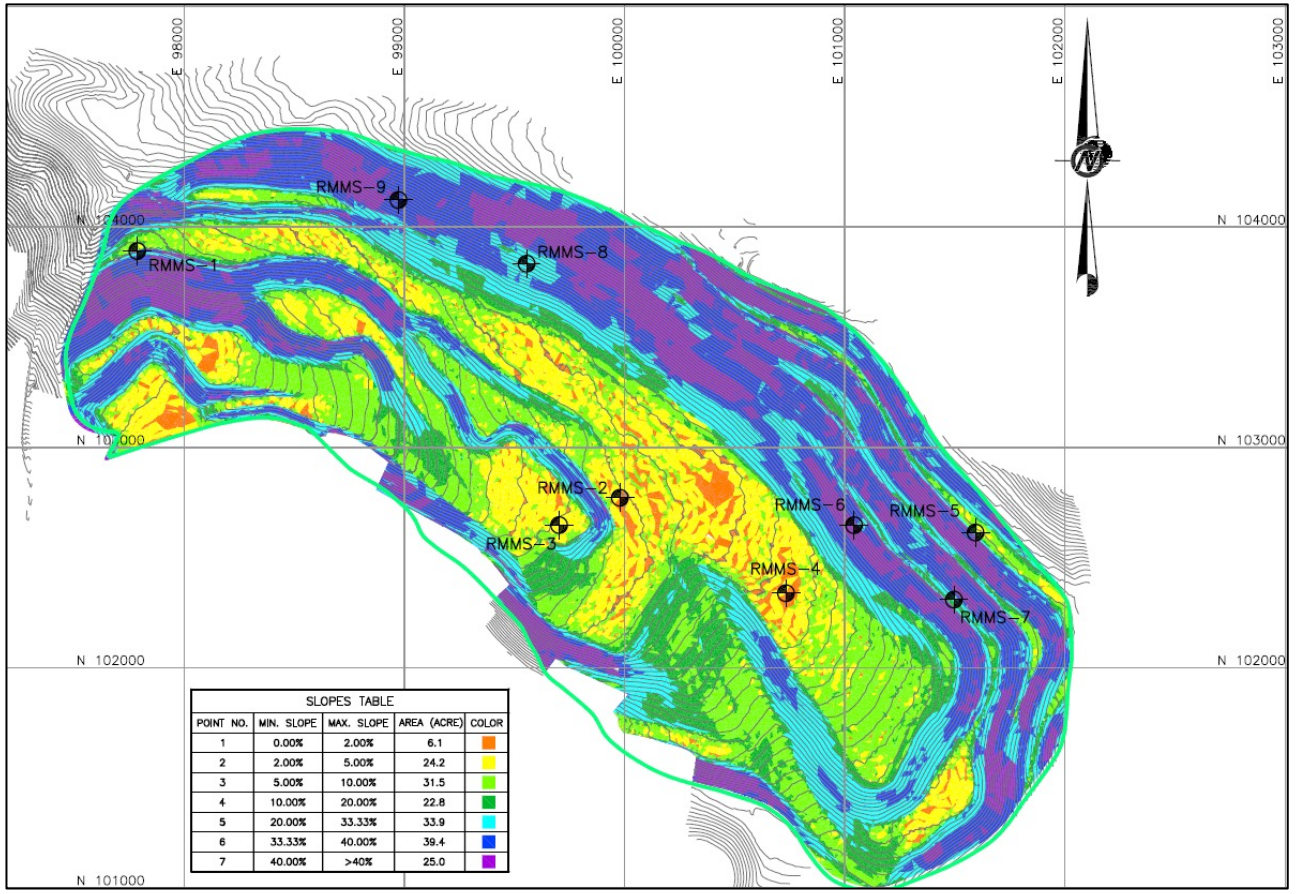


- Field capacity (θc): Normally assumed to be the water content corresponding to a suction of 1/3 bar (33 kPa)
- The minimum water content (θm), or wilting point, is normally assumed to correspond to a suction of 15 bar (1,500 kPa)
- In the desert plant communities, wilting point to correspond to a much higher suction, i.e., 4,000 kPa, to account for their higher salt tolerance
- The AWC:

$$AWC = \theta c - \theta m$$

3. Measured AWC (θc – θm)

Station	Material	FC (θ_c)	WP (θ_m)	Available WC ($\theta_c - \theta_m$)
RMMS-1	Topsoil	20%	12%	8%
RMMS-1	Cover	18%	13%	5%
RMMS-2	Topsoil	23%	13%	10%
RMMS-2	Cover	22%	14%	8%
RMMS-3	Topsoil	25%	14%	11%
RMMS-3	Cover	22%	14%	8%
RMMS-4	Topsoil	19%	11%	8%
RMMS-4	Cover	23%	15%	8%
RMMS-5	Topsoil	20%	11%	9%
RMMS-5	Cover	20%	13%	7%
RMMS-6	Topsoil	20%	12%	8%
RMMS-6	Cover	19%	13%	6%
RMMS-6	Cover	22%	16%	6%
RMMS-7	Topsoil	20%	12%	8%
RMMS-7	Cover	30%	19%	11%
RMMS-8	Topsoil	20%	12%	8%
RMMS-8	Cover	25%	17%	8%
RMMS-9	Topsoil	20%	12%	8%
RMMS-9	Cover	22%	14%	8%
Average		22%	14%	8%



3.Measured AWC (θc – θm)

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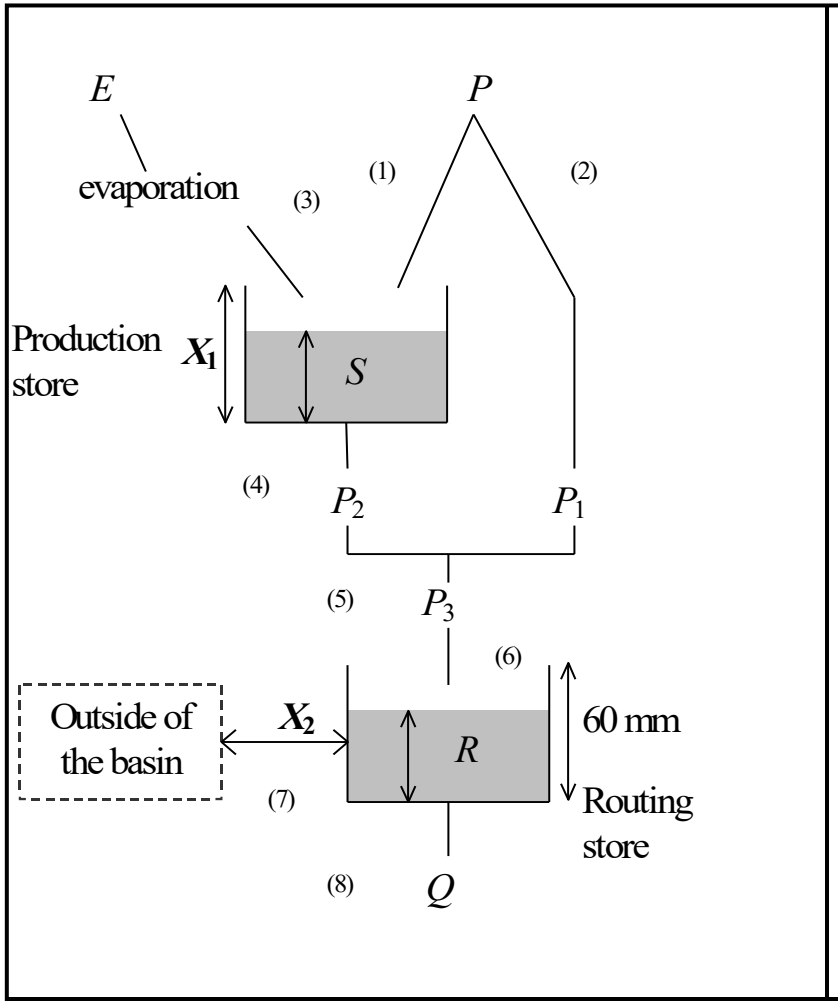
Material	Thickness (ft)	FC (θ_c)	WP (θ_m)	AWC ($\theta_c - \theta_m$)
Topsoil	1	20.8%	12.1%	8.7%
Cover	3	22.3%	14.8%	7.5%
Thickness Weighted	4	21.9%	14.1%	7.8%

- AWC is bout 8% based on wilting point at 15 bar. 10% is the most likely value if wilting point would be determined at 40 bar
- The total required storage is 166.5 mm (6.6 in), and actual storage of the 4 ft cover is 121.9 mm < 166.5 mm with a storage deficit of 44.6 mm (1.8 in)
- The required optimum cover thickness would be about 5.5 ft, instead of the 4 ft

4. Seepage Model (GR2M, Mouelhi 2003)



(1) $$S_1 = \frac{S + X_1\varphi}{1 + \varphi\frac{S}{X_1}} \quad \text{with} \quad \varphi = \tanh\left(\frac{P}{X_1}\right)$$

(2) $$P_1 = P + S - S_1$$

(3) $$S_2 = \frac{S_1(1-\psi)}{1+\psi\left(1-\frac{S_1}{X_1}\right)} \quad \text{with} \quad \psi = \tanh\left(\frac{E}{X_1}\right)$$

(4) $$S = \frac{S_2}{\left[1+\left(\frac{S_2}{X_1}\right)^3\right]^{1/3}} \qquad P_2 = S_2 - S$$

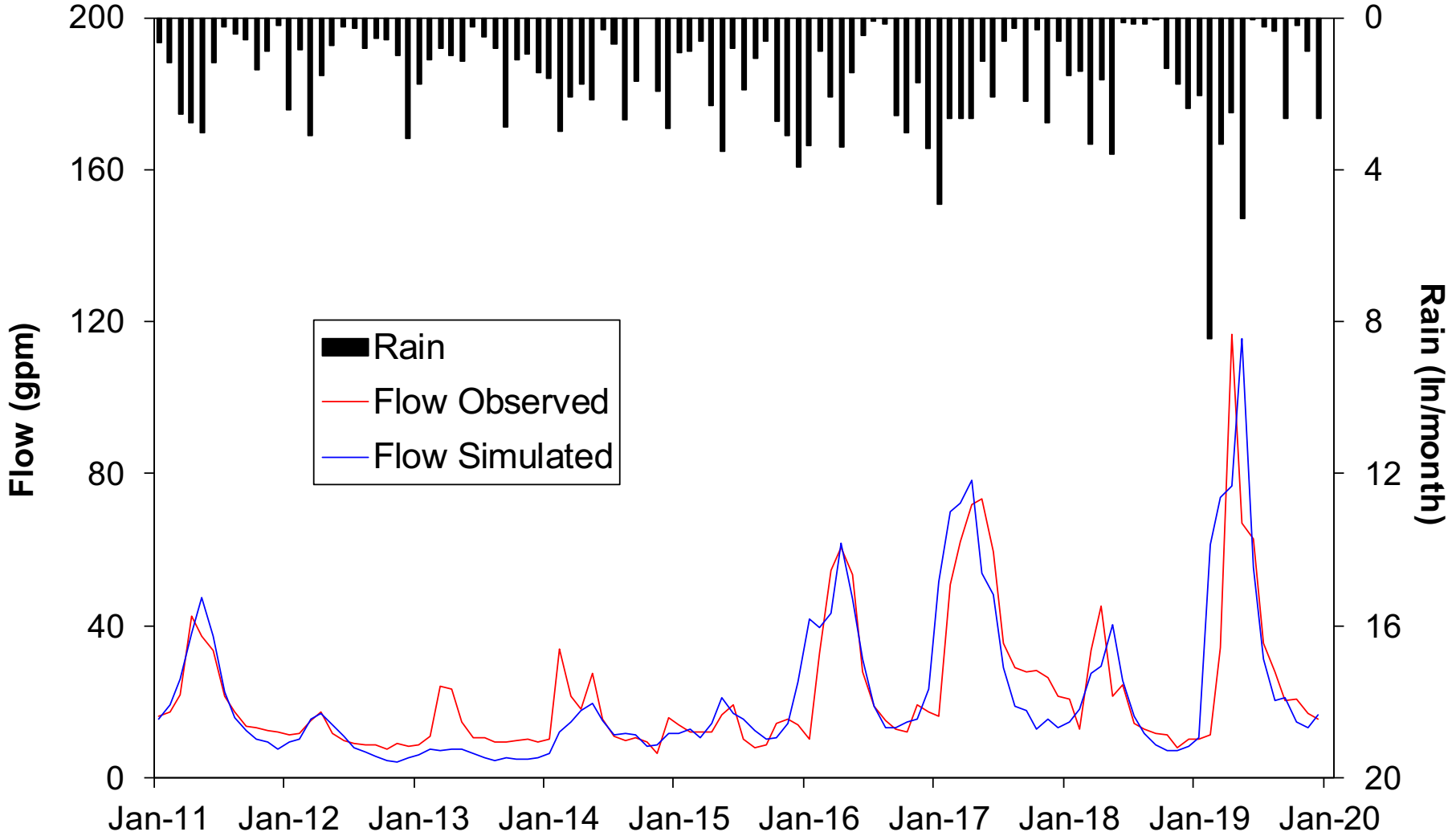
(5) $$P_3 = P_1 + P_2$$

(6) $$R_1 = R + P_3$$

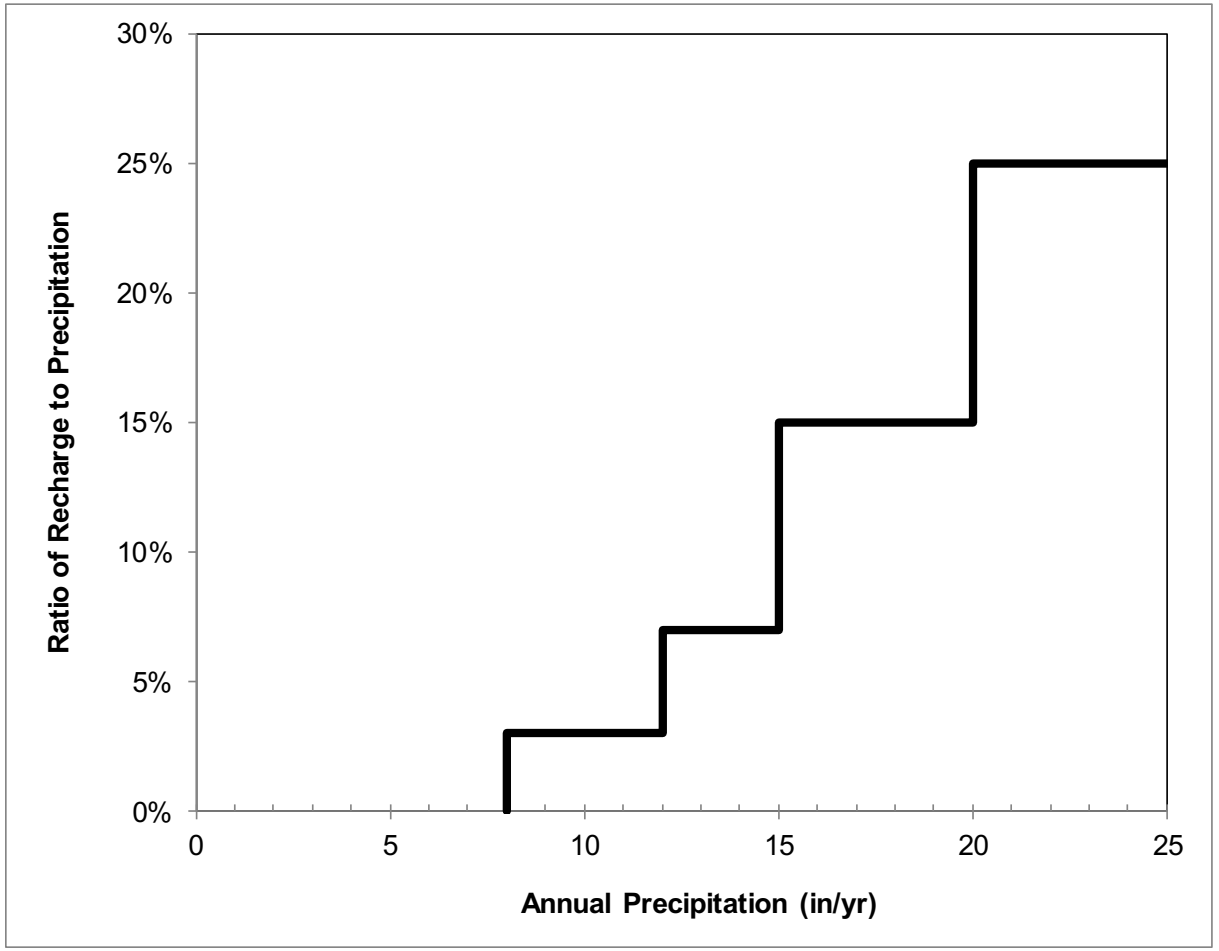
(7) $$R_2 = \frac{X_2 R_1}{}$$

(8) $$Q = \frac{R_2^2}{R_2 + 60} \qquad R = R_2 - Q$$

4. Seepage Model Results

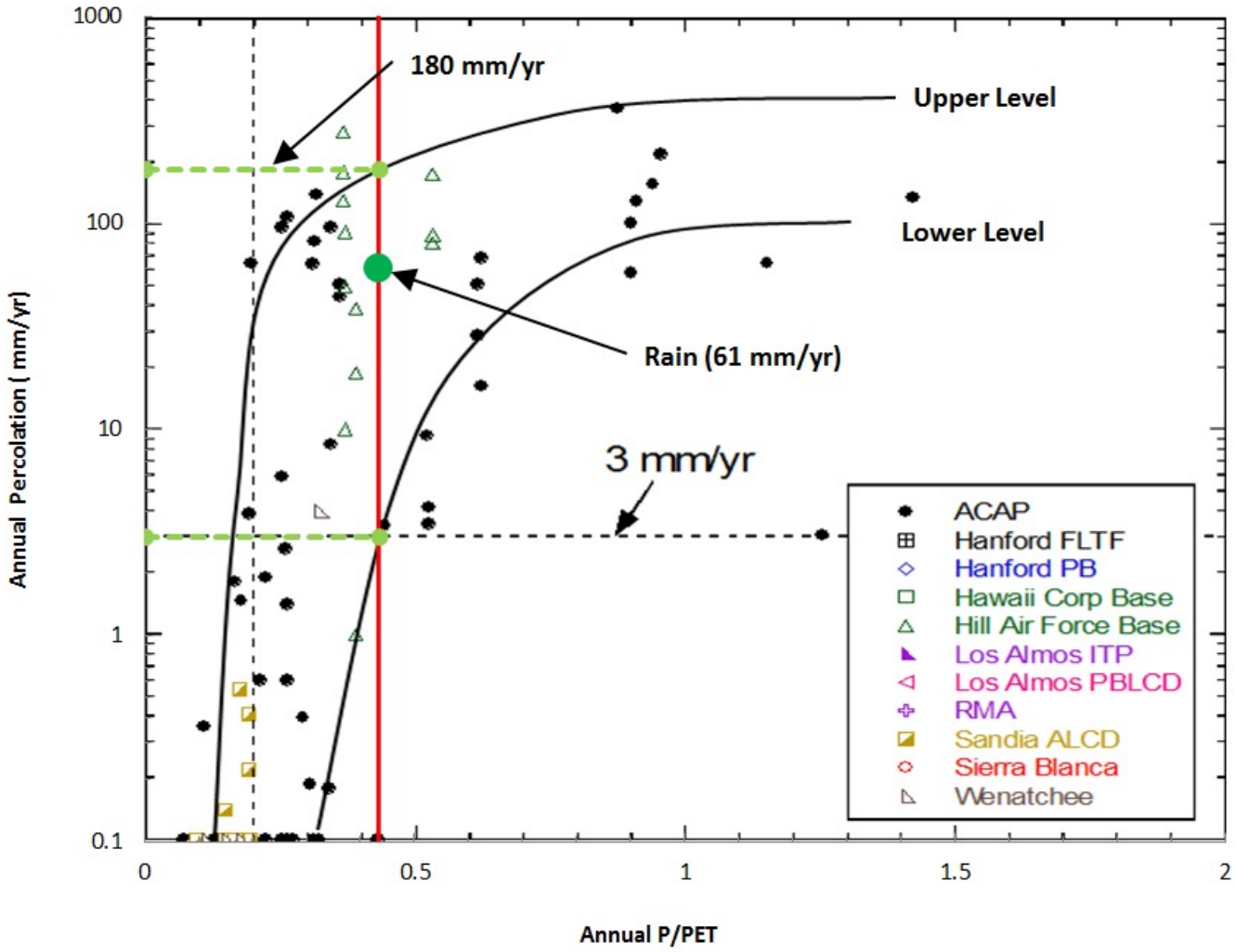


5. Performance Evaluation (M-E Method)



- Cover performance became dynamically stable around year 2011 after vegetation became mature
- Average annual precipitation (2011-2019) is 20 in/yr, percolation is 2.4 in/yr
- Seepage rate is about 12% of precipitation
- It is lower than the expected groundwater recharge of 15% from Maxey-Eakin method

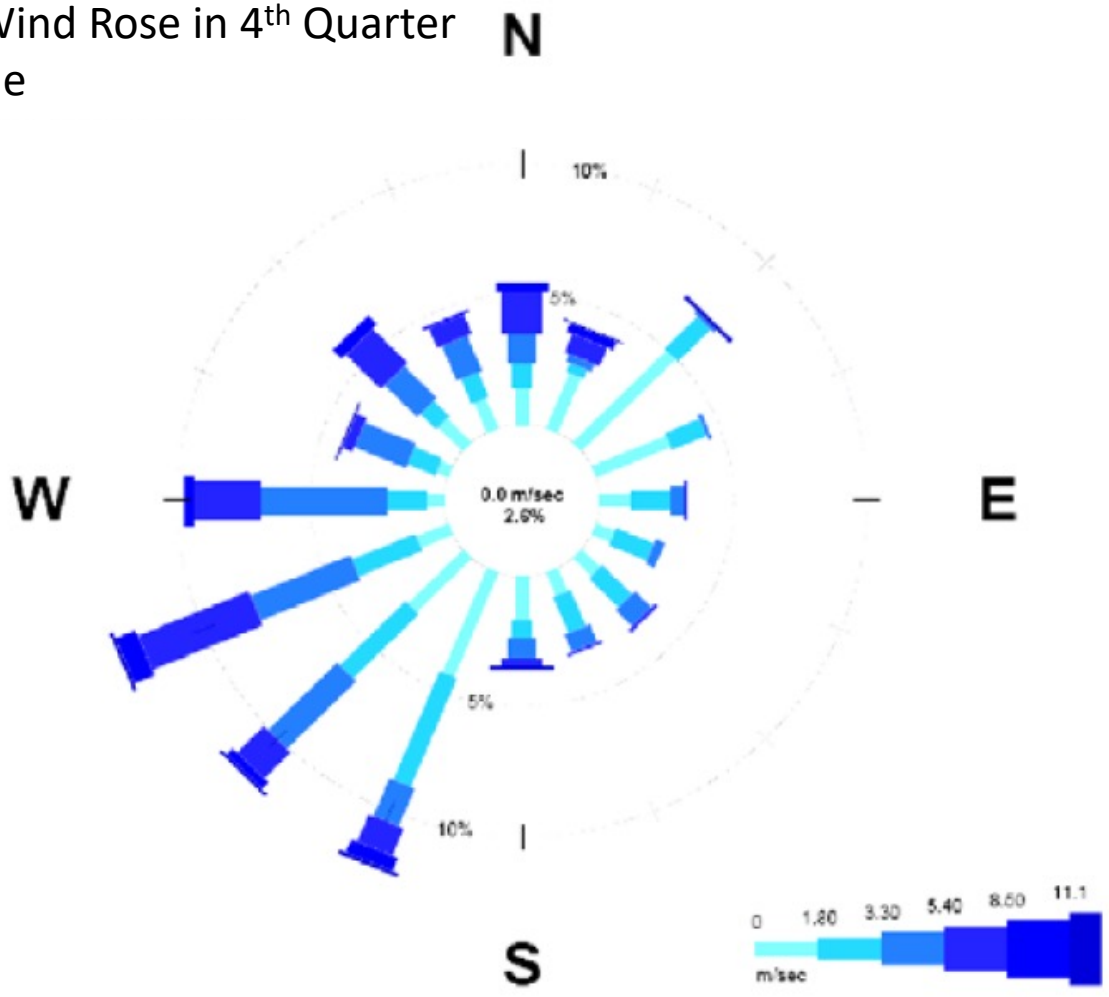
5. Performance Evaluation (Benson et al.)



- P/PET = 20/46 =0.43
- Expected percolation rate between 3 mm/yr and 180 mm/yr
- Rain percolation rate is 61 mm/yr, well within the range
- Cover system at Rain performs reasonably well

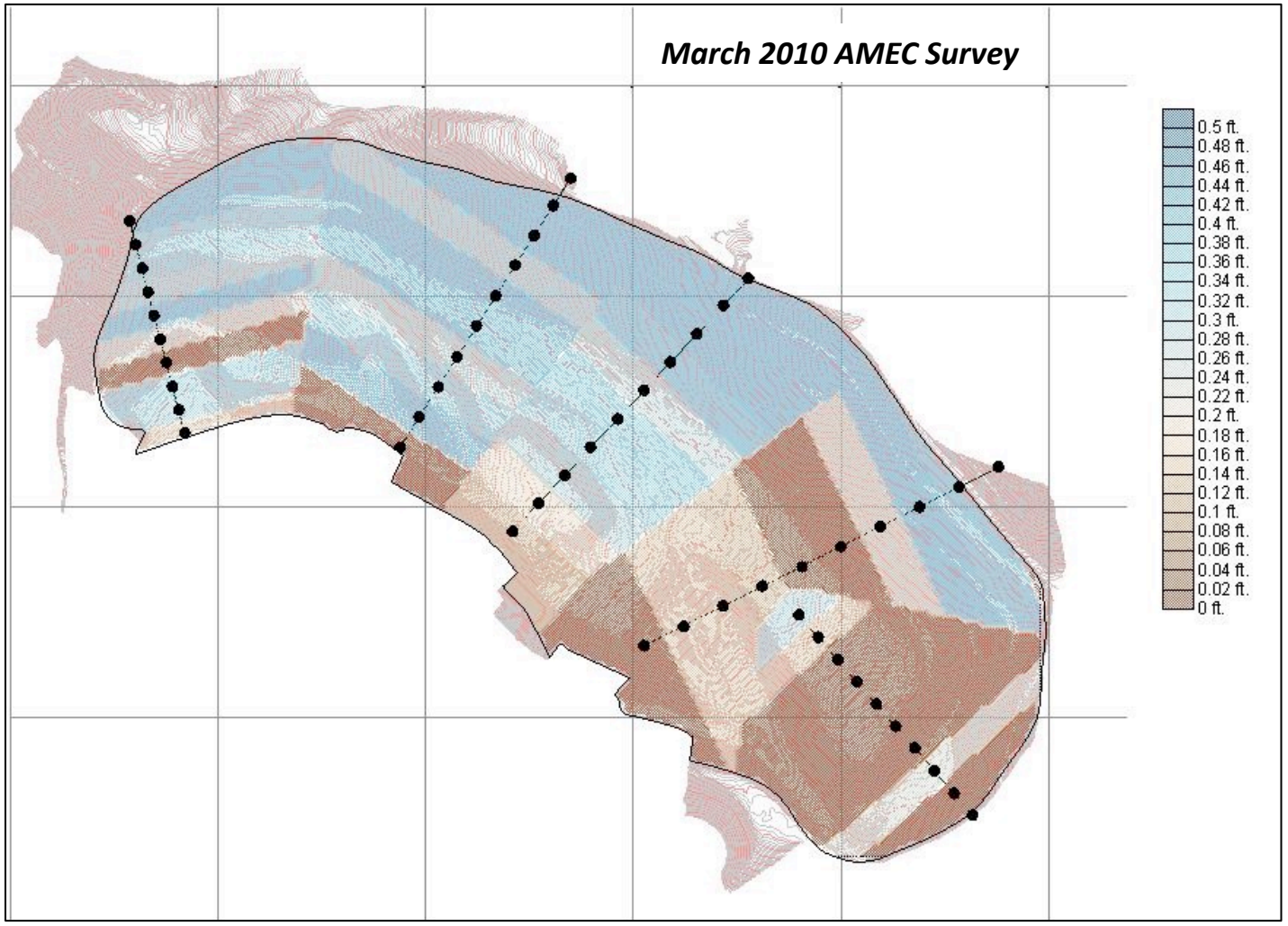
6. Synthetic Cover: Wind Rose

Typical Wind Rose in 4th Quarter Rain Mine



- Snow accumulation on northeast facing slope because snow drifting

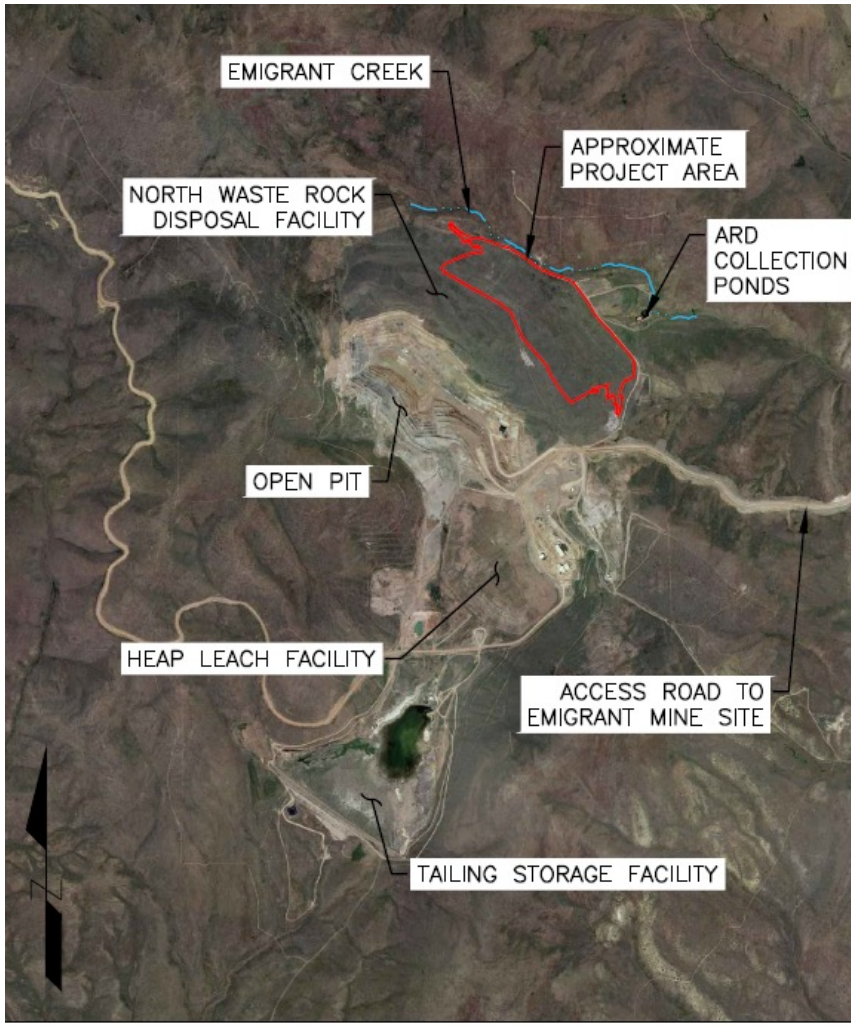
6. Synthetic Cover: Snow Surveys



- SMI (March 2001): Average snow depth 16.5 in (4.9 in SWE) with greatest snow accumulation found on **northeast facing slope** 59 in (26 in SWE)
- ASW (2009): No details. 2-3 ft of snow depth on the **northing face** and 0.01-2 ft on the south facing slopes and flat area
- AMEC (Jan, Feb, Mar, Apr 2010): The most detailed study. 5 transects with 10 locations along each transect. Greatest snow accumulation found on **northeast facing slope**

6. Synthetic Cover

- ~80 acres covered, representing a 43% of total facility footage
- New cover consisting of
  - Liner bedding
  - Plastic liner and geotextile (Super Gripnet®)
  - 2 ft Overliner Soil
  - 1 ft Topsoil



6. Sequence 1 - Removing & Stockpiling Existing ET Cover

6. Sequence 2 - Re-contour Slope & Construct Drainage Benches

6. Sequence 3 - Liner Bedding Preparation

6. Sequence 4 - HDPE & Geotextile Deployment

6. Sequence 5 - Placement of Soil Cover Over Geosynthetics

6. Drainage Channels

6. During Construction (June 30, 2022)

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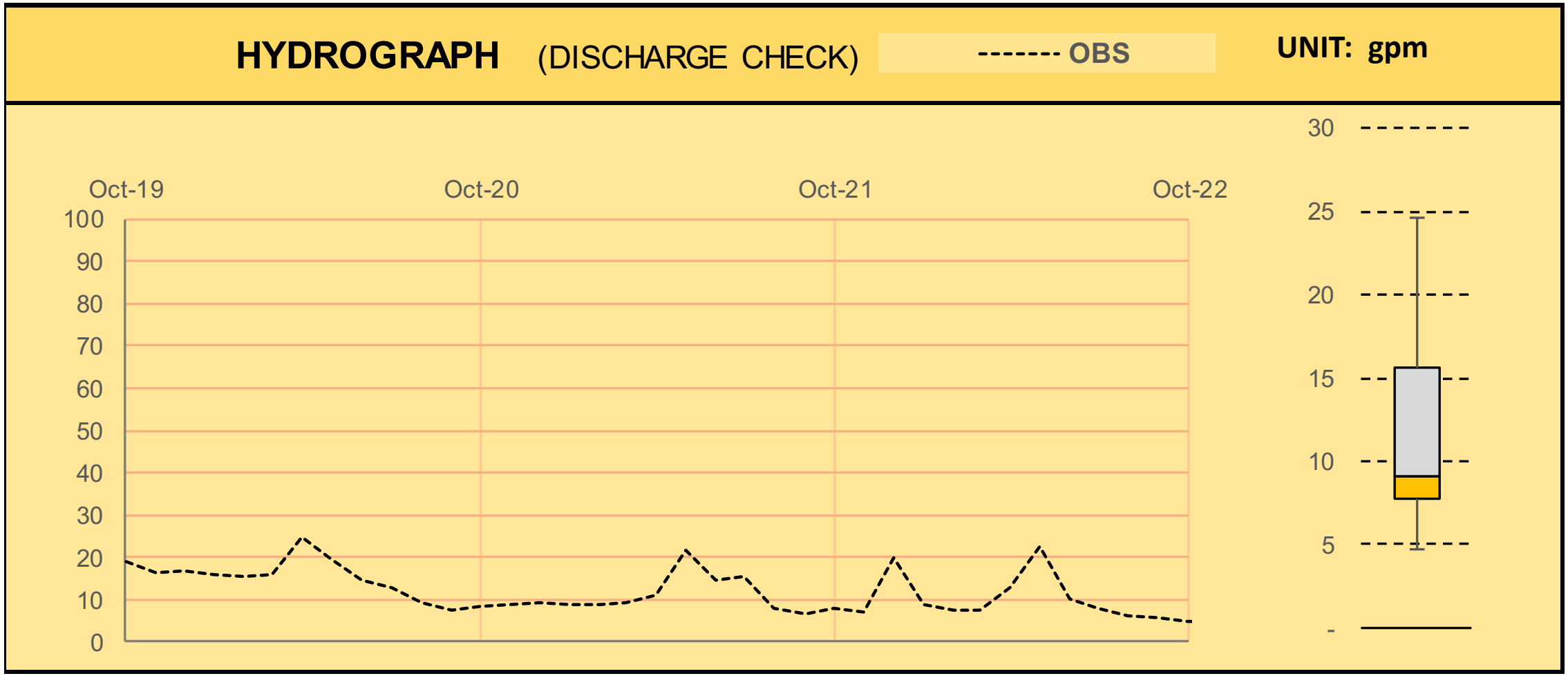
6. Post Construction (October 2022)

6. Initial Results: Only South Part Covered with the Synthetic Cover



7. Conclusions

- Annual precipitation at Rain is estimated at 17 in/yr
- Monthly seepage ranges from 10 gpm to 120 gpm. Peak monthly flows occur in April. The lowest monthly flows (baseflow) occur in February before snowmelt
- The seepage is reasonably modeled using the hydrological model
- Percolation through the ET cover is about 12% of precipitation, compared favorably with benchmarks
- Cover design driven by snowmelt hydrology – difficult to manage the water due to rapid infiltration
- Difficult to achieve very low percolation rates with earthen covers, therefore very low percolation rates require geosynthetics
- Because most seepage originates in the northeast slope face, the cover improvement focused on this area
- The enhanced synthetic cover costed ~ US$18M for ~ 80 acres, and initial results are encouraging
- It is expected that new cover could reduce percolation rate to ~ 10 gpm level, potentially suitable for passive treatment