2023 Fall Conference at Ashore Resort & Beach Club
Ocean City, Maryland

Sensored Evaluation of Permeable Pavement Performance: 2 Year Case Study Results

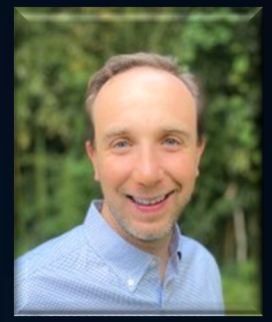
Dr. Aaron Fisher PhD

September 29, 2023

BIOGRAPHY

- Dr. Aaron Fisher
  - PhD in Chemical Engineering from the University of Maryland
  - B.S. in Chemistry from Duke University

  - Vice President of Business Development for Ernest Maier
  - U.S. Department of Energy (contractor); Water Research Foundation; GlaxoSmithKline
  - Focused on sustainability and innovation around water, energy, manufacturing, and construction



ABSTRACT

Sensored Evaluation of Permeable Pavement Performance: 2 Year Case Study Results

- What is a Permeable Articulating Concrete Block permeable pavement?
- How does this system differ from other permeable pavement options?
- How can this system address stormwater challenges within the right-of-way?
- Construction Process in Colmar Manor
- Performance of the system over 2 years in Colmar Manor, MD

- 1.0 PDH

Permeable Articulating Concrete Blocks: Designed to Work with Water

- Matrix of interconnected concrete block units
- Form a Hard, yet Pervious Surface via Open Joints

City of Goshen, Indiana – Jefferson Street

P-ACB and Pavers: Differences

	P-ACB	Pavers
Governing ASTM Standard	D6684	C936
Joints	Open	Filled
Interlocked	Yes	Sometimes
Bedding	57 Stone	89 Stone
Geofabrics	Required	Optional

Permeable Surface Infiltration Rate Comparison

1,640 in/hr

Open Joints = High Infiltration Rates

Table 1: Summary of Infiltration Rates Tested of Various Surfaces

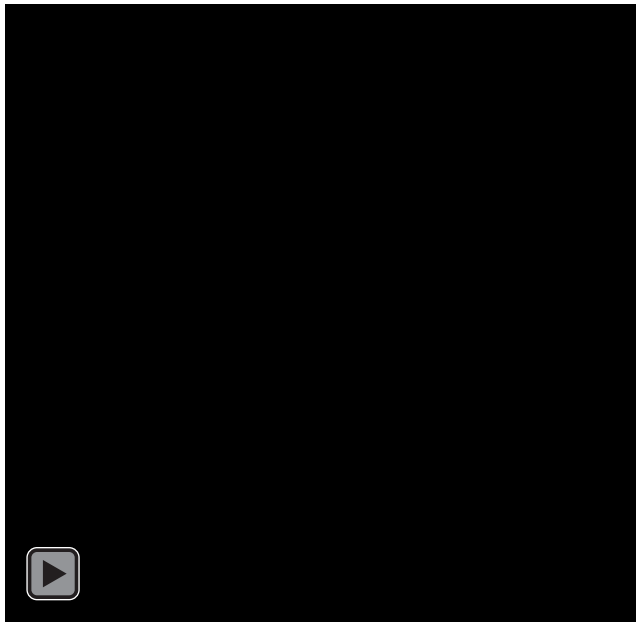
Surface Material	Infiltration rate (in/hr)	Mass of infiltrated water (lb)	Diameter of infiltration ring (in)	Time (sec)
P-ACB	1,640	40.0	12.187	19.53/18.42/24.53
Porous pavers	3.2	2.54	12.187	683
Porous concrete	2.4	3.80	12.187	1,380
Porous asphalt	3.1	5.58	12.187	1,515

ASTM C1701/C1781: Standard Test Methods Infiltration Rates of In-Place Pervious Concrete

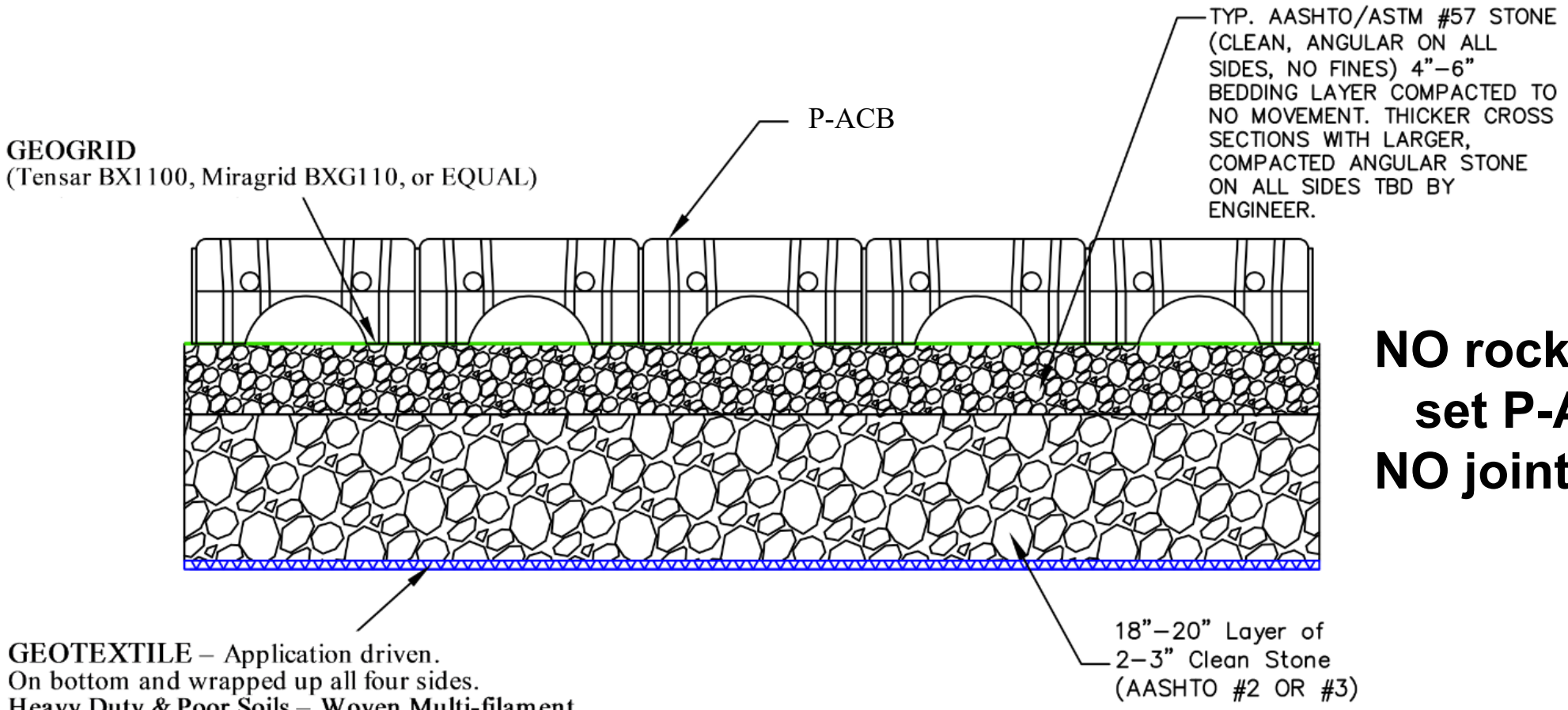
Permeable Roadway Options with ACBs

Baltimore City

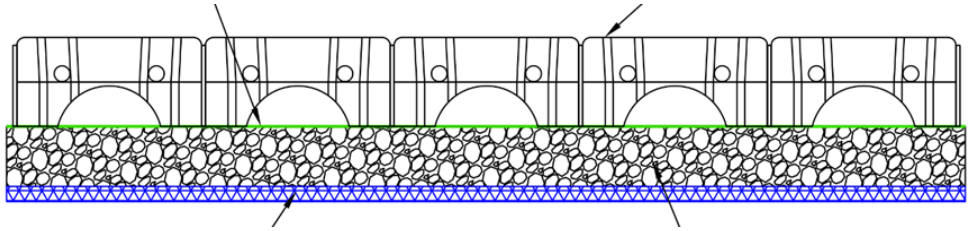
+5 years



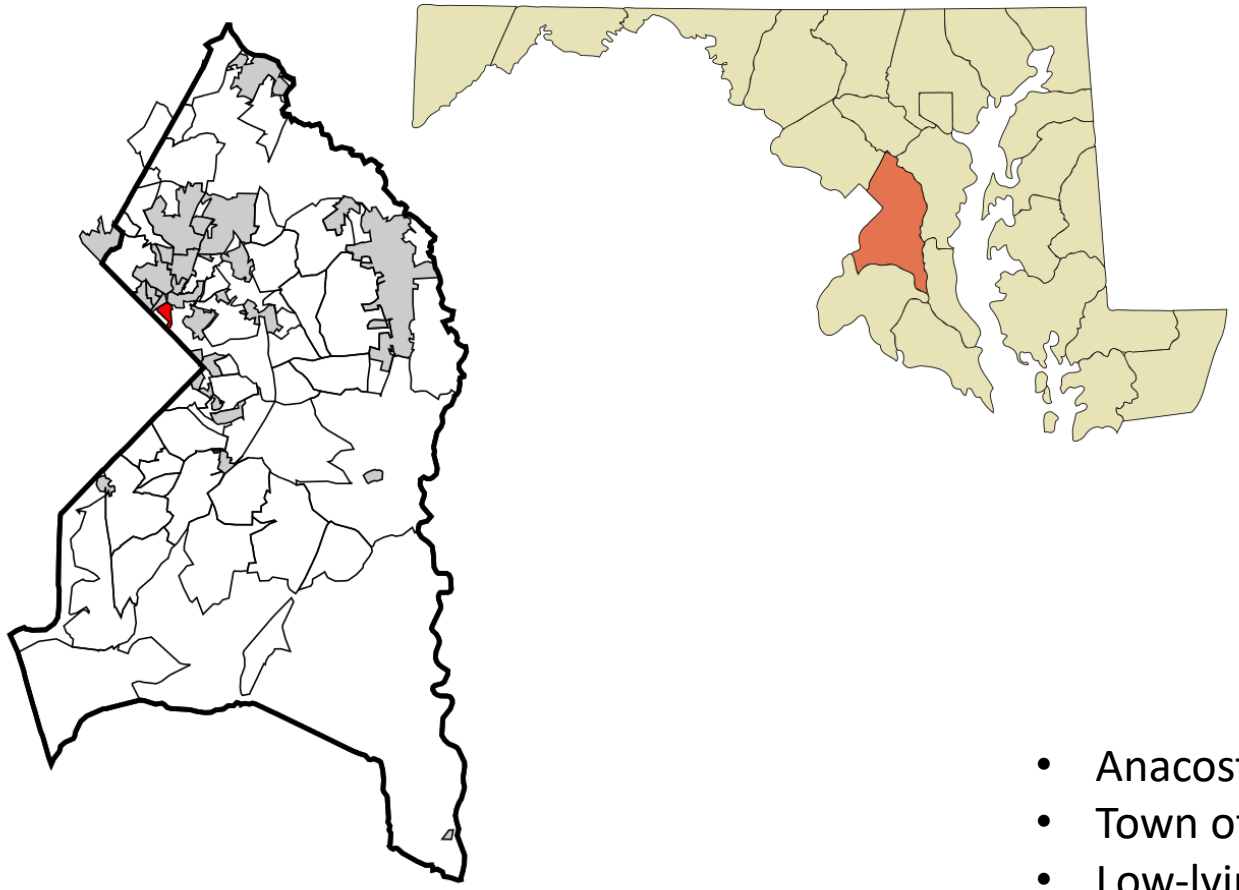
Typical P-ACB Cross-Section(s)



NO rock chips to set P-ACB on NO joint material

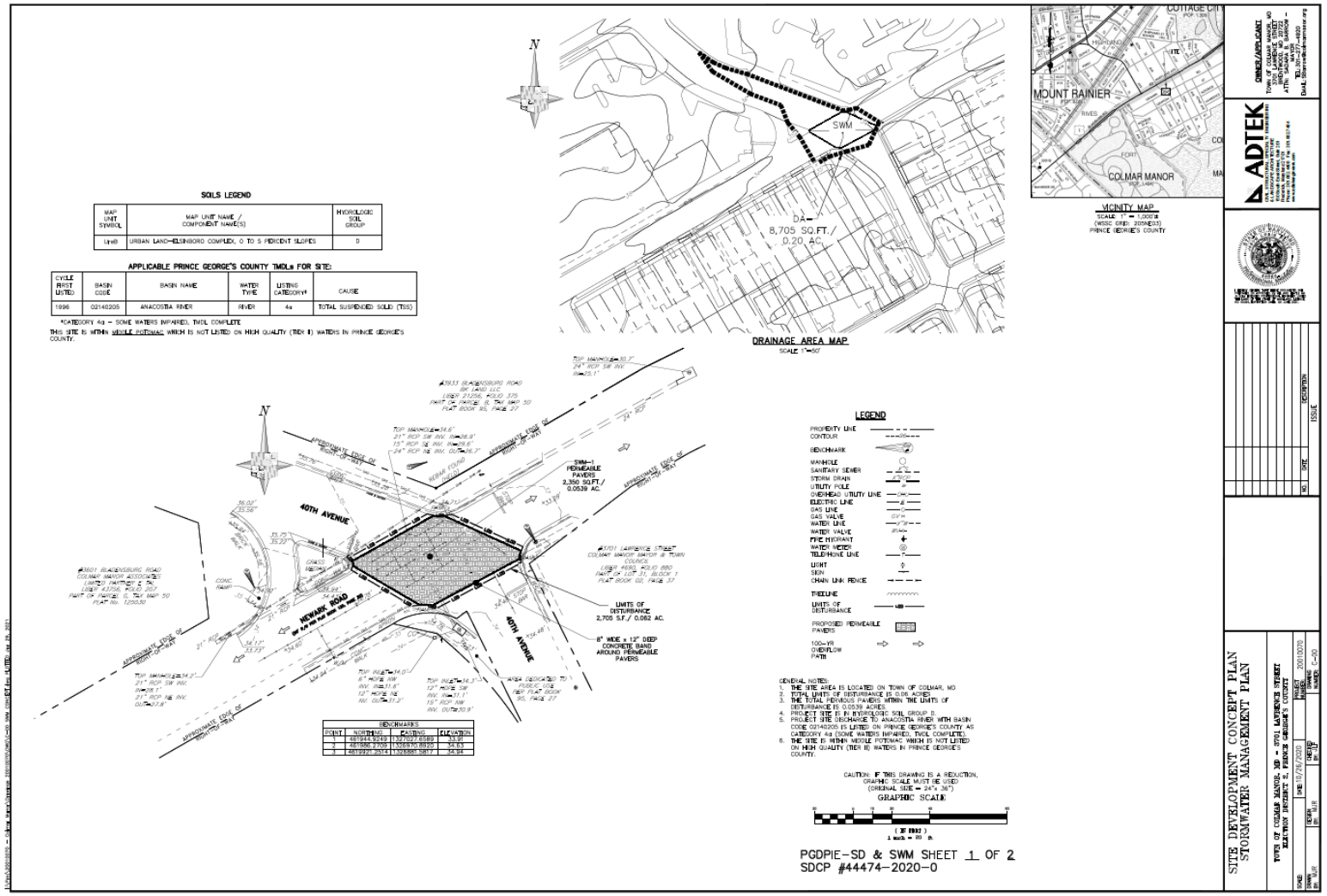


About Colmar Manor



- Anacostia River's Historic Port Towns
- Town of 1500
- Low-lying, highly urbanized; Low-income community
- Challenged by poor drainage and pluvial flooding

Colmar Manor, MD



Owner: Town of Colmar Manor, MD
Engineer: Adtek Engineering
Manufacturer & Distributor: Ernest Maier
Sensor: P4 Infrastructure-INFIL-Tracker
Installation Contractor: Capitol Hardscapes
Application: Roadway Intersection
PaveDrain Quantity: 2,350 Square Feet
Cost of System: $107,000 (including design and construction)

Courtesy: Adtek Engineering

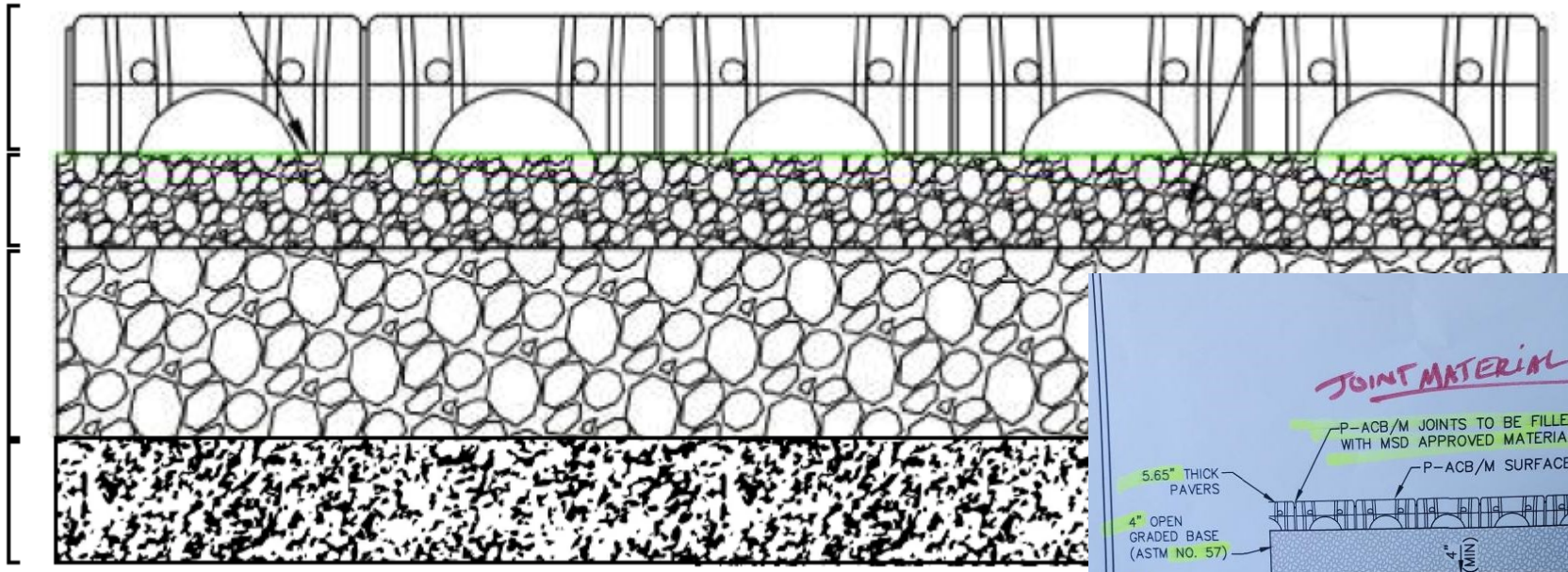
Colmar Manor Cross Section

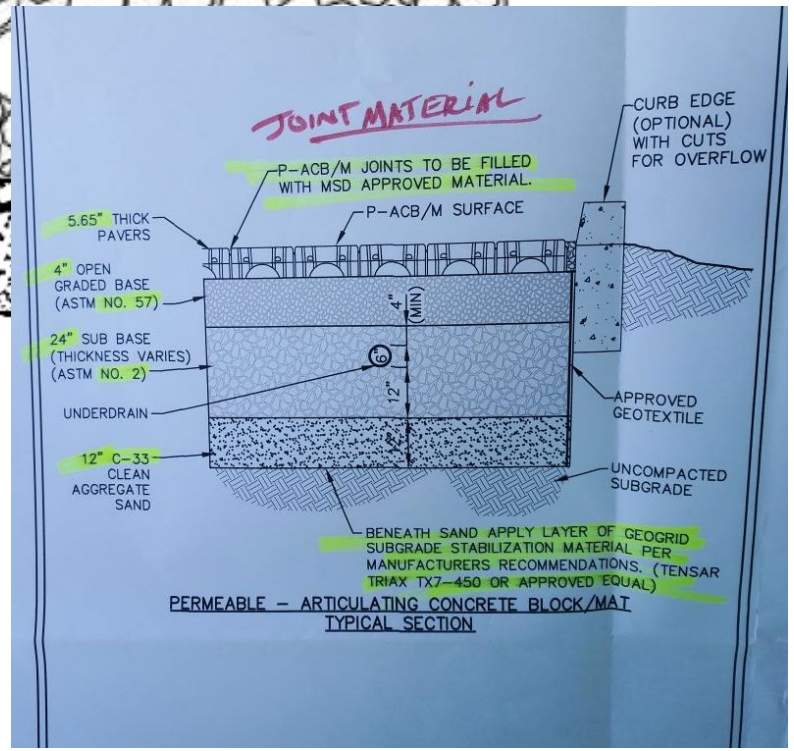
5.65" Thick Blocks

4" Open Graded Base (No. 57)

24" Sub Base (No. 2)

12" Sand



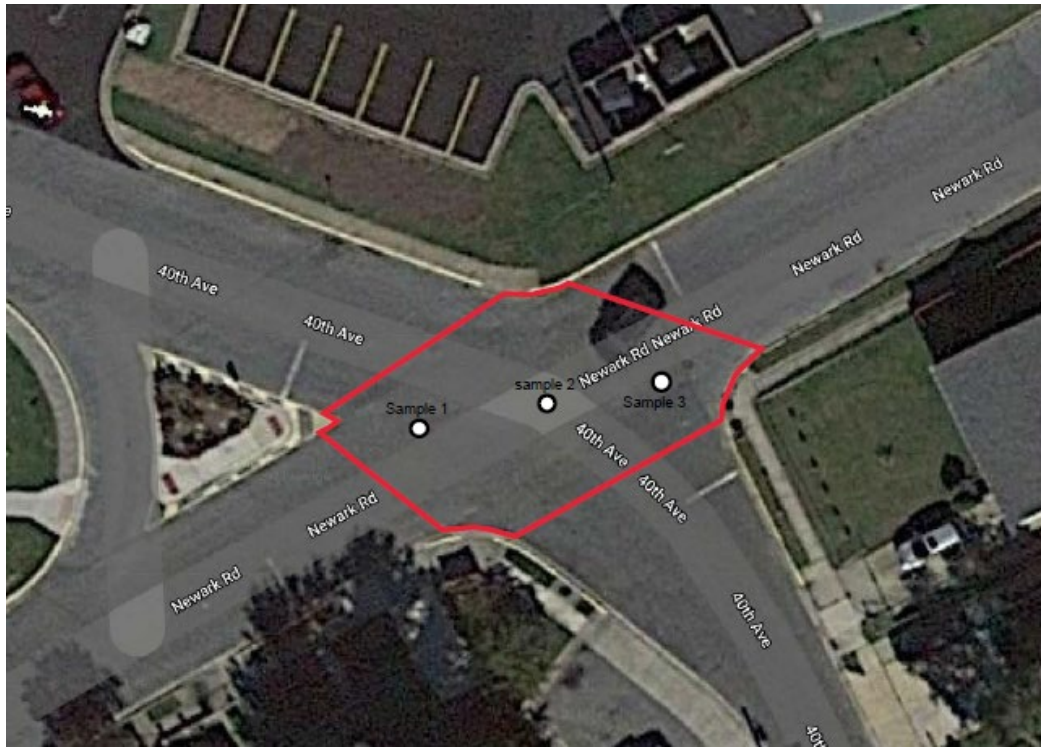


Courtesy: Adtek Engineering

Base Installation

Soil

Sample	Depth [ft]	%Gravel	%Sand	%Silt	%Clay	Classification	USDA	K
1	1.5	0	14.6	54.6	30.8	Gray Silt	Silty Clay Loam	0.26 in/hr
2	2	0.2	86.7	7.2	5.9	Brown Silty Sand	Loamy Sand	3.85 in/hr
3	1	0	11.1	49.4	39.5	Gray Lean Clay	Silty Clay	0.18 in/hr



The mean saturated hydraulic conductivity of the 3 soils types is 1.43 in/hr and the geometric mean is 0.56 in/hr.

Placing the PaveDrain

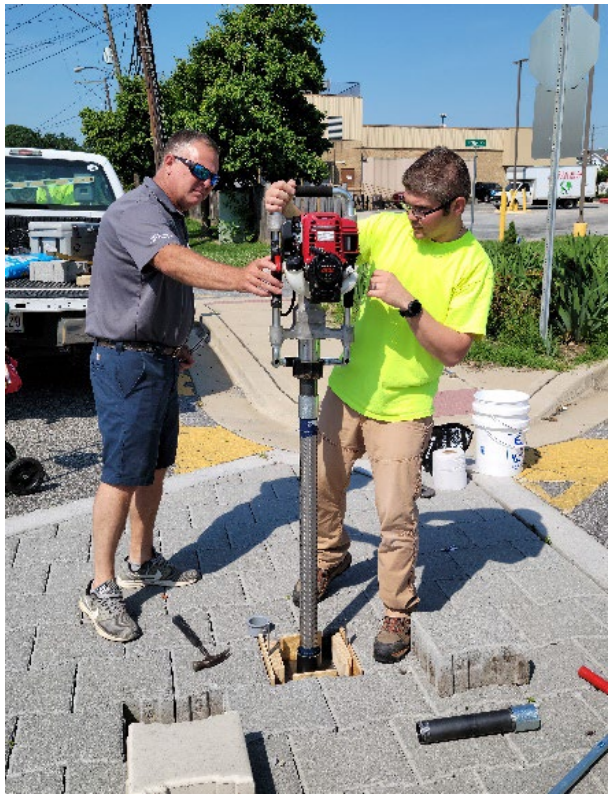
Town of Colmar Manor

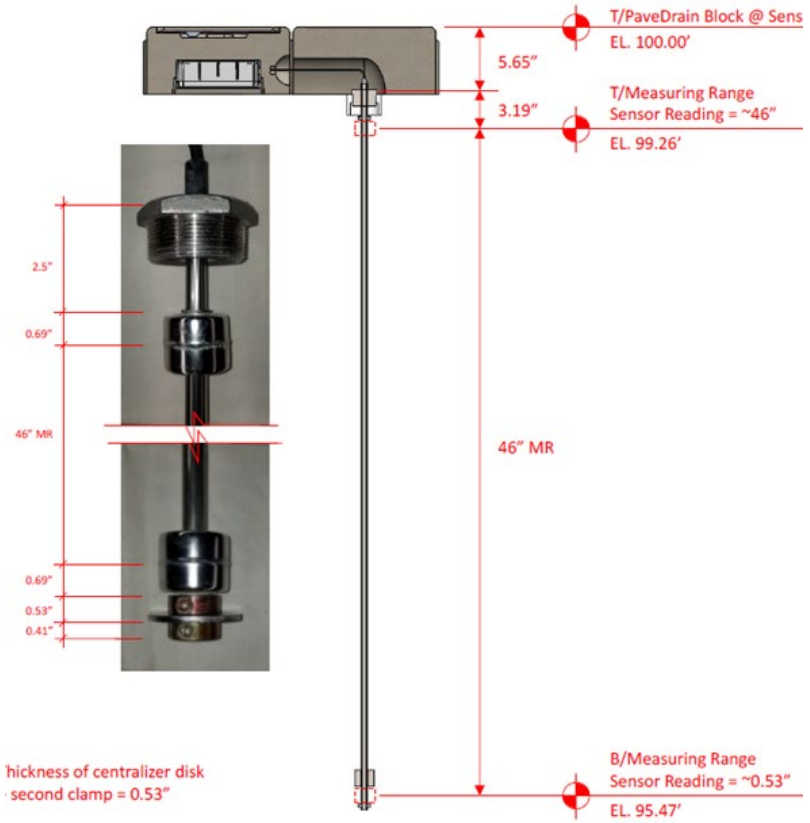
Beyond Day 0

+12 Months / 0 Cleanings / April 2022

+16 Months / 0 Cleanings / August 2022

INFIL Tracker Installation

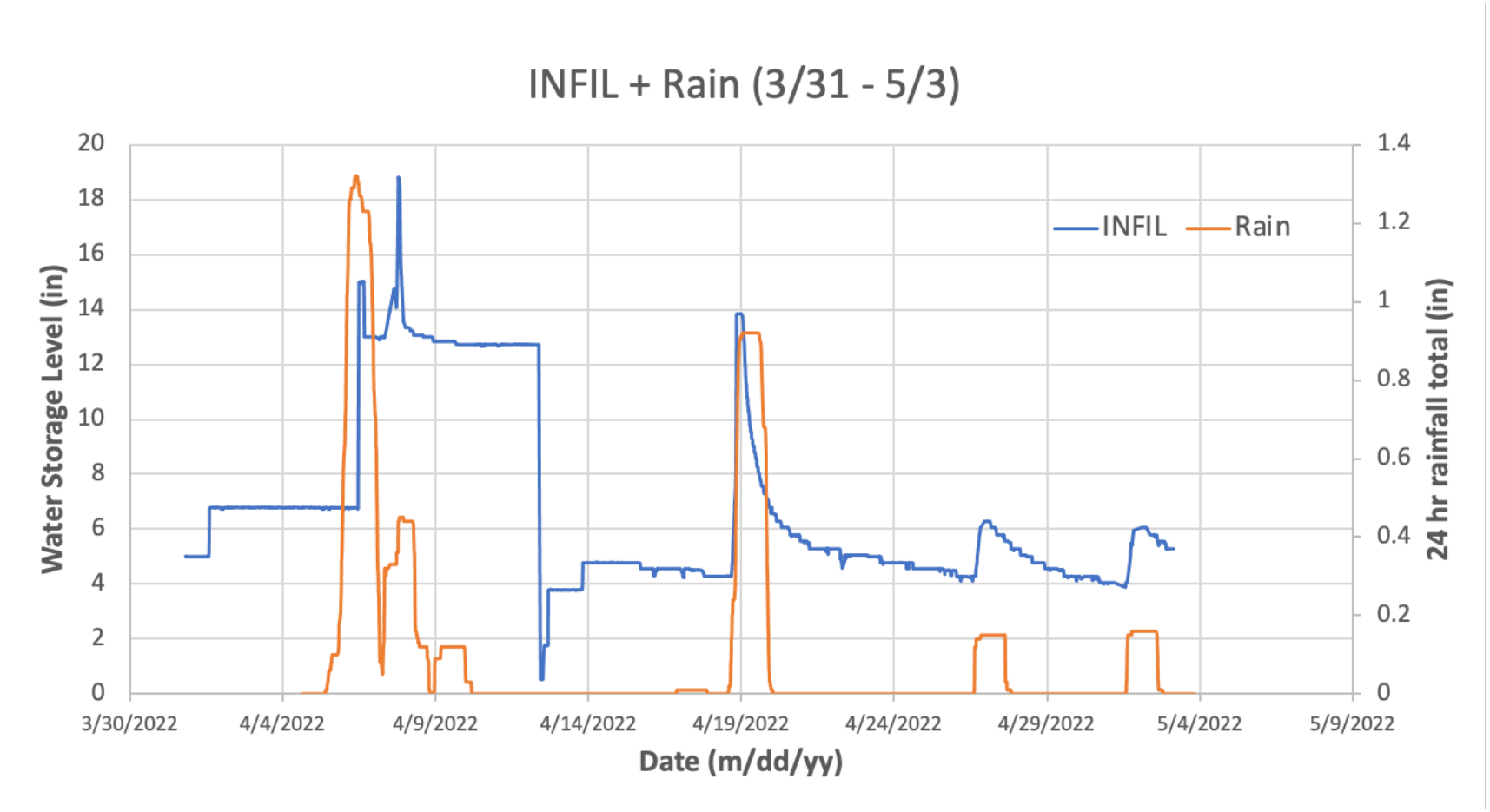




INFIL-Tracker Installation

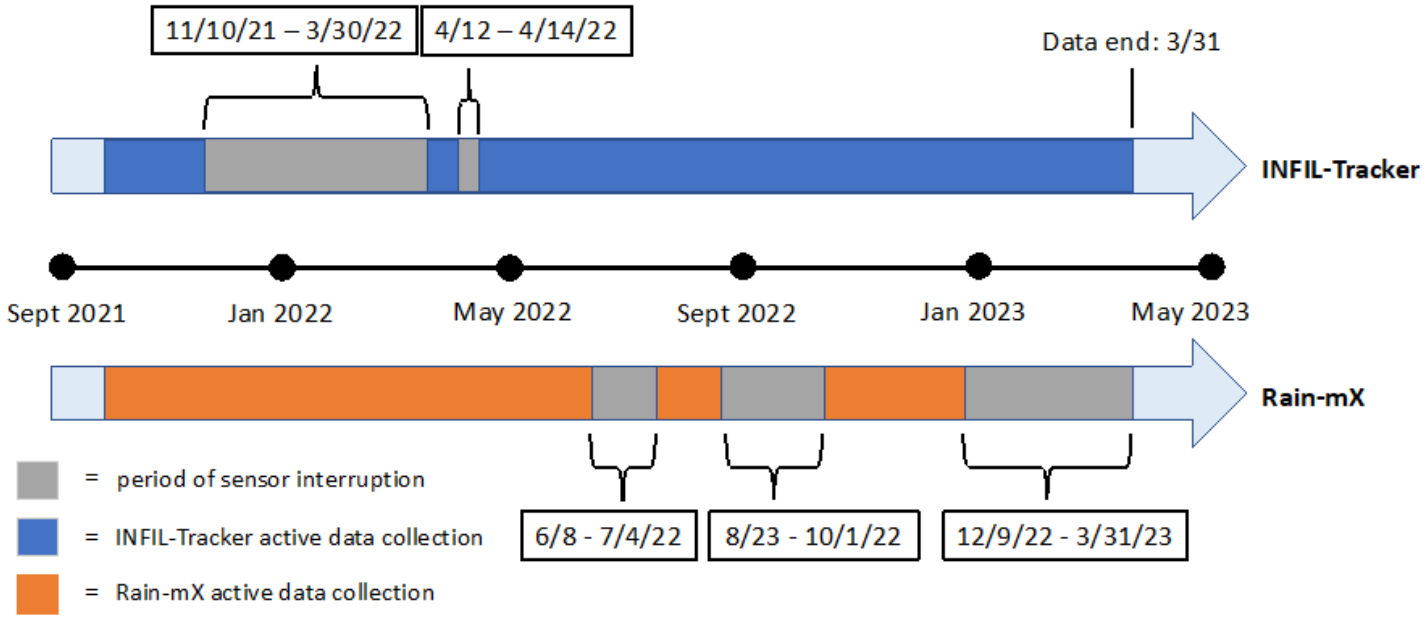
Example Data

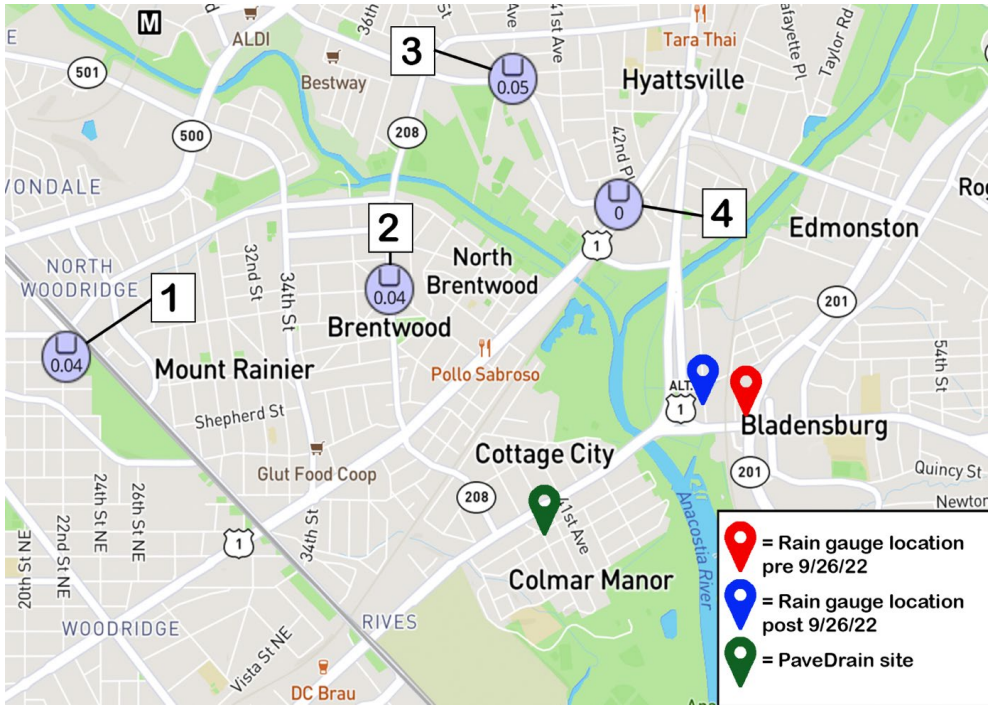
What does the raw sensor data look like?



Rainfall Gauges

50 Storm Events in 2 Years

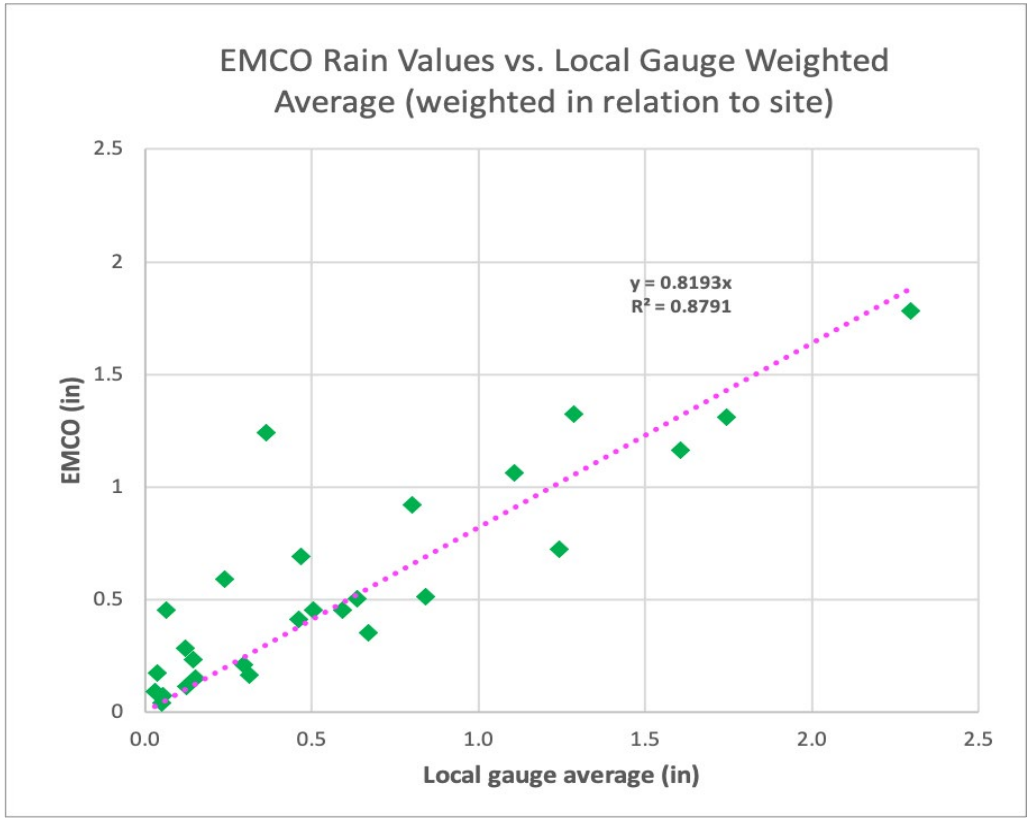




Over the course of the study, the largest 24-hr rain total measured 2.41 in, which corresponds to a return period of less than 1 year

Rain Gauge Verification

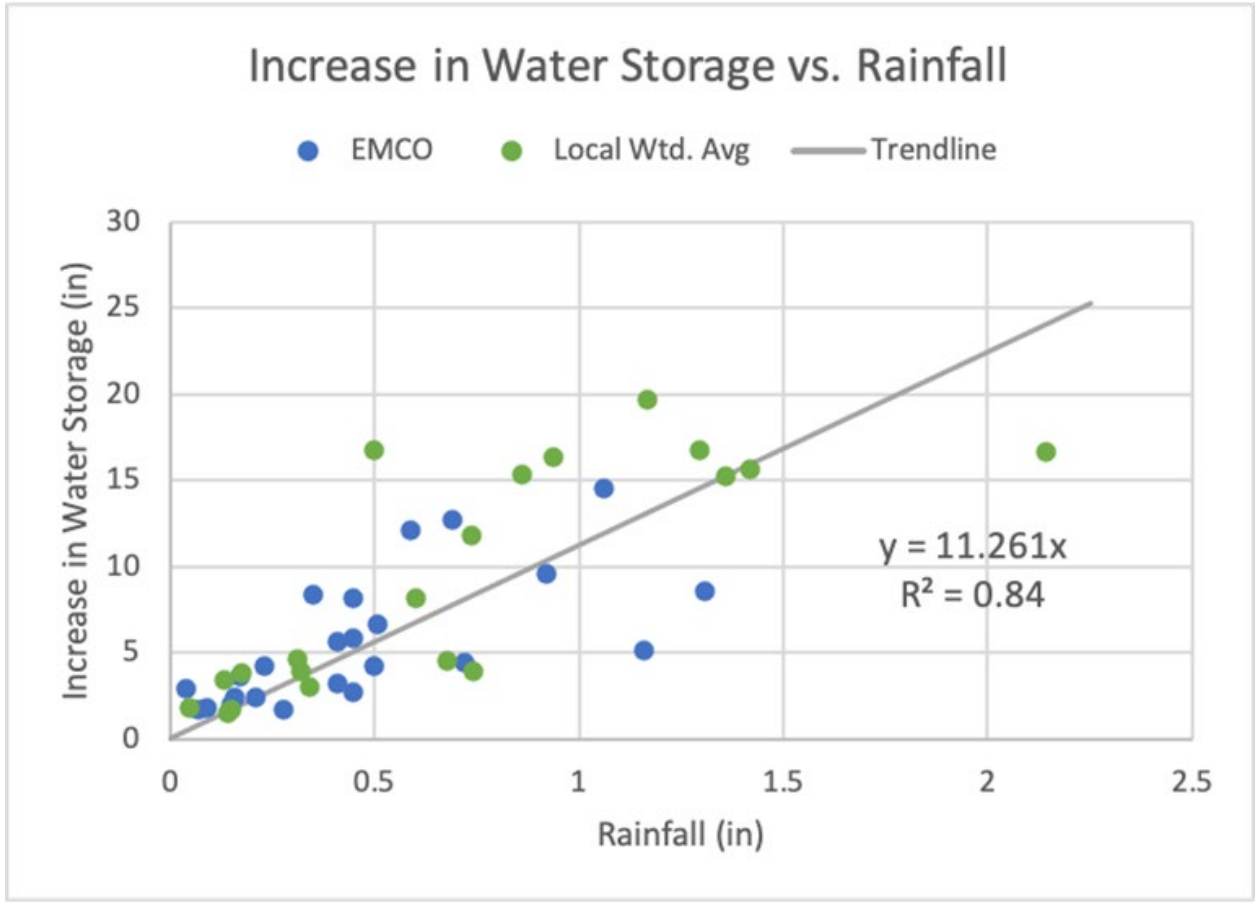
How do we interpolate our local rain gauge with those slightly further?



Scatter plot comparing EMCO rain values to distance-weighted average of 4 local rain stations

Water Balance

Correlating signal height to volume



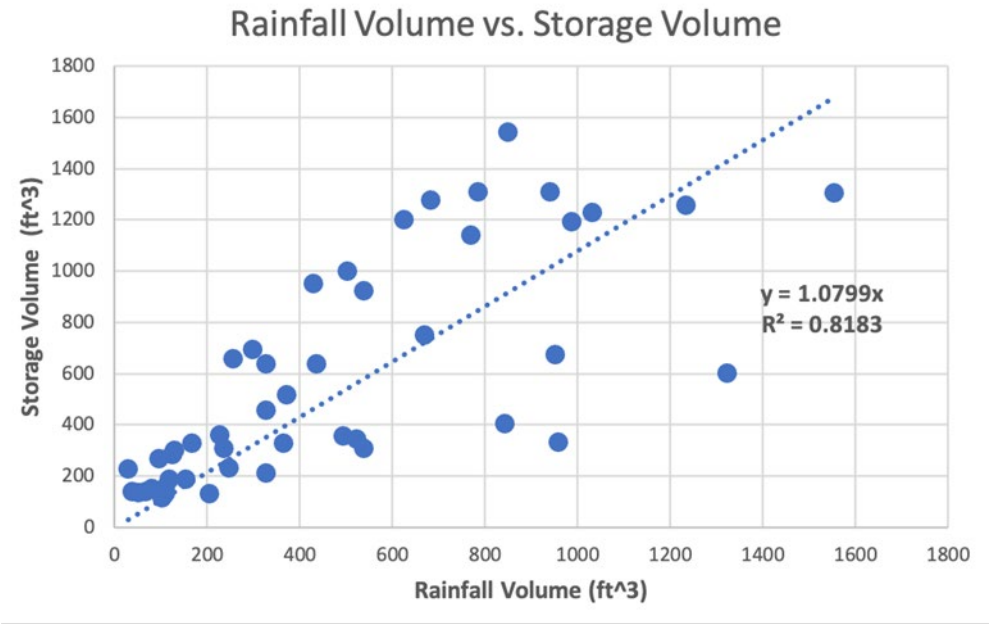
Plot of correlation between rainfall and increase in water storage

The total storage volume at the site is approximately 3630 ft^3 based on the available depth, area of 2350 ft^3 and a porosity of 0.4.

Rainfall Volume vs Storage Volume

What is the run-on ratio?

$$Run - on\ ratio\ = \frac{A_{ro}}{A_p}$$



Volumetric water balance of water entering pavement system through rainfall and water draining from storage per storm event.

The slope is 783 ft^3/in or 9400 ft^2, equal to total drainage area A_d. With the pavement area, A_p, equal to 2350 ft^2, the run-on area is calculated as 7050 ft^2 and the run-on ratio is 3.00. This value is 10.9% greater than the 6355 ft^2 of run-on area estimated during the facility design

Static Storage

What size storm could it handle (without exfiltration)?

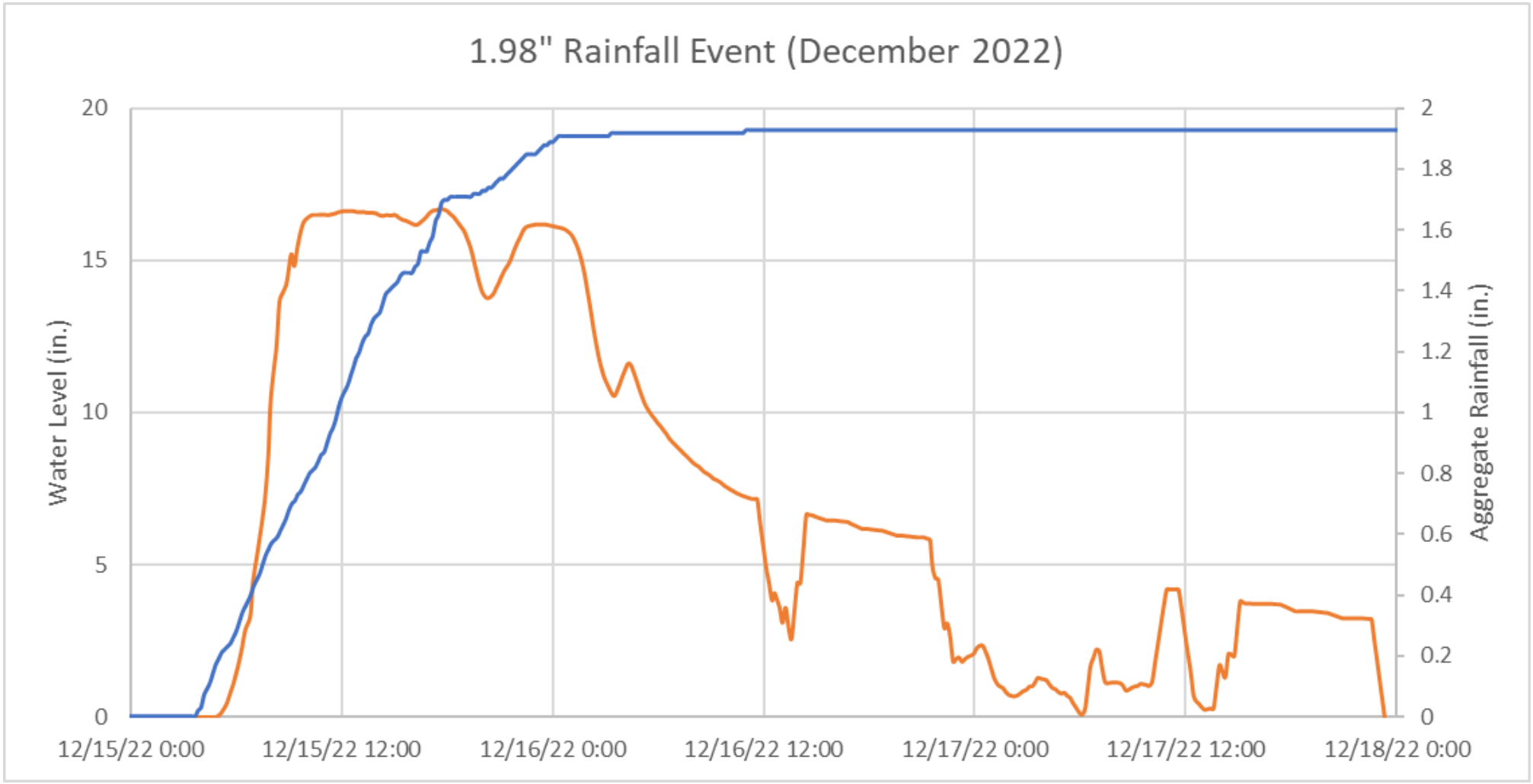
Estimated return periods (NOAA Atlas 14) for rainfall events exceeding 4.11 inches of rainfall over the entire drainage area at Colmar Manor, MD. The 90-percentile rainfall value is used to account for climate change.

Rainfall Duration (hrs)	Approximate Return Period for 4.11 in. Rainfall (yrs)
24	3.8
12	6.5
6	18
3	50
2	86
1	360

Return period is equal to the *average* time interval in which an event of this magnitude will occur. That is, a 3.8-year return period corresponds to an event that is expected, on average, to occur once every 3.8 years.

Exfiltration from the Stone Base

How quickly is the water leaving?



Soil Infiltration Rates

What is the real soil infiltration rate?

Linear and Exponential Infiltration Rates (in/hr)					
	Range	**Mean**	**Median**	**25th percentile**	**75th percentile**
Linear					
1-hr rates	0.12 - 5.34	1.04	0.50	0.23	1.57
2-hr rates	0.10 - 5.05	1.21	0.53	0.20	1.99
4-hr rates	0.08 - 3.00	0.89	0.78	0.18	1.08
Exponential					
1-hr rates	0.12 - 3.70	0.99	0.66	0.34	1.11
2-hr rates	0.10 - 3.89	1.13	0.59	0.34	1.78
4-hr rates	0.10 - 2.35	0.92	0.58	0.33	1.45

The observed mean 1-hr exponential infiltration rate of 0.99 in/hr is 0.44 in/hr less than the mean and 0.33 in/hr greater than the geomean.

"Though the subsurface soil was classified based on the lowest hydrologic group (D for soil at the PaveDrain site), it is recommended that for stormwater BMP site selection that soil borings are analyzed to reflect the infiltration potentials for all types of soils found on site."

Dynamic Storage

(Filling a Bucket with a Hole)

What size storm could it handle?

Rainfall Duration (hrs)	Exfiltration (in)	Total Rainfall Depth Managed (in)	Approximate Return Period (yr)
24	1.39	5.50	11.4
12	0.70	4.81	12.8
6	0.35	4.46	25
3	0.17	4.28	65
2	0.12	4.23	100
1	0.06	4.17	390

Estimated return periods (NOAA Atlas 14) for rainfall events exceeding 4.11 inches of rainfall over the entire drainage area with exfiltration at Colmar Manor, MD. The 90-percentile rainfall value is used to account for climate change.

Pollutant Load Reduction

What is the environmental value of the system?

Annual Value of Nutrients Removal by the PaveDrain System				
	5.3.0		5.3.2	
Total Nitrogen	2.33 lbs	$3,646	3.28 lbs	$5,141
Total Phosphorus	0.44 lbs	$4,241	0.36 lbs	$3,470
Total Sediment	0.10 tons	$9,555	0.09 tons	$8,600
Total		**$17,442**		**$12,481**

Payback: 6.13 years – 8.57 years

Total: $107,000. Chesapeake Annual Pollutant Loads for Urban Impervious Surfaces Versions 5.3.0 and 5.3.2

BEST ULTRA-URBAN BMP FINALIST

- 2 years worth of storms; Never more than 50% full
- Biggest 1-day storm handled: 2.41 in. (August 5, 2022)
- Ability to handle 5.50 in/day (1 in 11.4 years; 90-percentile value)
- No maintenance

QUESTIONS?

Contact:

- Dr. Aaron Fisher

  Ernest Maier Inc / PaveDrain

  Phone: 202-510-5545

  E-mail: afisher@emcoblock.com

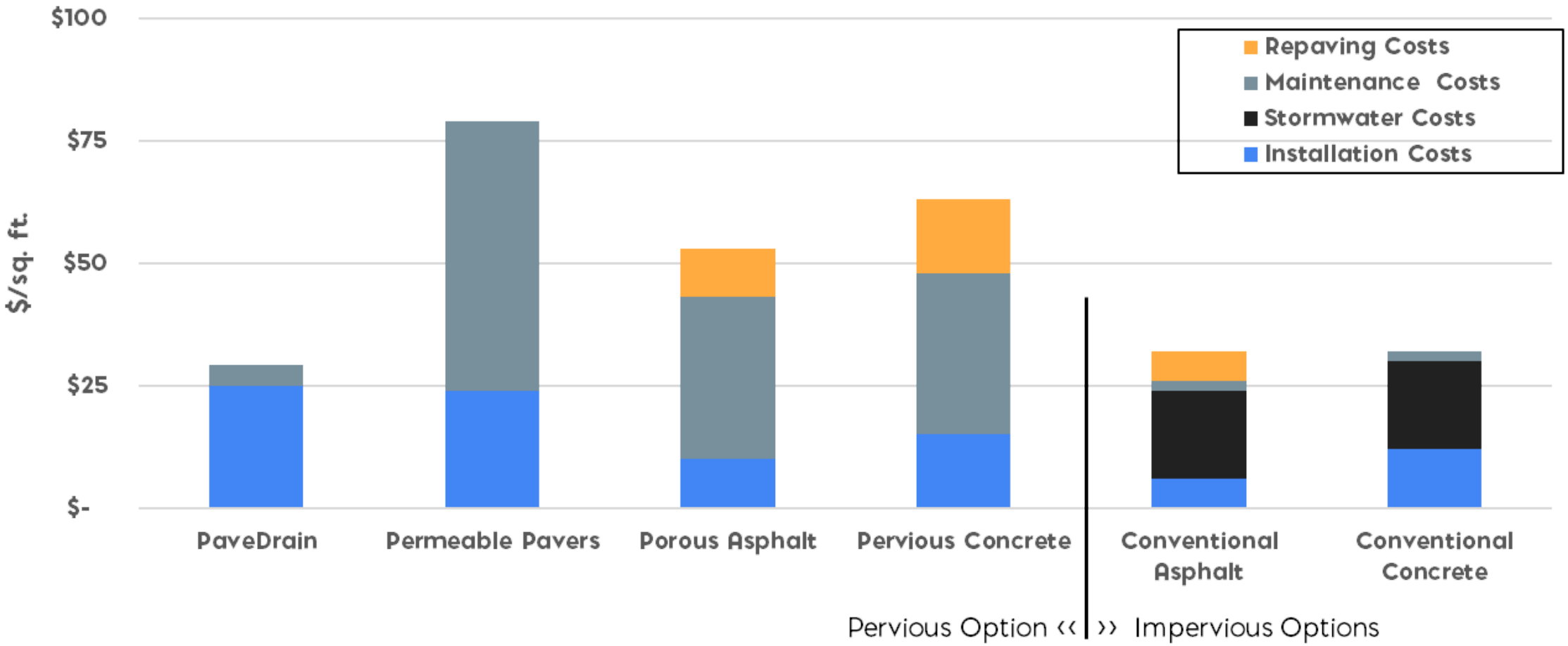
Manufacturer Warranty

- **3 years-**500 in/hr (w/ maintenance)
- 6 years-8 in/hr (w/o maintenance)

- Restrictions
  - Proper installation
  - Voided if loose aggregate stored on surface (sand, stone, soil, mulch, etc)
  - Other terms as specified

PAVE DRAIN®
STORMWATER'S ARCH ENEMY

Total Costs @ 10 Years



Thank You

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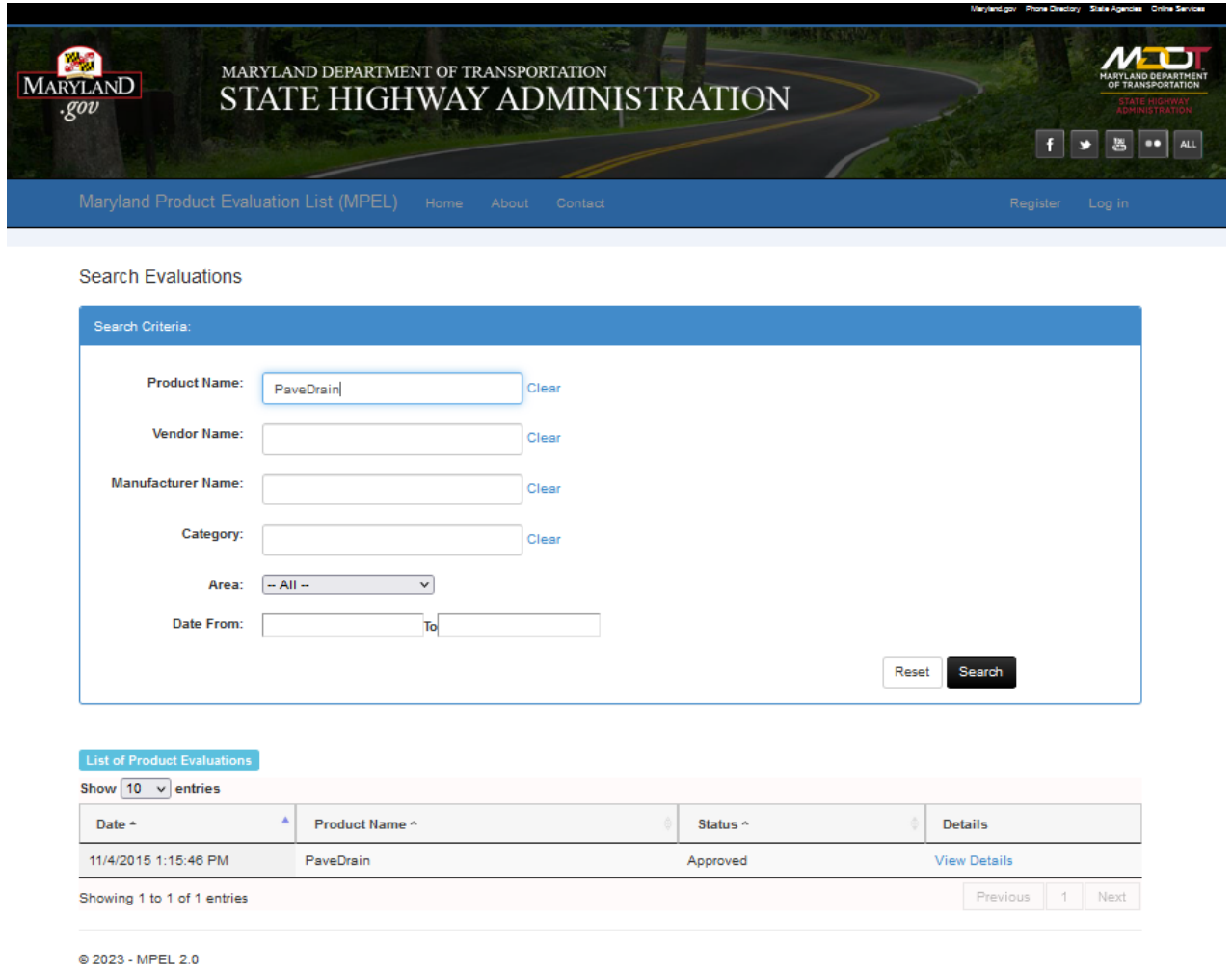
ERNEST MAIER

PAVE DRAIN
STORMWATER'S ARCH ENEMY

Approvals

- MDOT since 2015
- DOT
  - Florida
  - Georgia
  - Indiana
  - Maryland
  - Wisconsin
- MDE since 2012 and most MD counties



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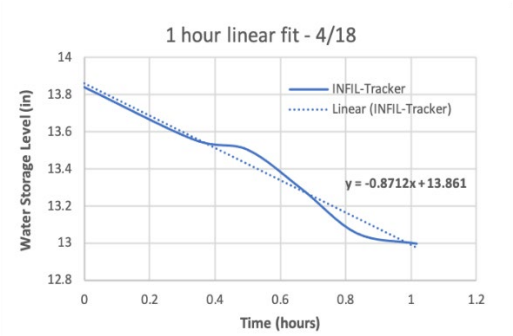

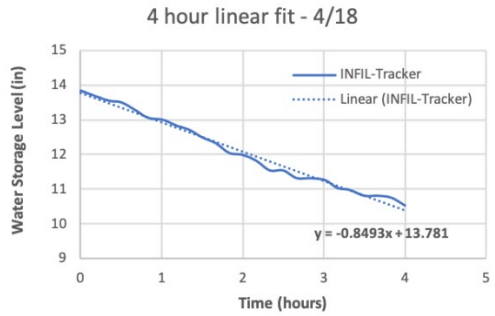

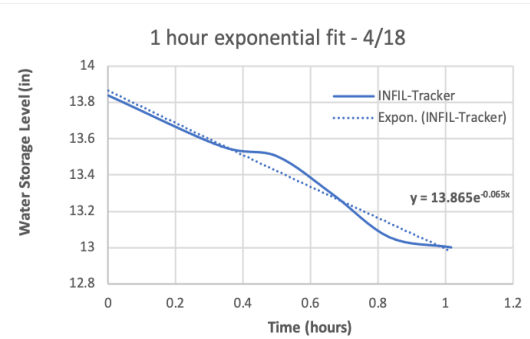

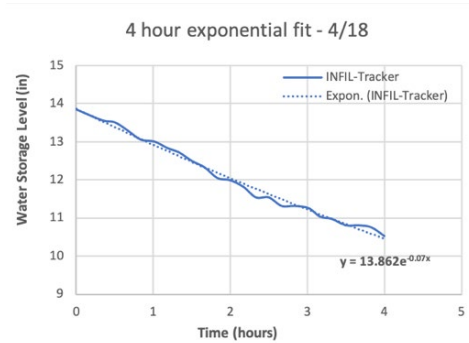

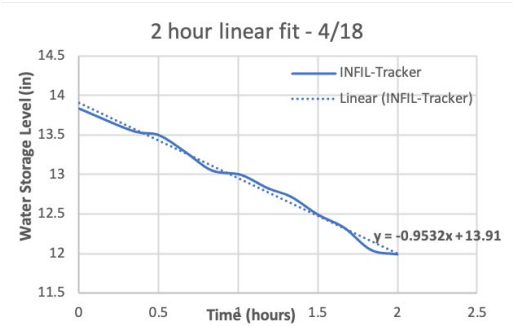

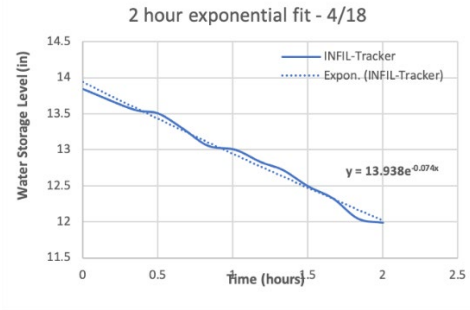

The highest recorded water storage level across all storm events was 23.33 inches on 9/21/21 during a rain event of magnitude of 1.32 inches (24-hr total).

Other P-ACB Benefits

- Never have to replace joint filler (sand/stone dust)
- High void space avoids freeze-thaw and frost heaving challenges
- Can seal after installation to prevent salt damage
- Able to function in high water levels (e.g., sunny day flooding)
- Long lifetime of concrete (40 years)
- Single person can replace an ACB unit with a block extractor
- Increases resiliency of traditional paving surfaces