Long-term Infiltration Capacity of Different Types of Permeable Pavements

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(image credit: www.icpi.org)

Permeable Pavements

- Alternative paving surfaces for stormwater runoff management
- Barrier to wider adoption: uncertainty over their long-term performance

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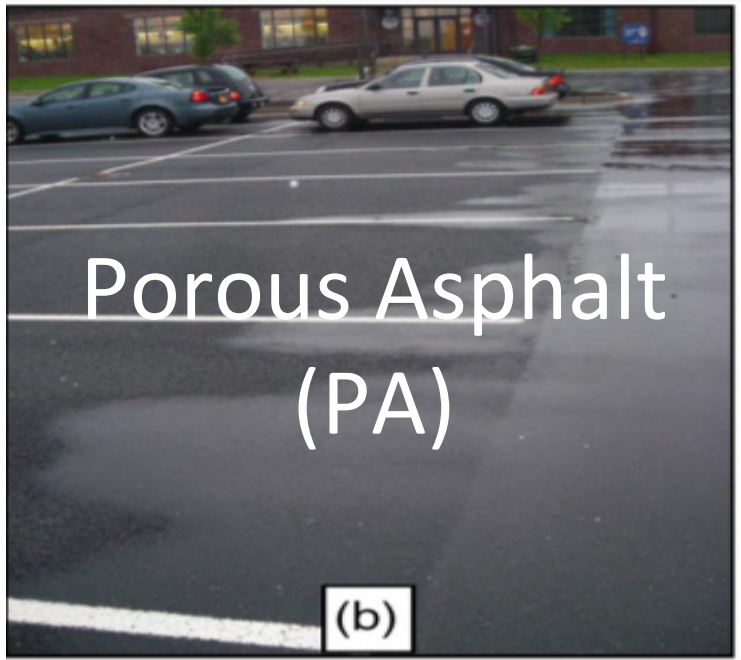
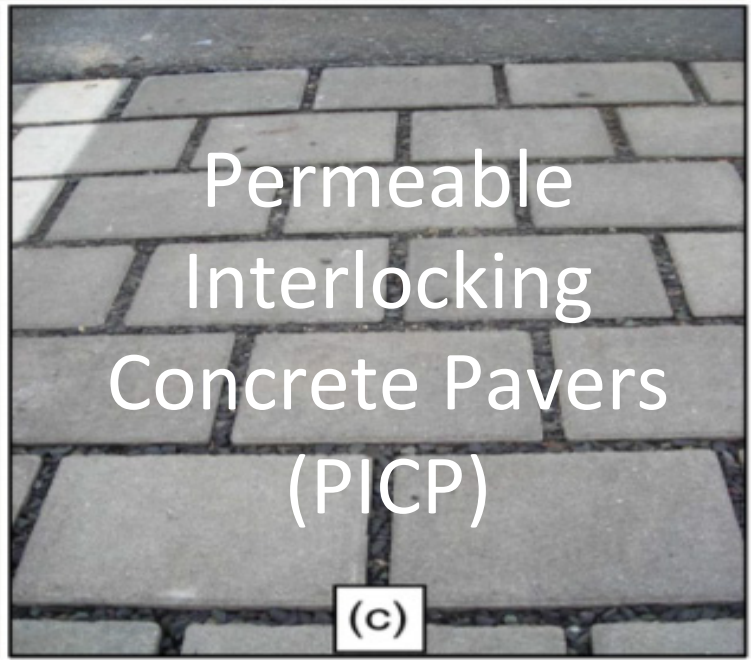
Permeable Pavement at EPA Edison Environmental Center (EEC)

- Robert A. Brow and Michael Borst study (2009 -2012)

- Present study (2014-2016)

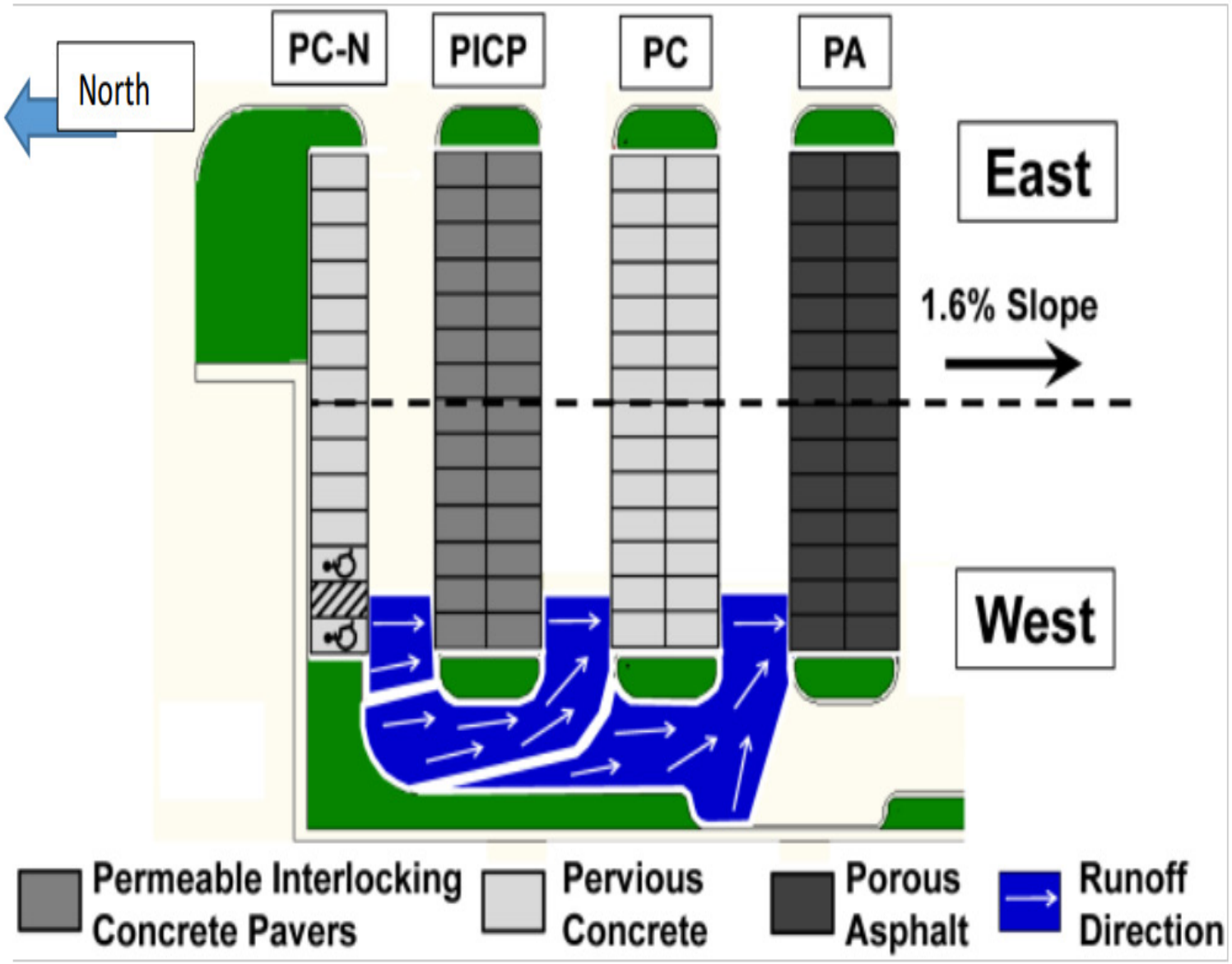
(Images by Brown and Borst)





Site Description

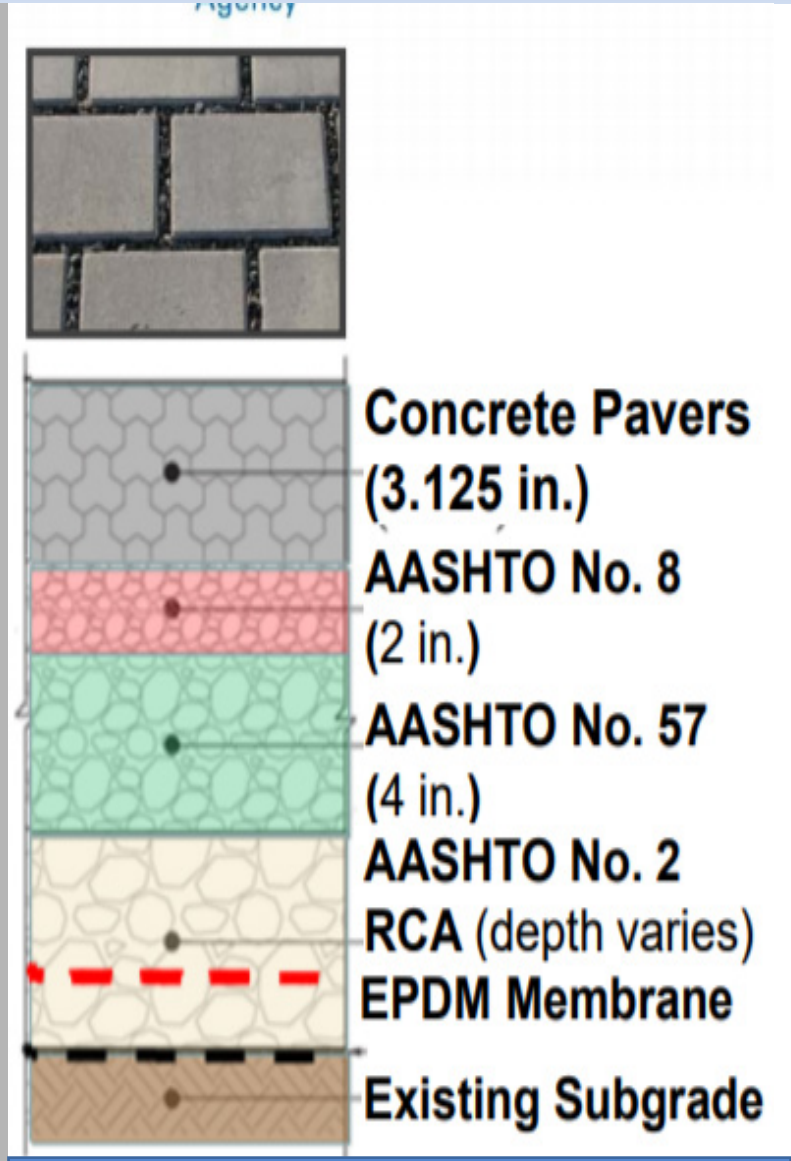
- 1-acre Parking Lot
- Parking lot was constructed in 2009
- Each double-parking row measures 494 square meter
- Driving lanes between the parking rows are surfaced with conventional hot-mix asphalt



(Image by Brown and Borst)

Permeable Interlocking Concrete Pavers (PICP)

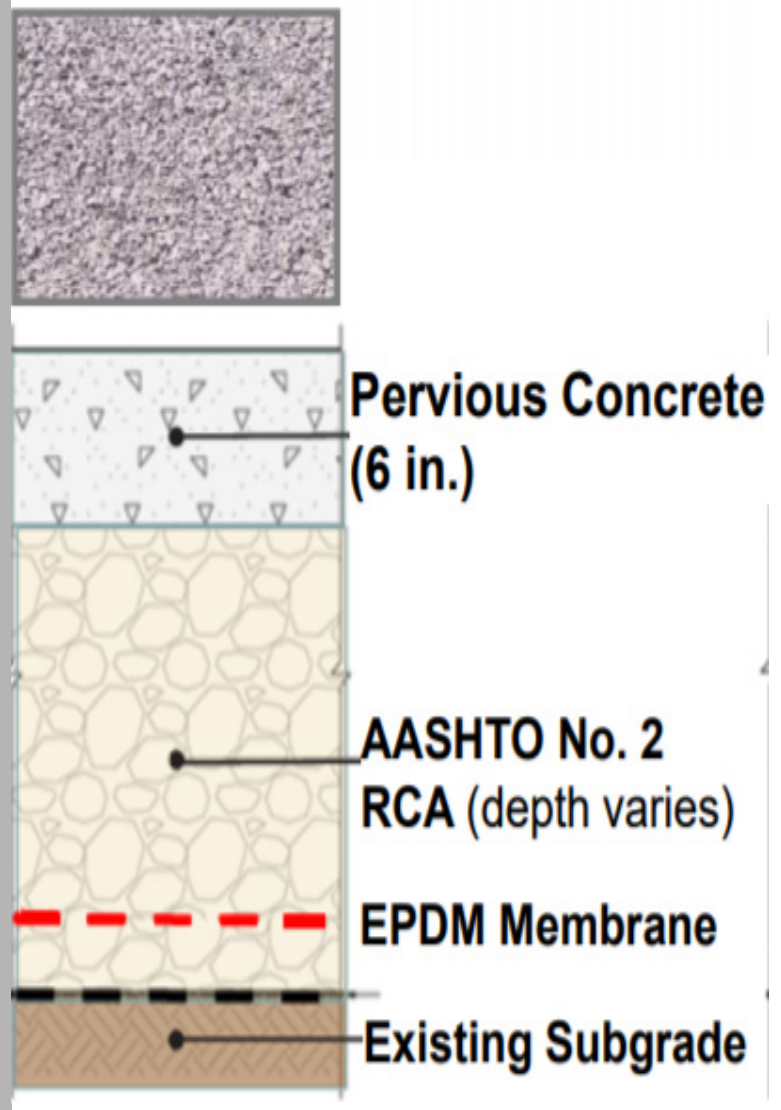
- Blocks:
  - Thickness: 3.125 in
  - 6.1 in. x 8.5 in
- AASHTO No. 8 aggregate fill the 0.5-in gaps between the blocks



(image credit: www.icpi.org)

Pervious Concrete (PC)

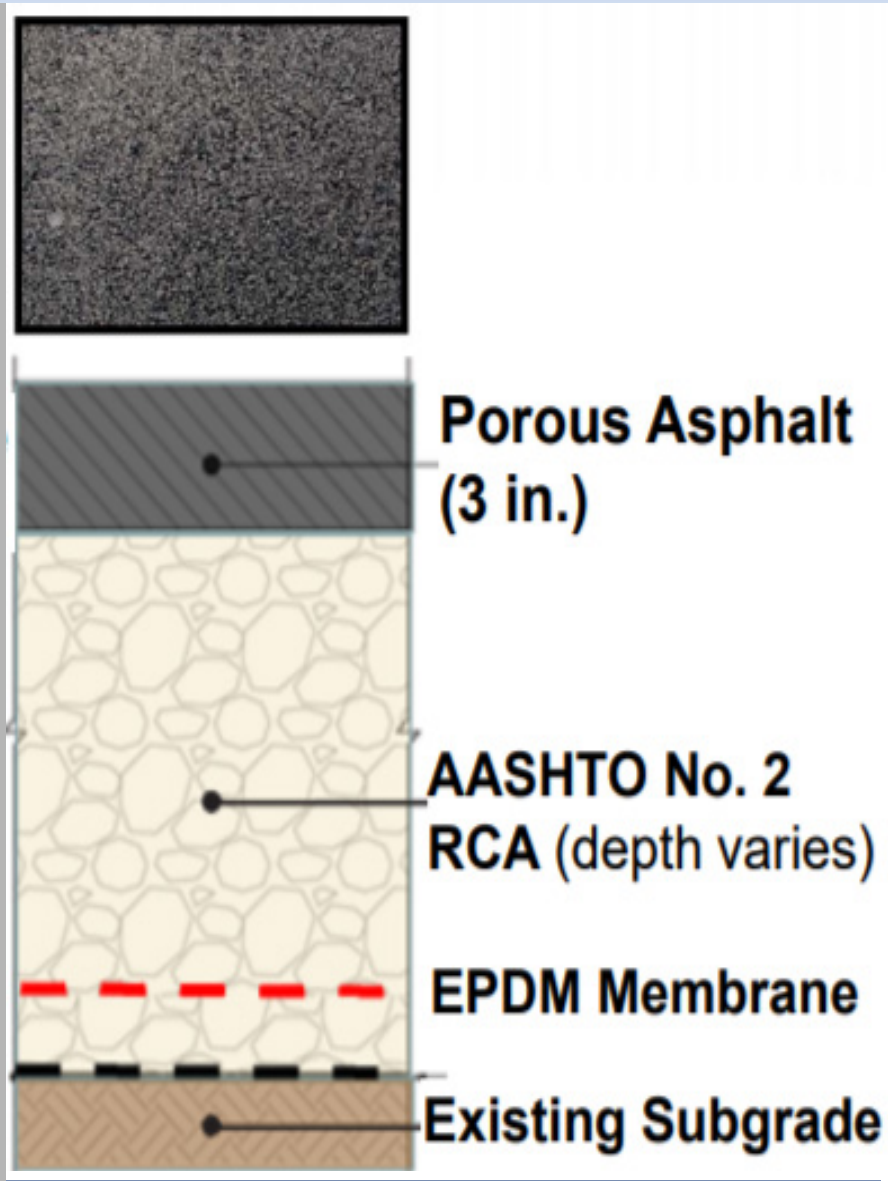
- The PC was poured directly over recycled concrete aggregate (RCA)
- Thickness: 6 in
- Mean density: about 2 g/cm^3 (125 lb./ft^3)
- Average porosity: 25%
- Degraded overtime and was replaced by a new PICP in 2016



(image credit: www.icpi.org)

Porous Asphalt (PA)

- The PA was poured directly over AASHTO No. 2 recycled concrete aggregate (RCA)
- Thickness: 3 in

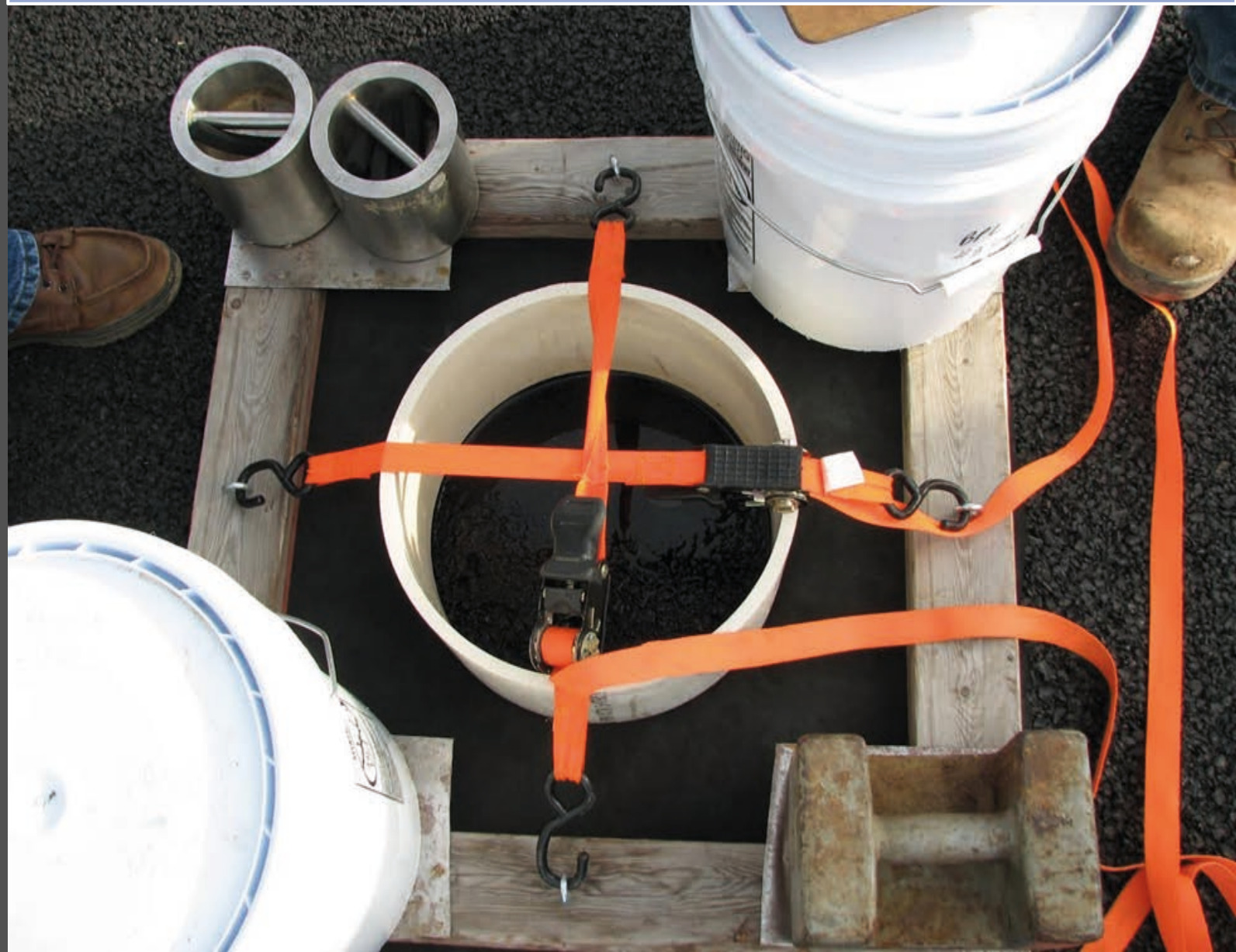


(image credit: www.icpi.org)

Monitoring Method

- Brown and Borst's methods for monitoring infiltration capacity (Modified ASTM C1701)

- Monitoring Apparatus:
  - 6-in long section of 11.875 in diameter PVC pipe
  - 0.5-in thick Neoprene sheet
  - Weights
  - Wooden panel with fastening belts
  - Stopwatch
  - Carboys with 18.0 and 3.6 kg of water



(Photo provided by Thomas O'Connor)

Infiltration Capacity Measurement

Pre-wet Infiltration Capacity Test:

3.6 kg of water was poured into the cylinder and time from when the water first impacted the permeable pavement surface to when water was no longer visible on the surface was measured with a stopwatch and recorded as “Pre-wet time”

Infiltration Capacity Measurement

Standard Infiltration Capacity Test:

If the measured “pre-wet time” was less than 30 s, the infiltration measurement was completed with 18.0 kg of water; otherwise, the infiltration measurement was completed with 3.6 kg of water

Mass of water infiltrated (M in kg) and drain time (t in seconds) are recorded

Infiltration Rate Calculation

$$I = 4.586 * 10\uparrow 9 * M/t * D\uparrow 2$$

I = infiltration rate (mm/h)

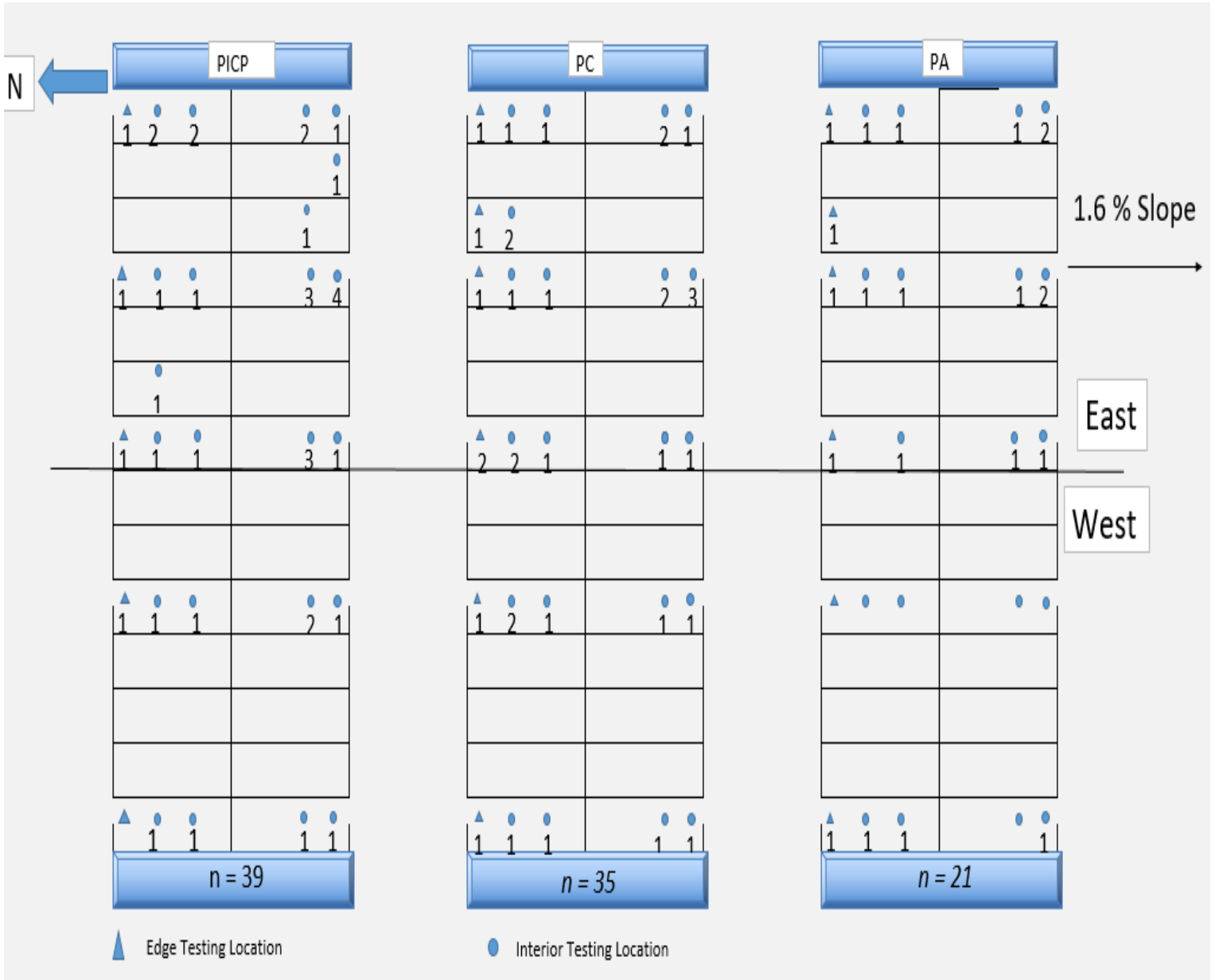
M = mass of water (kg) infiltrated

D = inside diameter of the PVC cylinder (mm)

t = measured drain time (s)

Infiltration Capacity Data

- PICP: 39
- PC: 35
- PA: 21
- NEW PICP: 25



Monitoring Problems

- Difficulty accessing testing sites due to parked cars
- Leakage during testing
- Consequently, of the **129** IC data points, only **120** (35 PC, 21 PA, 39 PICP and 25 PICP_NEW) were used in the statistical analysis

Statistical Analysis

Three separate hypotheses were tested based on the infiltration capacity results:

1. Average infiltration capacities varied by pavement type

2. Average infiltration capacities for the edge testing locations were less than the average of the interior testing locations

3. Average infiltration capacity of each pavement type decreased with time

Hypothesis #1: Infiltration Capacity by Pavement Type

Table 1: Mean infiltration capacity for each pavement type, sorted by rank, and pairwise differences in means. Bolded values indicate significant difference (α = 0.05) between pairs based on Dunn's test (d-stat > d-crit=2.64).

Pavement Type	Mean infiltration capacity with 95% confidence interval, cm/h	Number of tests		Pavement Type (Mean Infiltration Capacity)		
			PC	PICP_NEW	PICP	PA
			Difference in mean, (cm/h)			
PC	1,568 ± 385	35	---	+525	**+918**	**+1547**
PICP_NEW	1,043 ± 241	25	-525	---	+396	**+1022**
PICP	649 ± 206	39	**-918**	-396	---	**+628**
PA	21 ± 8	21	**-1547**	**-1022**	**-628**	---

Hypothesis #1: Interior vs Edge locations IC

Table : Comparison of mean IC of edge and interior locations for different pavement types, with significance of differences tested by the Kruskal-Wallis test

	Interior		Edge				
Pavement Type	Mean Infiltration Capacity (cm/h)	Number of samples	Mean Infiltration Capacity (cm/h)	Number of samples	Reduction (cm/h)	Percent Reduction	p-value
PC	1823	29	333	6	1489	82%	0.001
PA	16	16	10	5	6	38%	0.046
PICP	730	34	100	5	630	86%	0.0004

Hypothesis #2: Infiltration Capacity (IC) of Edge Testing Locations vs Interior Testing Locations

Table 2: Comparison of mean IC of edge and interior locations for different pavement types, with significance of differences tested by the Kruskal-Wallis test

	Interior		Edge				
Pavement Type	Mean Infiltration Capacity (cm/h)	Number of samples	Mean Infiltration Capacity (cm/h)	Number of samples	Reduction (cm/h)	Percent Reduction	p-value
PC	1823	29	333	6	1489	82%	0.001
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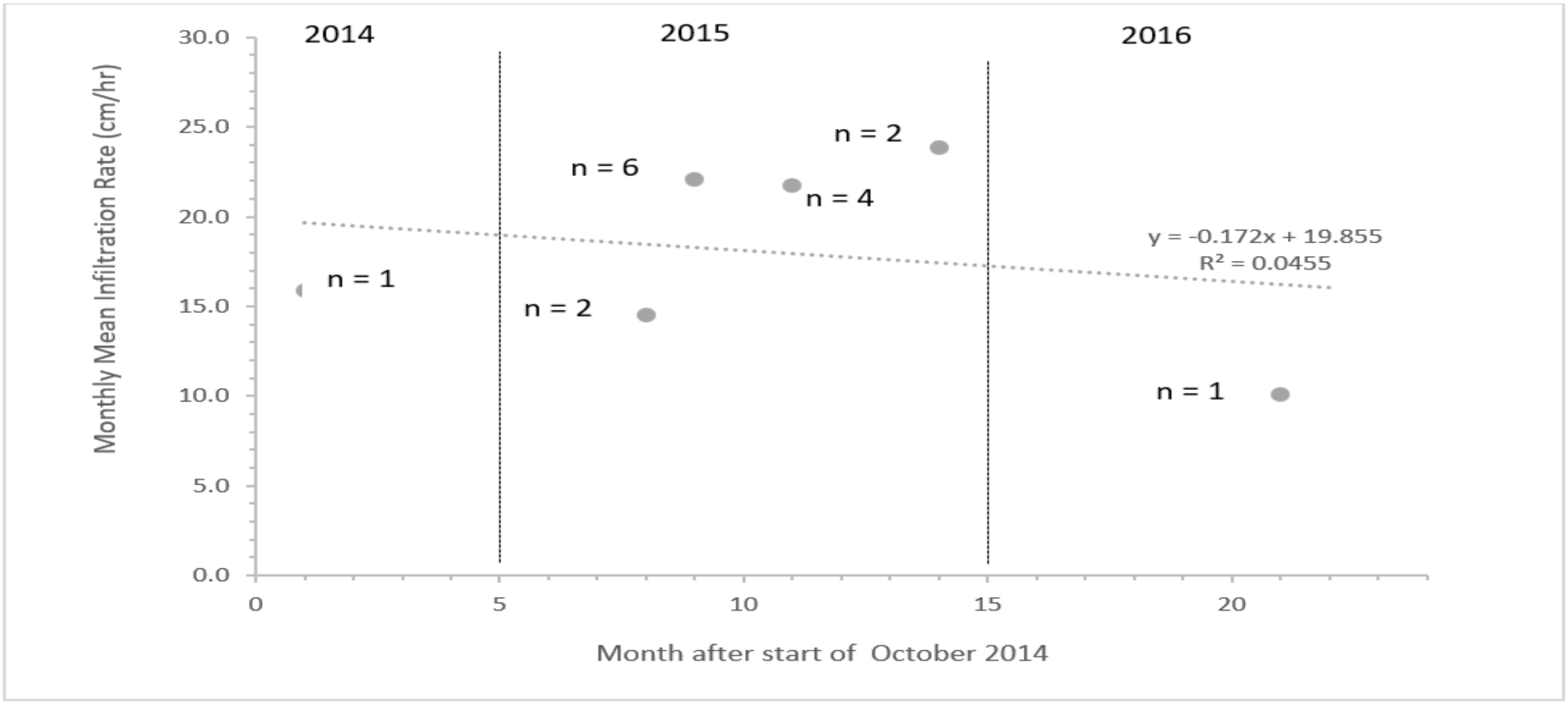
Hypothesis #3: Infiltration Capacity Declines Over Time

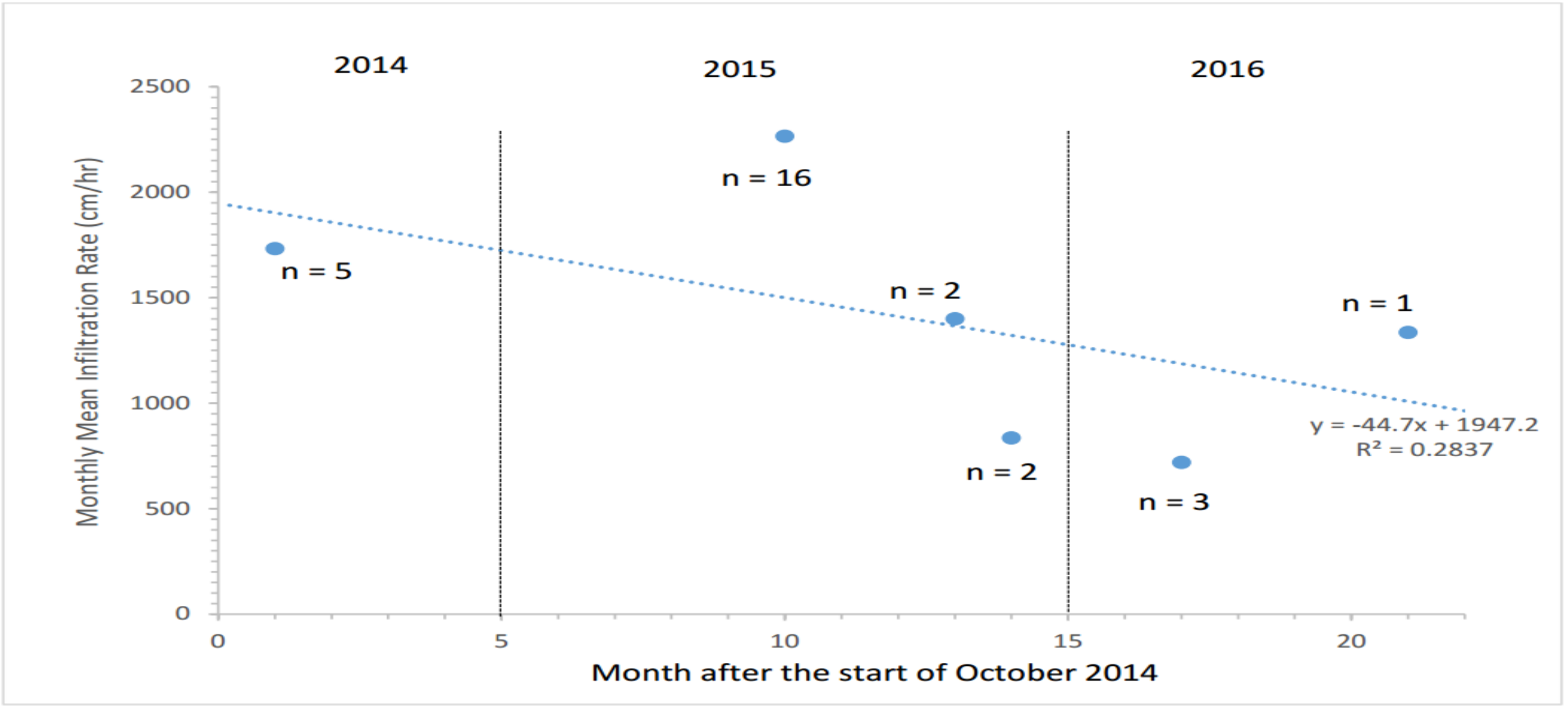
Table 3: Summary of linear regressions between mean IC for interior locations vs. month, for all pavement types

Pavement Type	Number of tests	Slope, cm/hr/month	R^2	p-value
PC	29	-44.	0.28	0.28
PA	16	-0.2	0.05	0.68
PICP	34	-54.	0.36	0.15

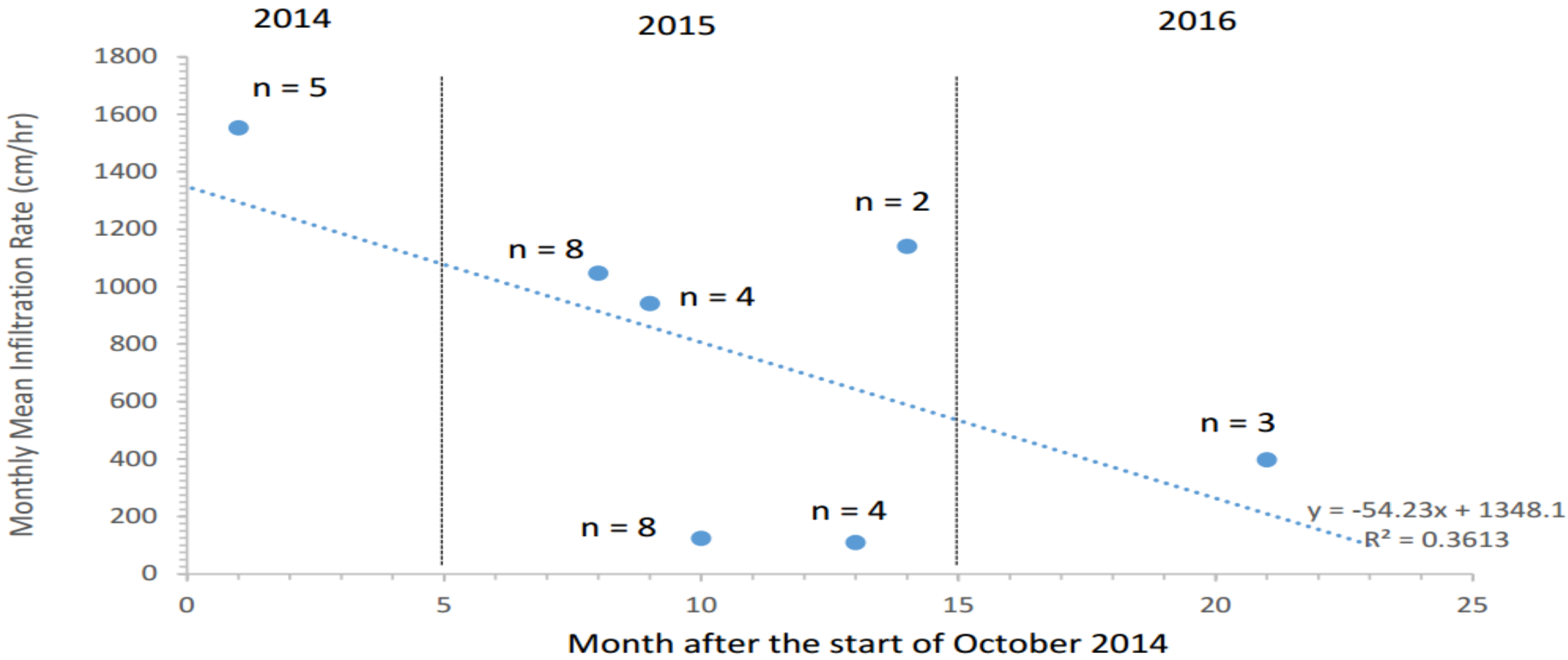
Linear regression of mean monthly infiltration capacity for PA on the interior testing locations with number of monthly samples (n)



Linear regression of mean monthly infiltration capacity for PC on the interior testing locations with number of monthly samples (n)

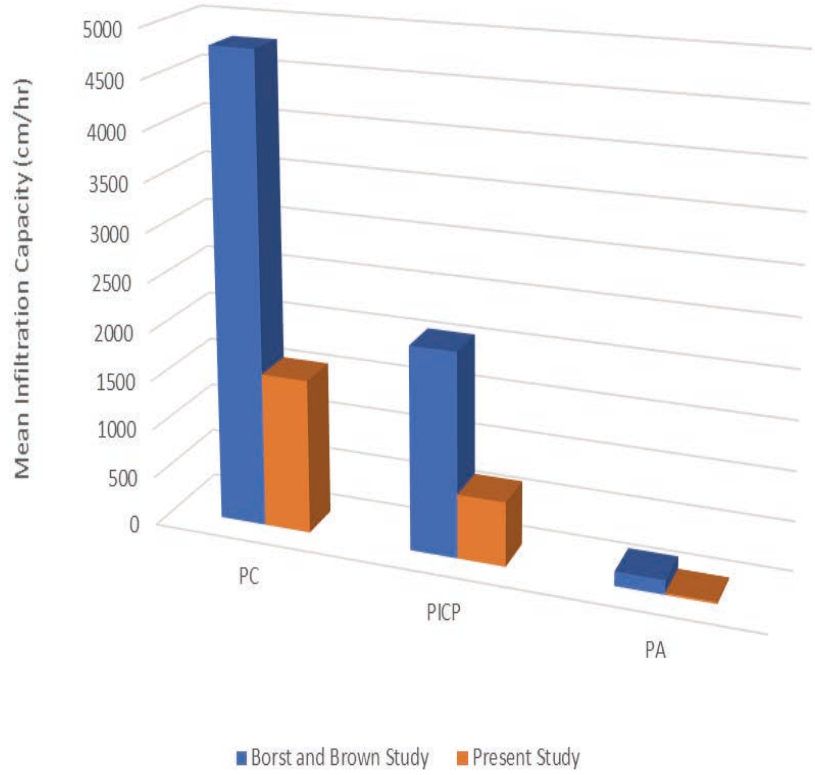


Linear regression of mean monthly infiltration capacity for PICP on the interior testing locations with number of monthly samples (n)



Comparing Brown and Borst study (09-12) and present study (14-16)

Pavement Type	2009-2012 Mean Infiltration Capacity (cm/h)	2014-2016 Mean Infiltration Capacity (cm/h)	Reduction in Infiltration Capacity (cm/h)	% Reduction In Infiltration Capacity
PC	4,799 ± 250 (n=162)	1,568 ± 385 (n=35)	3,231	67 %
PICP	2,074 ± 90 (n=162)	649 ± 206 (n=39)	1,425	69 %
PA	145 ± 28 (n=162)	21 ± 8 (n=21)	124	86 %



T-test: ***p < .0001***
for all three pavements

Conclusion

- Mean Infiltration Capacity (IC) of PC > IC of PICP > IC of PA
- Mean infiltration capacity of edge locations was less than interior locations by 38% (for PA) to 86% (for PICP) -- presumably due to clogging
- Reductions in mean IC from 2009-2012 to 2014-2016 were large, from 67% for PC to 86% for PA

Conclusion-cont.

- Mean IC of each surface was much larger than the local, 100-year, 5-min peak rainfall intensity of 20.9 cm/h (Brown and Borst 2014) except for PA

- Mean IC of PA (21 cm/hr.) was much larger than the infiltration rate of sandy gravel of 4.14 cm/h (Minnesota Stormwater Manual)

Acknowledgements

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THANKS