Pervious Pavement Systems

The Proposed Statewide Stormwater Rule: How We Got There

At a Meeting of the

AMERICAN ACADEMY OF ENVIRONMENTAL ENGINEERS®

Proudly Serving the Environmental Engineering Profession since 1955

September 22, 2009

At the Science Applications International Corporation Facilities, Orlando Fl

a program from the

University of Central Florida Stormwater Management ACADEMY

"Managed Stormwater is Good Water"

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Pervious Pavement

- Good design is important, but also:
- Locate it properly,
- Construct it properly

and Maintain It.

Past Historyof Pervious Pavements

Fair / Poor in most cases due to:

- **Design errors** (poor soil conditions not taken into account, improper locations, inadequate layer thicknesses, edge of pavement not restrained).
- **Construction problems** (specialized construction crews were NOT utilized as recommended by the product manufacturer).
- **Improper use/maintenance**(ADA Requirements, Failure to prevent silts & sands from plugging the pervious pavement void spaces).

UCF Research Publications on pervious pavement

***"Compressive Strength of Pervious Concrete Pavements – Final Report"*, dated January, 2007**

"*Construction and Maintenance Assessment of Pervious Concrete Pavements* - *Final Draft"*, datedJanuary, 2007

***"Hydraulic Performance Assessment of Pervious Concrete Pavements for Stormwater Management Credit -Final Report"*, dated January, 2007**

UCF research publications available at:http://stormwater.ucf.edu/research_publications.asp

Previous Studies at UCF

- Researchers at the Academy Conducted Four Related Studies to Evaluate Performance of Pervious Concrete (PC) Pavements

- First Study –
  - Field Testing at Eight Parking PC Lots with average of 12 years
  - Created a Model to Simulate Hydraulic Function and Predict its Behavior under Various Rainfall Conditions over One Year Period
  - Developed a new field infiltration rate test using an Embedded Ring Infiltrometer Kit(ERIK) – monitor rates through the system (pavement and sub-base) over time

Previous Studies at UCF

- Second Study –
  - Investigated Construction and Maintenance Techniques used at sites in Florida, Georgia, and South Carolina
  - Suggested updates for Construction Specifications for locations with similar soil conditions
  - Evaluated two maintenance techniques – Vacuum Sweeping and Pressure Washing
- Third Study -
  - Studied the strength of Pervious Concrete
  - Confirmed Lower Compressive Strength than regular and should not be used for heavy vehicle loads

Previous Studies at UCF

- Fourth Study –
  - Evaluated the wear and infiltration of a pervious concrete shoulder along Interstate 4 near Orlando
  - Shoulder showed no visible wear from truck traffic
  - Infiltration rates remained constant during study period of one year
  - Tests of filtered water showed it to be equivalent to rainwater quality
  - It generated significantly less runoff than the asphalt parking areas

I-4 Rest Area [shoulder]

JONES TRAILHEAD

FCPA BUILDING

ERIK Test for Infiltration Rates

EXPERIMENTAL SETUP:

FIELD

In-situ:

Driveway Infiltration and Water Quality Testing:

PC - Pervious Concrete ----1500 sf

FP – Flexipave ----------1500 sf

PP - Permeable Pavers ------ 660 sf

PA - Porous Asphalt----------1500 sf

HP – Hanson Pavers ---------- 980 sf

LABORATORY

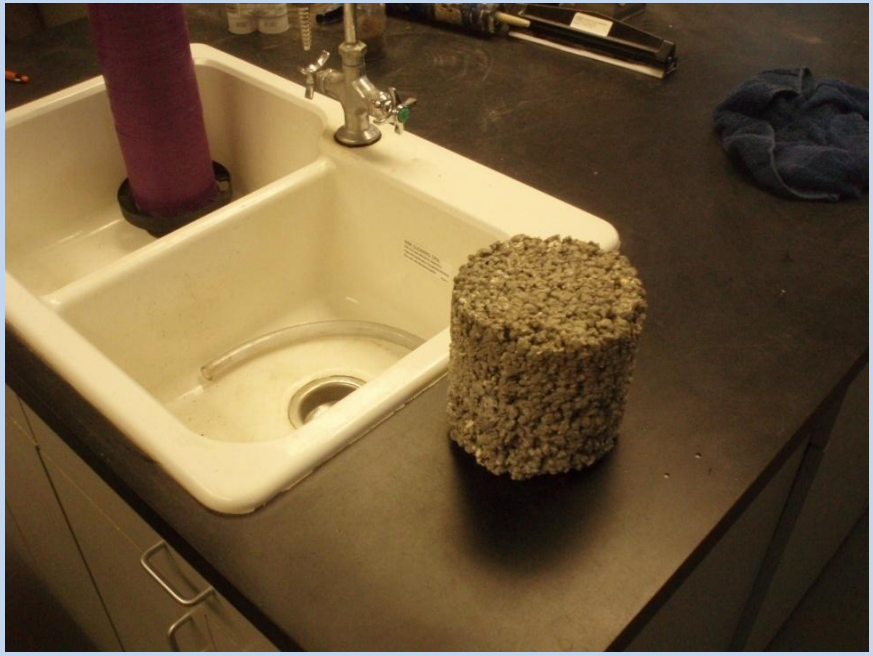
Ex-situ:

Sustainable void space:

- Bench scale [barrels]
- Pilot scale [small containers]

Infiltration:

- 6” cylinders



SMART LAB DRIVEWAY

Pervious Concrete

Clean Fill vs. Black & Gold Sub-base Materials

Water Quality pipe

Infiltrometers

Flexi-Pave

Permeable Pavers

Pervious Brick Pavers

Porous Asphalt

Porous Asphalt Pavement

HANSON PAVERS

ERIK TESTING

Embedded Ring Infiltrometer Kit

-In-situ, nondestructive, replicable

- Constant head test

- Measure rate of water "upstream" of sample

- 4" embedment into parent soil

* (except for research)

Sand Loading of Flexipave

Sand Loading of Pervious Pavers

Sand loading of Porous Asphalt

Wetting of Surface

Compaction

LIMESTONE LOADING

SANDY Surface Ready for Sweeping

LIME “DUST” Surface Ready for Sweeping

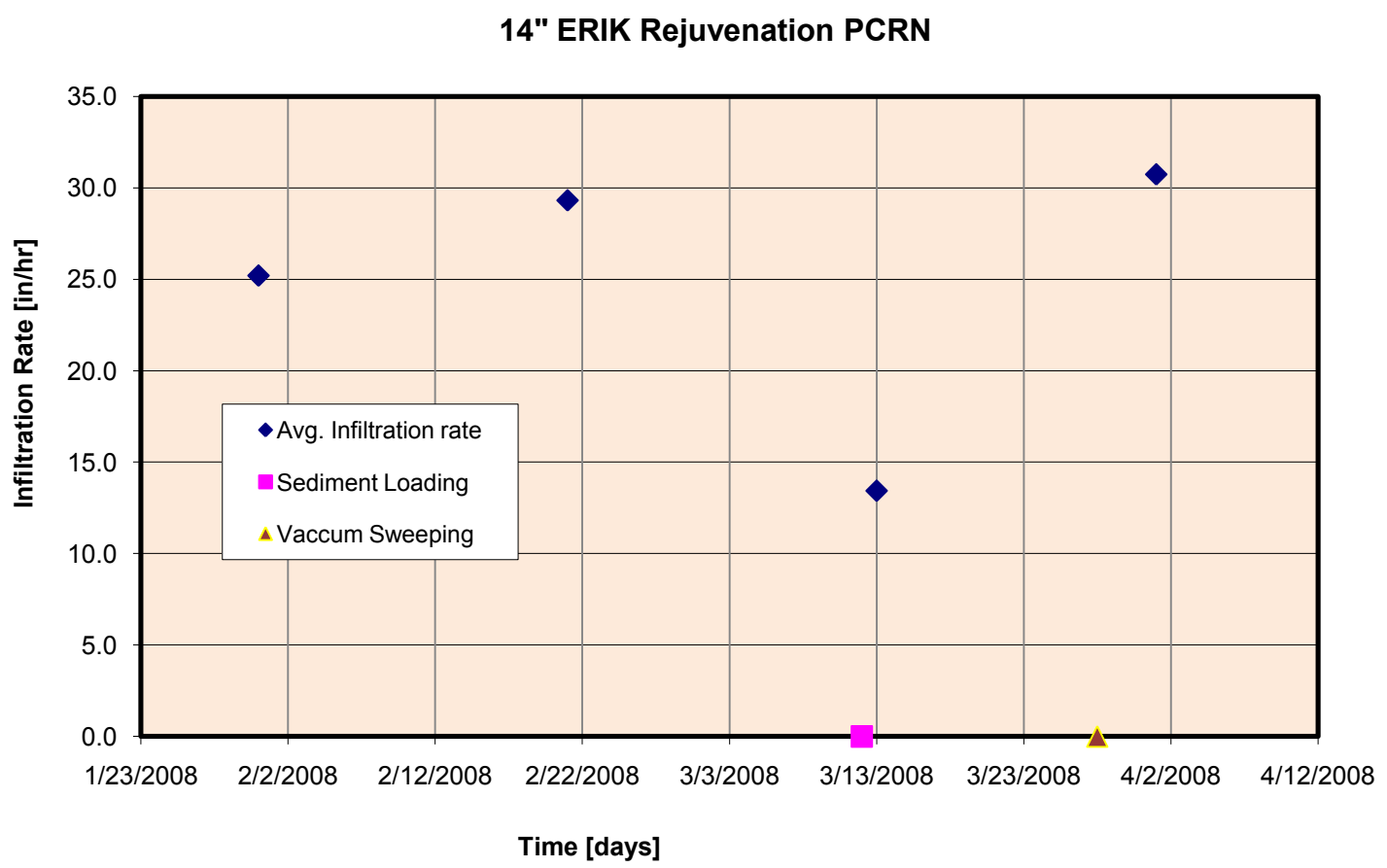
[DRY] Vacuum Sweeping - SAND

SEDIMENTS REMOVED

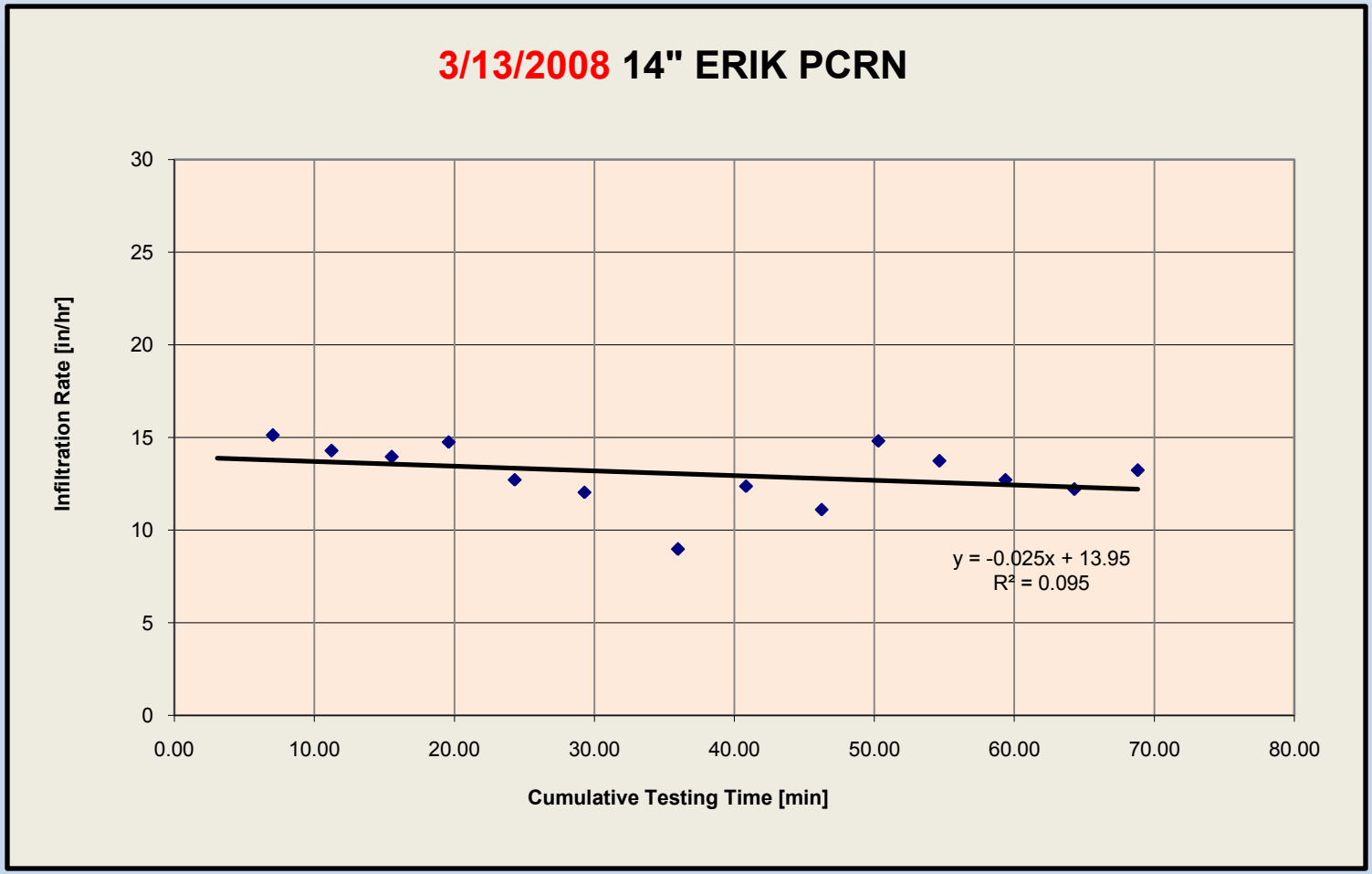

ELGIN
ELGIN


ELGIN

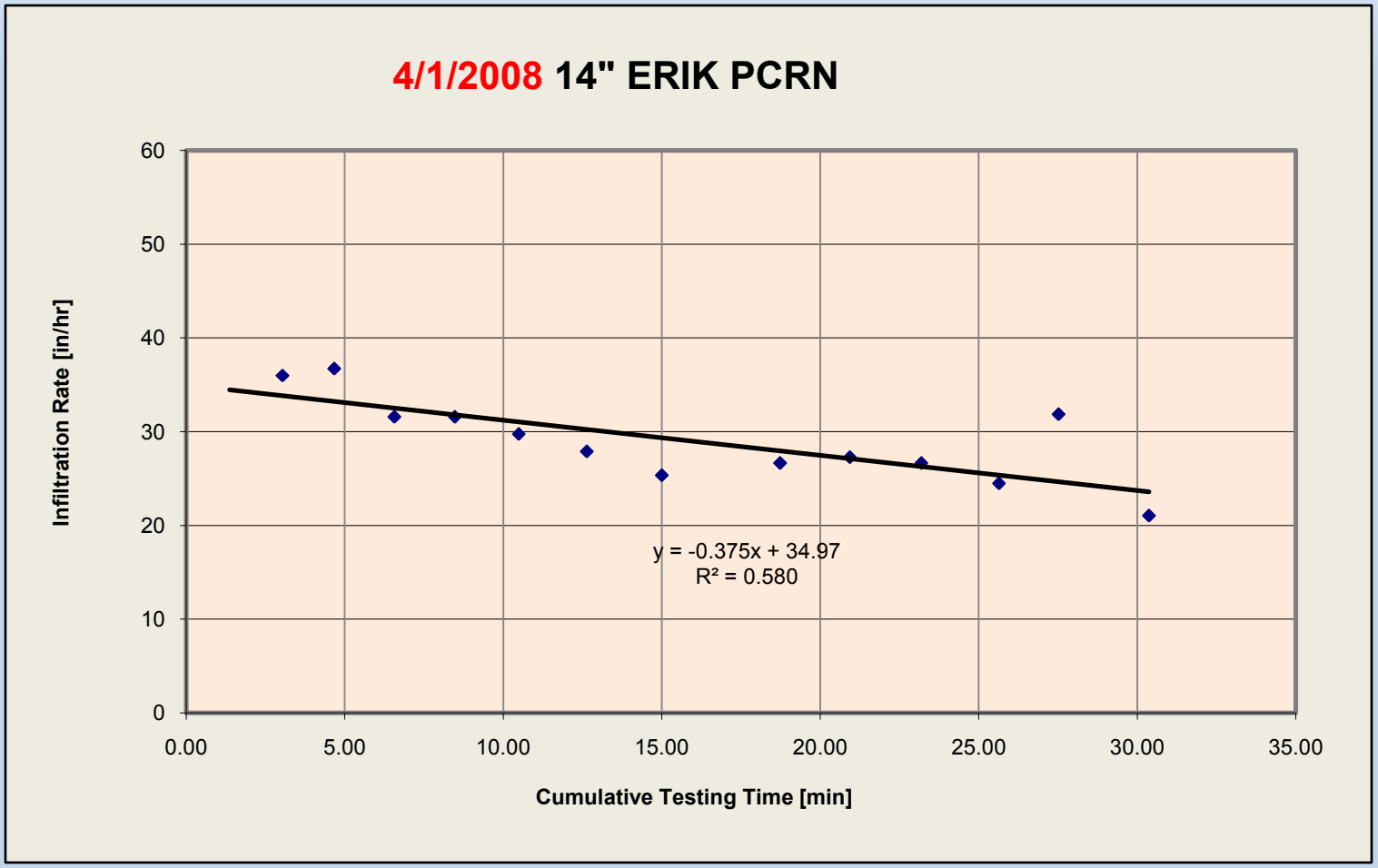
Rejuvenation of PC Pavement



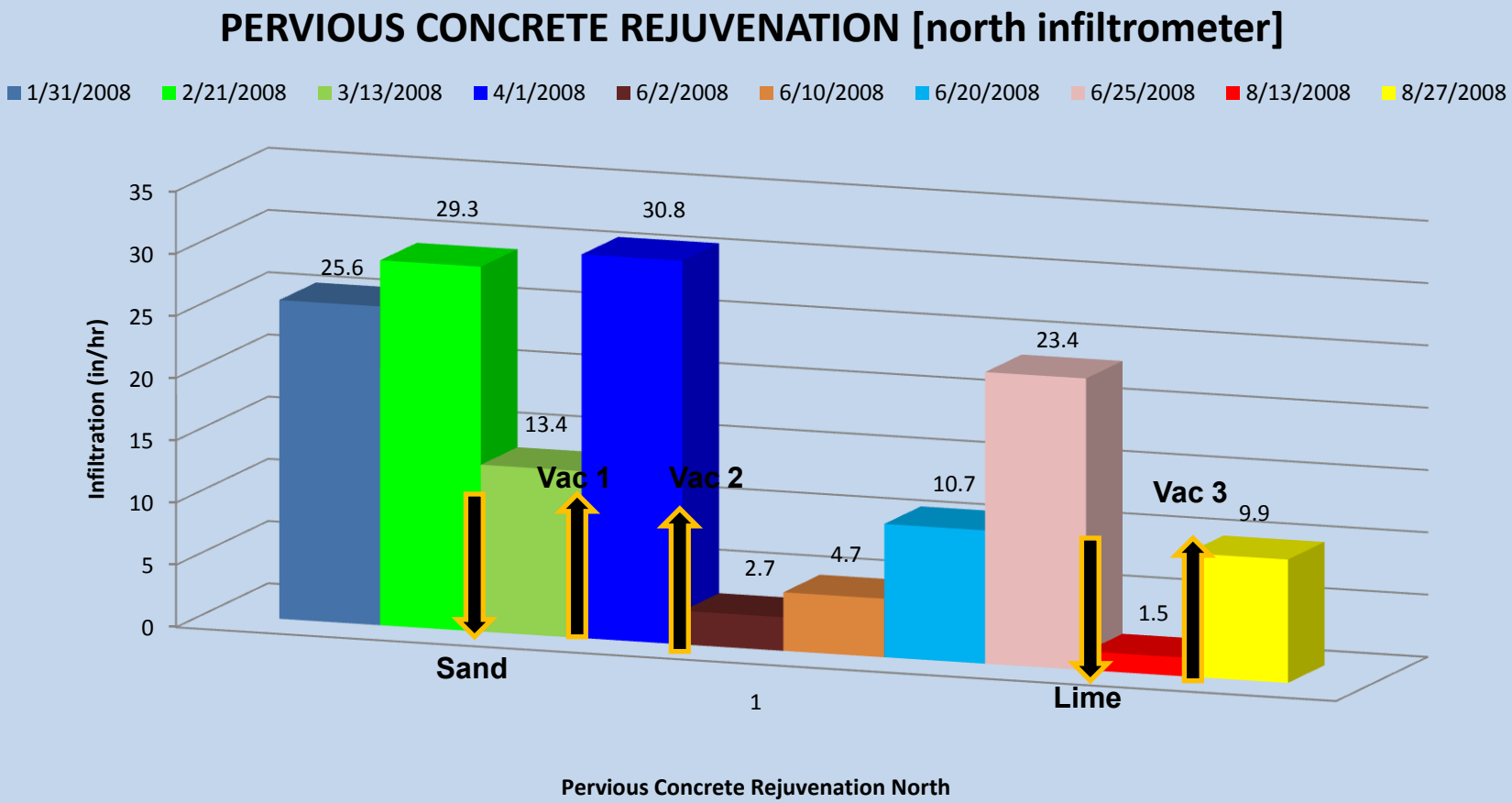
Infiltration test on PC Pavement



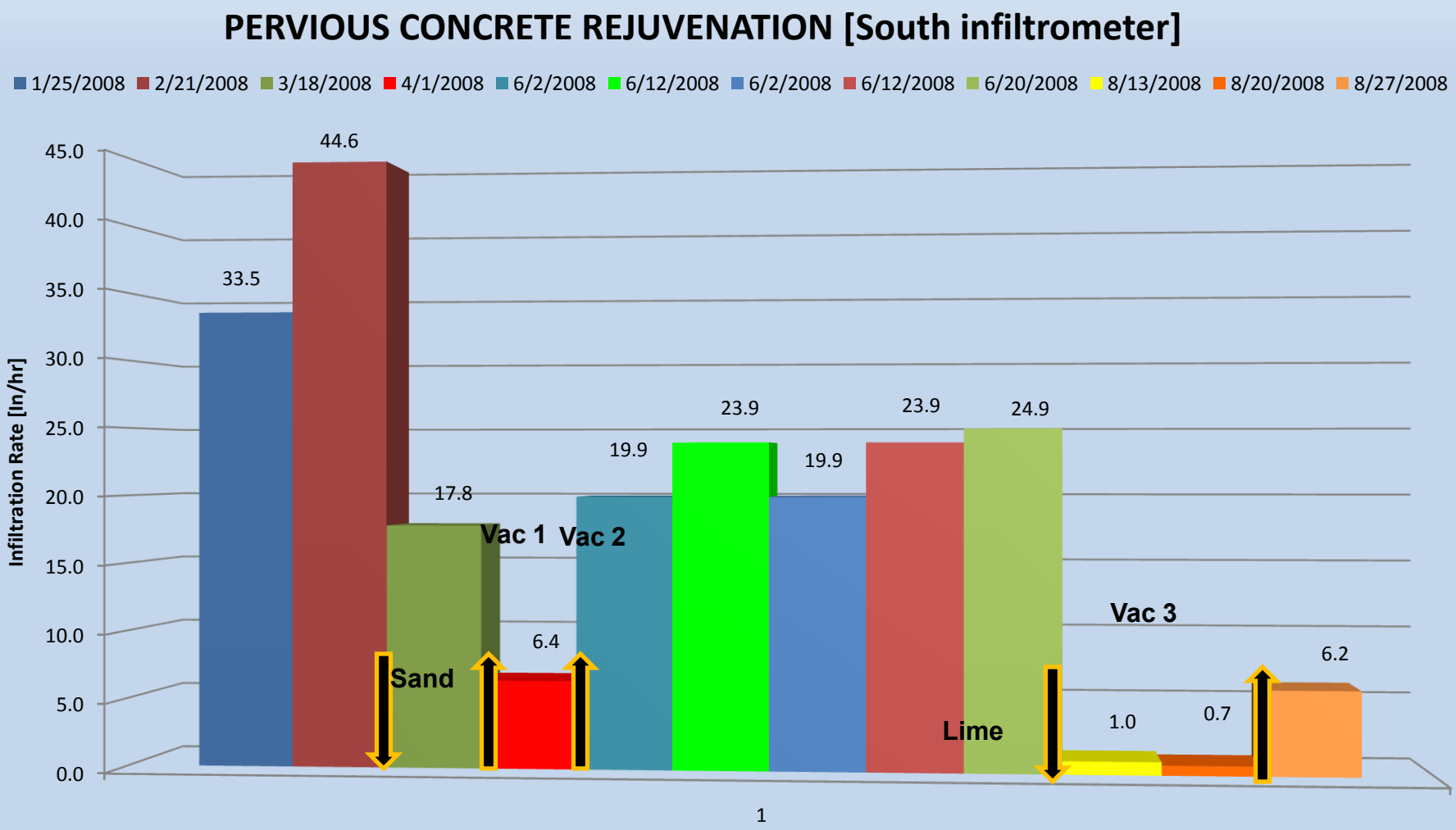
Rejuvenation of PC Pavement



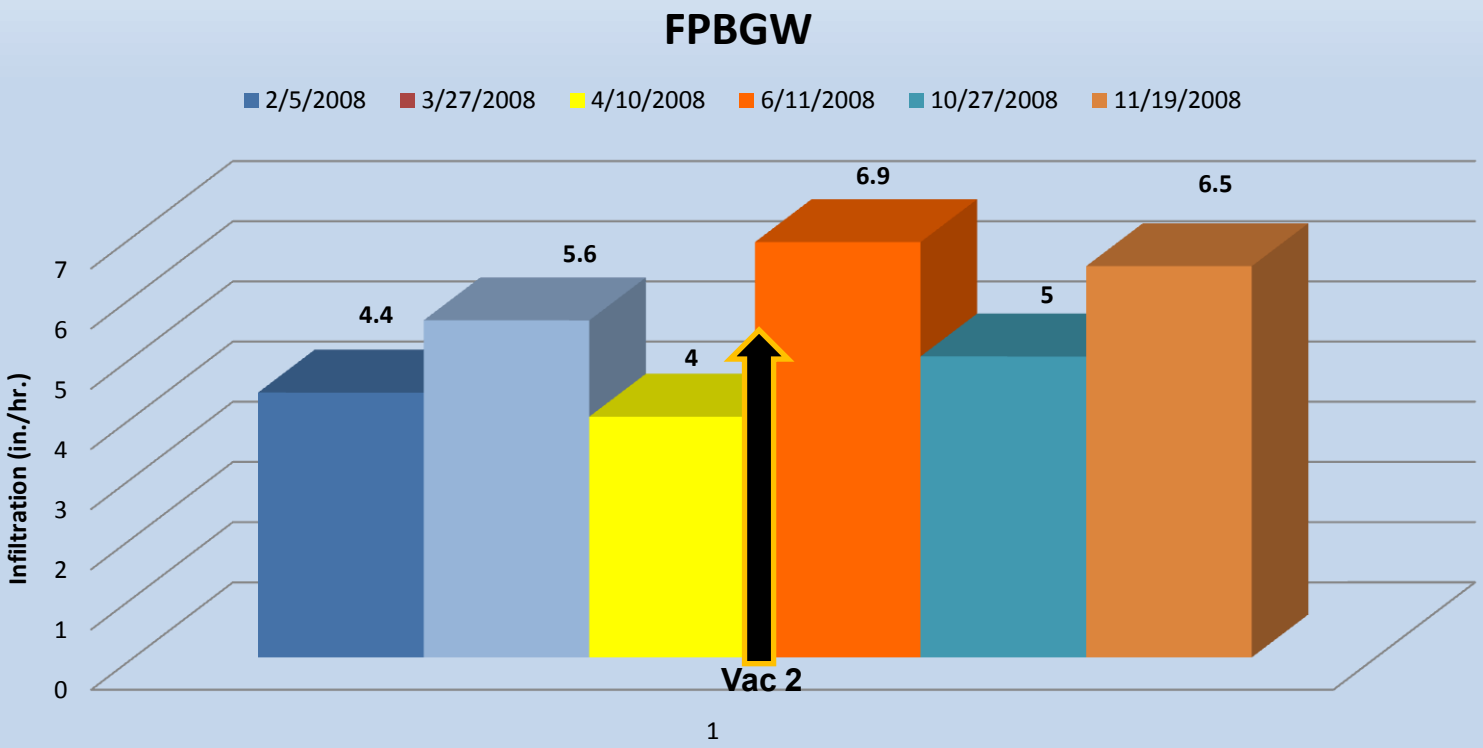
Infiltration Test Results



Infiltration Test Results



ERIK DATA



Flexi-Pave Black & Gold
[West Infiltrometer]


EC1
PA1
PA2
PC1
PC2
PC3

Bench Scale [#4 Limestone]

Pervious Concrete [Bench Scale]

Well pipe for drainage→

Sediment loading →

Laboratory Testing

Pre-Load							
EFFECTIVE POROSITY (pre-loading)							
S/NO.	MATERIAL	TEST SERIES					AVERAGE EFFECTIVE POROSITY
		1	2	3	4	5	
1	Pervious concrete	24.5	25.9	30.0	27.3	28.6	**27.2**
2	Flexi-pave	27.3	31.3	28.6	35.4	32.7	**31.1**
3	Porous asphalt	32.7	30.0	36.8	34.1	28.6	**32.4**
4	Permeable Pavers PP	10.0	8.1	8.8	9.5	-	**9.1**
5	Black & Gold	8.2	5.5	13.6		-	**9.1**
6	Pea rock (#89)	31.1	38.2	36.8	38.2	38.2	**36.5**
7	HPF	39.5	38.2	38.2	39.5	39.5	**39.0**
8	Crushed concrete (#57)	43.6	31.3	43.6	45.0	43.6	**41.4**
9	Limestone (#4)	45.9	47.7	45.0	46.3	41.0	**45.2**
10	Granite (#4)	40.9	43.6	45.0	43.6	45.0	**43.6**

Laboratory Testing

Post Load							
EFFECTIVE POROSITY (post loading)							
S/NO.	MATERIAL	TEST SERIES					AVERAGE EFFECTIVE POROSITY
		1	2	3	4	5	
1	Pervious concrete	21.8	21.8	28.6	24.5	20.4	**23.4**
2	Flexi-pave	6.8	20.4	17.7	1.4	5.5	**10.4**
3	Porous asphalt	16.4	15.0	27.3	23.2	16.4	**19.6**
4	Permeable Pavers PP						**NA**
5	Black & Gold						**NA**
6	Pea rock (#89)	12.3	10.9	21.8	9.5	8.2	**12.5**
7	HPF	13.6		16.4			**15.0**
8	Crushed concrete (#57)	1.4	1.4	1.4	1.4	1.4	**1.4**
9	Limestone (#4)	2.7	4.1	1.4	4.1	2.7	**3.0**
10	Granite (#4)	2.7	4.1	2.7	1.4	4.1	**3.0**

Recommended Effective Porosity

Type	Sub-Type	Sustainable Void Space (%)
Pervious Concrete		**20**
Porous Asphalt		**20**
Flexi-pave™		**20**
Pervious Pavers	Old Castle	**10**
	Hanson	**10**
#4 Rock	Limestone	**30**
	Granite	**30**
#57 Recycled Crushed Concrete		**25**
#89 Pea Rock		**25**
Black and Gold Media		**9**

Storage Calculations with 16-in Sections

Calculator for Section Storage		
Layer	Depth (in)	storage (in)
Pervious ConcretePavement	6	1.2
#57 Rock	0	0
#89 Pea Rock	0	0
#57 Recycled Crushed Concrete	0	0
Black and Gold Media	10	0.9
#4 Rock	0	0
Storage	S'=	2.1
Curve Number	CN=	83
Runoff Coefficient	C=	0.66

Example Problem #1

** This mention does not constitute an endorsement of product.*

Six (6) inches of pervious concrete * placed directly on top of the parent soil.

C (% OF RAINFALL), CN VALUES AS A FUNCTION OF PERVIOUS PAVEMENT SYSTEM STORAGE AND RAINFALL EVENT VOLUME

Note: **Design Storm Rainfall amount should range between 4.0 and 15.0 inches.**

VIEW RUNOFF PERCENT AND CN VALUE CURVES FOR THE SPECIFIED RAINFALL AMOUNT

Design Storm Rainfall Amount: (Hit "Enter" after input). 7.50

After entering the rainfall depth, hit this button to view the plots and pervious pavement storage calculator.

USER INSTRUCTIONS: INSERT THE DESIGN STORM RAINFALL AMOUNT FIRST, AND HIT "ENTER" AFTER INPUT (see above), THEN PRESS VIEW RUNOFF PERCENT AND CN VALUE BUTTON (see above right) TO SEE THE CHART WITH APPROPRIATE CURVES.

Notes: **1)** An S value of 1.2 inches is equal to 6 inches of pervious pavement with a porosity of 0.2 and 12 inches would be a 6 inch pervious over 3 feet of sub base with a porosity of 0.30. Thus there are many perviou pavement situations that can be modeled within the range of S'. **2)** Runoff coefficient on graphs is % of rainfall, thus divide by 100. Peak Runoff Qp = (C/100)iA where I (in/hr) and A (Acres) and the attenuation factor is 1 for parking areas and the 1.008 constant is not used.

24 hour, 25 year rainfall depth ≈ 7.5 inches.

S'	CN	C * 100	Ln (runoff %)
0.5	95	92.42	4.526
0.8	93	88.25	4.480
1	91	85.61	4.450
1.2	89	83.07	4.420
1.5	87	79.45	4.375
2	83	73.86	4.302
2.5	80	68.77	4.231
3	77	64.12	4.161
3.5	74	59.86	4.092
4	71	55.94	4.024
4.5	69	52.32	3.957
5	67	48.99	3.892
5.5	65	45.89	3.826

Blue Numbers =	Input data
Red Numbers =	Answers

Predictive Equations:

Rainfall Excess (in)	R = [P-0.2S']^2 / [P+0.8S']	If P>0.2S'
Maximum Storage (in)	S' = [1000/CN] - 10 and CN = 1000/(S'+10)	
Runoff Coefficient	C = R/P	

Variables:

Maximum Storage S' (inches) =	0.5 to 19 inches
Preciptation Event Volume P (inches) =	4.0 to 15 inches

Blue Numbers	= Input data
Red Numbers	= Answers

Example Problem #1

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For six (6) inches of pervious concrete * placed directly on top of the parent soil

Calculator for Pervious Pavement Section Storage (S')

Layer	Thickness (in)	SUSTAINABLE Void Space (%)	Storage (in)
Click to select Perv. Pvmt. Section	0	0	0
Click to select Perv. Pvmt. Section	0	15	0
Concrete Pervious Pavement	0	20	0
Asphalt Pervious Pavement	0	20	0
Flexi Pave®	0	20	0
Permeable Pavers®	0	20	0
#4 rock	0	20	0
Recycled (crushed) concrete	0	20	0

Blue Numbers	= Input data
Red Numbers	= Answers

Pull down menu for the type of pervious pavement

Example Problem #1

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For six (6) inches of pervious concrete* placed directly on top of the parent soil

Calculator for Pervious Pavement Section Storage (S')

Layer	Thickness (in)	SUSTAINABLE Void Space (%)	Storage (in)
Concrete Pervious Pavement	6	15	0.9
Other Perv. Pvmt. (see Note #1 above)	0	15	0
#57 rock	0	20	0
#89 pea rock	0	20	0
#4 rock	0	20	0
Recycled (crushed) concrete	0	20	0

Blue Numbers	= Input data
Red Numbers	= Answers

Note #1: For other pervious pavement sections, the User must supply the appropriate certified "Sustainable Void space percentages" from a licensed geotechnical laboratory.

If a storage reservoir is proposed, enter the appropriate thickness of the material(s)

Example Problem #1

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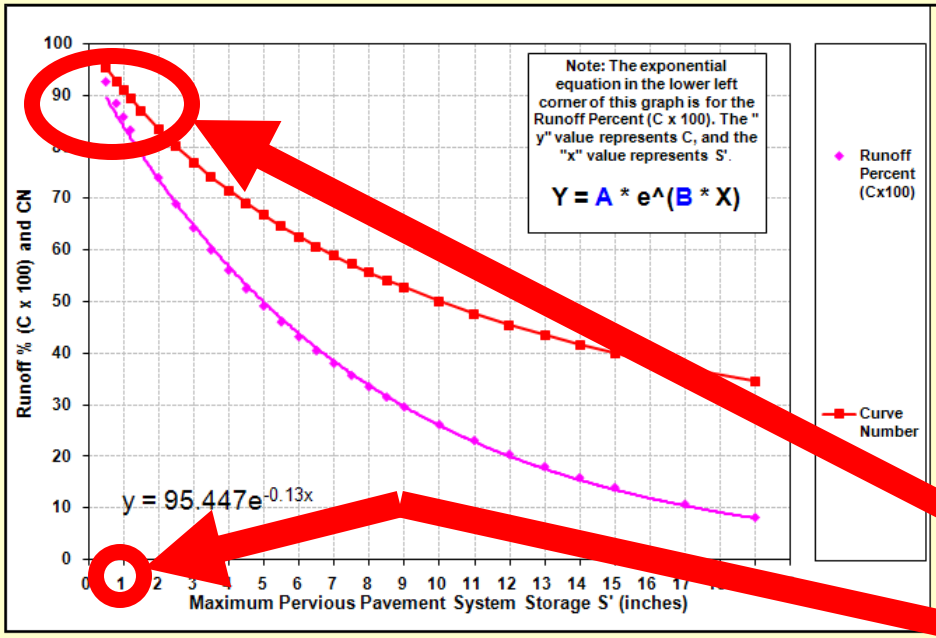
Runoff Percent and Curve Number(CN) for the: 7.50 inch Design Storm Event



Note #1: For other pervious pavement sections, the User must supply the appropriate certified "Sustainable Void space percentages" from a licensed geotechnical laboratory.

For six (6) inches of pervious concrete * placed directly on top of the parent soil, with a 7.5 inch rainfall depth:

System Storage (S') = 0.9"

CN = 92

Rational "C" = 0.85

Blue Numbers	= Input data
Red Numbers	= Answers

CLICK TO GO BACK TO DATA

Calculator for Pervious Pavement Section Storage (S')

Layer	Thickness (in)	SUSTAINABLE Void Space (%)	Storage (in)
Concrete Pervious Pavement	6	15	0.9
Other Perv. Pvmt. (see Note #1 above)	0	15	0
#57 rock	0	20	0
#89 pea rock	0	20	0
#4 rock	0	20	0
Recycled (crushed) concrete	0	20	0

S' =	0.9
CN =	92
C =	0.85

Automatic input of the "Best Fit" Exponential Equation Coefficients A and B (lower left corner of the above graph). y = C and x = S'

Y = A * e^(B * X)

A value:	B value:
95.447	-0.1299

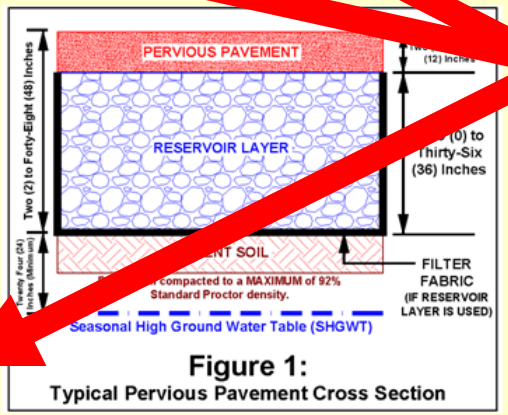


Figure 1:
Typical Pervious Pavement Cross Section

Water Quality Sampling

BACKGROUND SAMPLES

IMPERVIOUS RUNOFF SAMPLES

WATER QUALITY

TESTING:

-Ph

-Turbidity

-Alkalinity

-TP- Total Phosphorus

-OP- Ortho Phosphorus

- NH4- Ammonium

-NO3 + NO2- Nitrates plus Nitrites

- TN- Total Nitrogen

- TS & SS- SOLIDS

Heavy Vehicle Loading


C & J TRUCKING
Orlando, FL
USDOT 1290484 FL
KN05


SMOKEY

Future Directions for Our Research at UCF

- Water quality studies
- Strength of pervious pavements

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