Pervious Pavement Systems

Presented by

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In cooperation with

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A training presentation to the combined staff of Sarasota County and SWFWMD

Friday, 12/19/08 in Sarasota, Florida

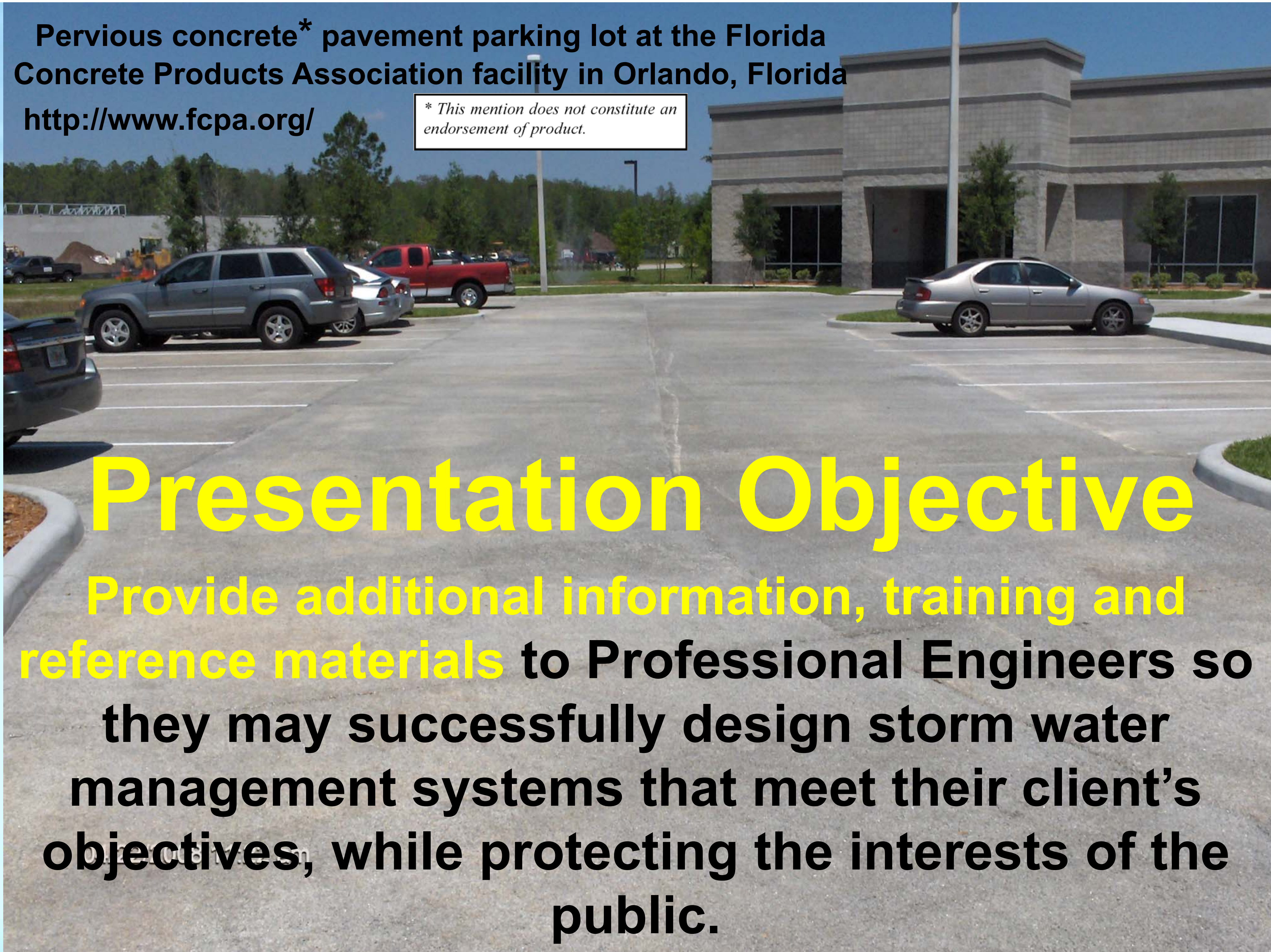
Friday, 01/30/09 in Tampa, Florida

http://www.swfwmd.state.fl.us/

University of Central Florida Stormwater Management ACADEMY "Managed Stormwater is Good Water"

http://stormwater.ucf.edu/

Power Point© file name: Pervious_Pavement _System_Training_with_Sarasota_County_ as_of_02_02_09.ppt



Pervious concrete* pavement parking lot at the Florida Concrete Products Association facility in Orlando, Florida

http://www.fcpa.org/

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

Presentation Objective

Provide additional information, training and reference materials to Professional Engineers so they may successfully design storm water management systems that meet their client's objectives, while protecting the interests of the public.

Pervious Pavement

Good design is important, but ---

You have to locate it properly, build it right and you have to maintain it.

Past History – Pervious Pavement

Fair / Poor in most cases due to:

- **Design errors** (poor soil conditions not taken into account, or placement of pervious pavement in high traffic volume / heavy wheel load areas, or areas of frequent turning movements – regardless of wheel loads).

- **Construction problems** (specialized construction crews were NOT utilized as recommended by the product manufacturer).

- **Improper maintenance** (failure to prevent silts & sands from plugging the pervious pavement void spaces).

Past design errors – Pervious Pavement

Not taking sub-soil compaction into account

(see the next slide)

LAND CLEARING, VEGEATION REMOVAL & INITIAL GRADING

80% compaction on first pass of equipment

(excluding compacting equipment)

Image Source: http://www.pbase.com/floridageologicalsurvey/phosphate_mining&page=all

Initial image sources: Eric Livingston, FDEP – LID Introduction to the 09-15-08 TAC meeting for the proposed statewide storm water Rule.

Recommendations – Pervious Pavement

Rear Ripper / Scarifier

http://safety.cat.com/cda/files/861819/7/140M.pdf

Ripper

Ripping Depth, Maximum	428 mm	16.8 in
Ripper Shank Holders	5	
Ripper Shank Holder Spacing	533 mm	21 in
Penetration Force	9026 kg	19,900 lb
Pryout Force	8555 kg	18,861 lb
Machine Length Increase, Beam Raised	919 mm	36.2 in

Maximum ripping depth = 16.8 inches.

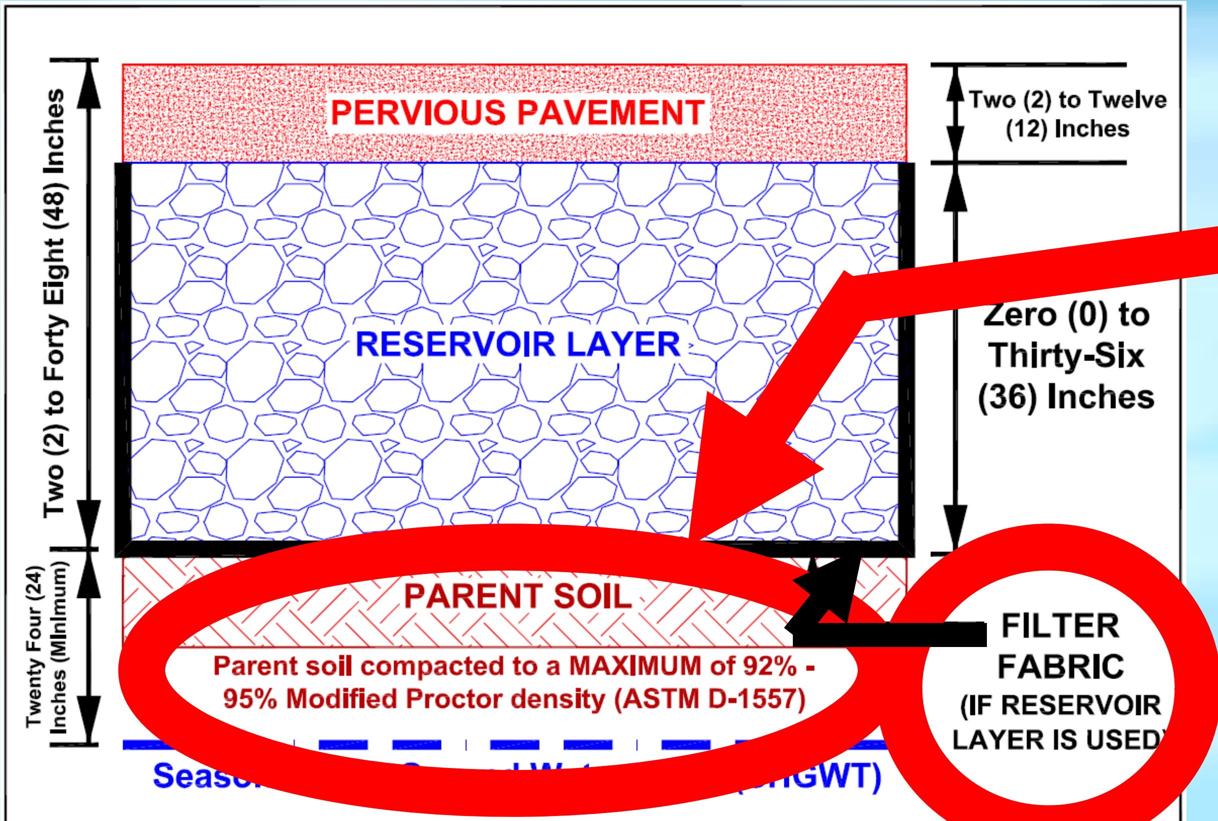


Figure 1:

Typical Pervious Pavement Cross Section

- **Parent soil - MAXIMUM compaction of 92% - 95% Modified Proctor density (ASTM D-1557) to a total depth of 24 - 36 * inches.**
- **Redevelopment projects – existing pavement section (including compacted base & stabilized sub-grade) to be removed. Underlying soils to be scarified to a minimum 24 - 36 * inch depth and re-graded / proof rolled to a MAXIMUM compaction of 92% - 95% Modified Proctor density (ASTM D-1557).**
- **Heavy wheel loads – if proposed (not recommended), then alternate methods of pavement design must be utilized (i.e. structural / permeable geo-fabrics above the parent soil).**

*** As a point of reference, the North Carolina DENR requires a vertical saturated hydraulic conductivity ≥ 0.52 in/hr for the soil horizon below the base of the pavement system to a total depth of 36 inches.**

Past design errors – Pervious Pavement

Locating pervious pavement in the wrong locations

See the next eight (8) slides

Locating pervious pavement in the wrong location

Improper placement of pervious pavement in high traffic volume / heavy wheel load areas, or areas of frequent turning movements (regardless of wheel loads).

Hopefully, this is an obvious place where pervious pavement should NOT be used.

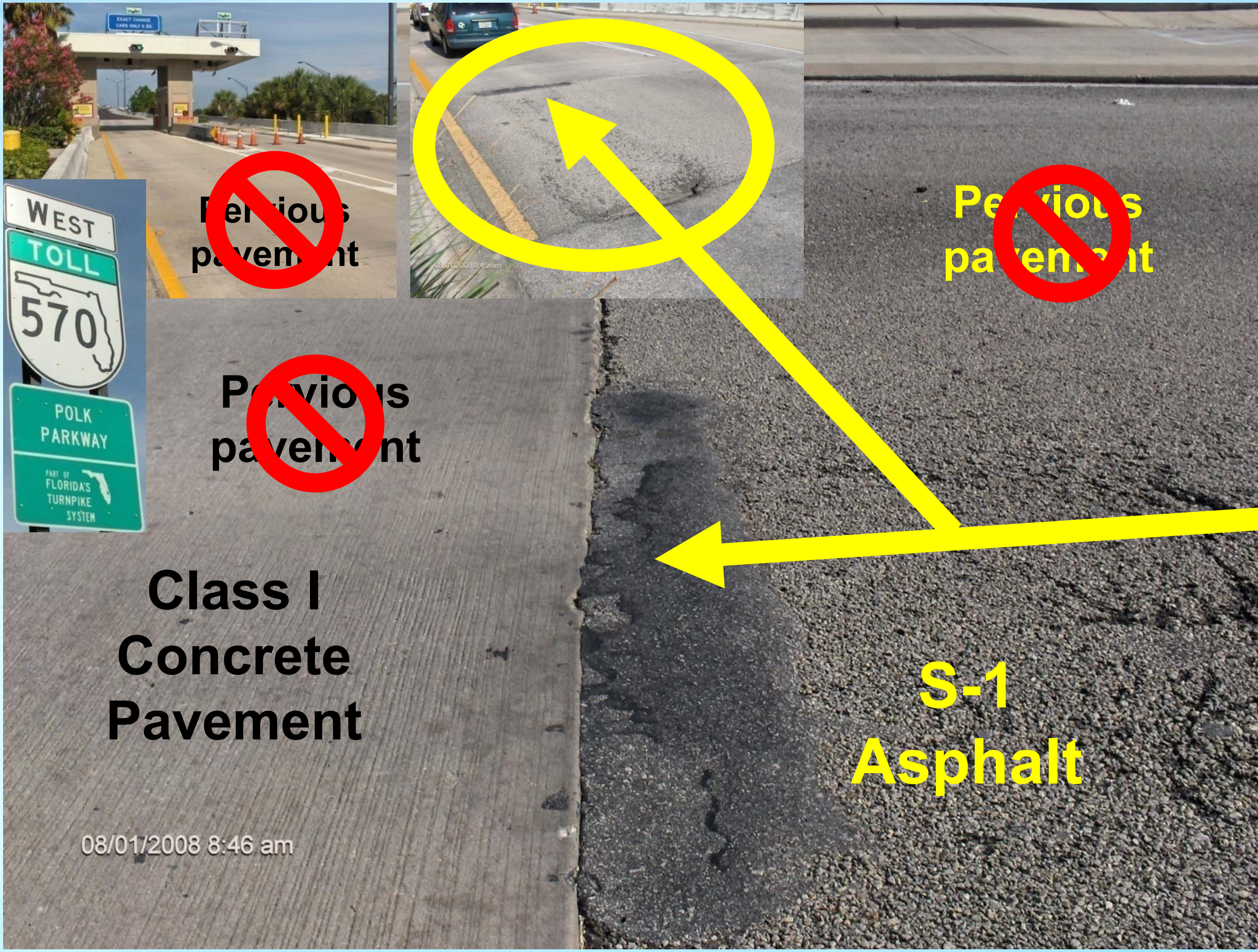
Locating pervious pavement in the wrong location

Improper placement of pervious pavement in high traffic volume / heavy wheel load areas, or areas of frequent turning movements (regardless of wheel loads).

This is another obvious place where pervious pavement should NOT be used.

Locating pervious pavement in the wrong location

Improper placement of pervious pavement in high traffic volume / heavy wheel load areas, or areas of frequent turning movements (regardless of wheel loads).

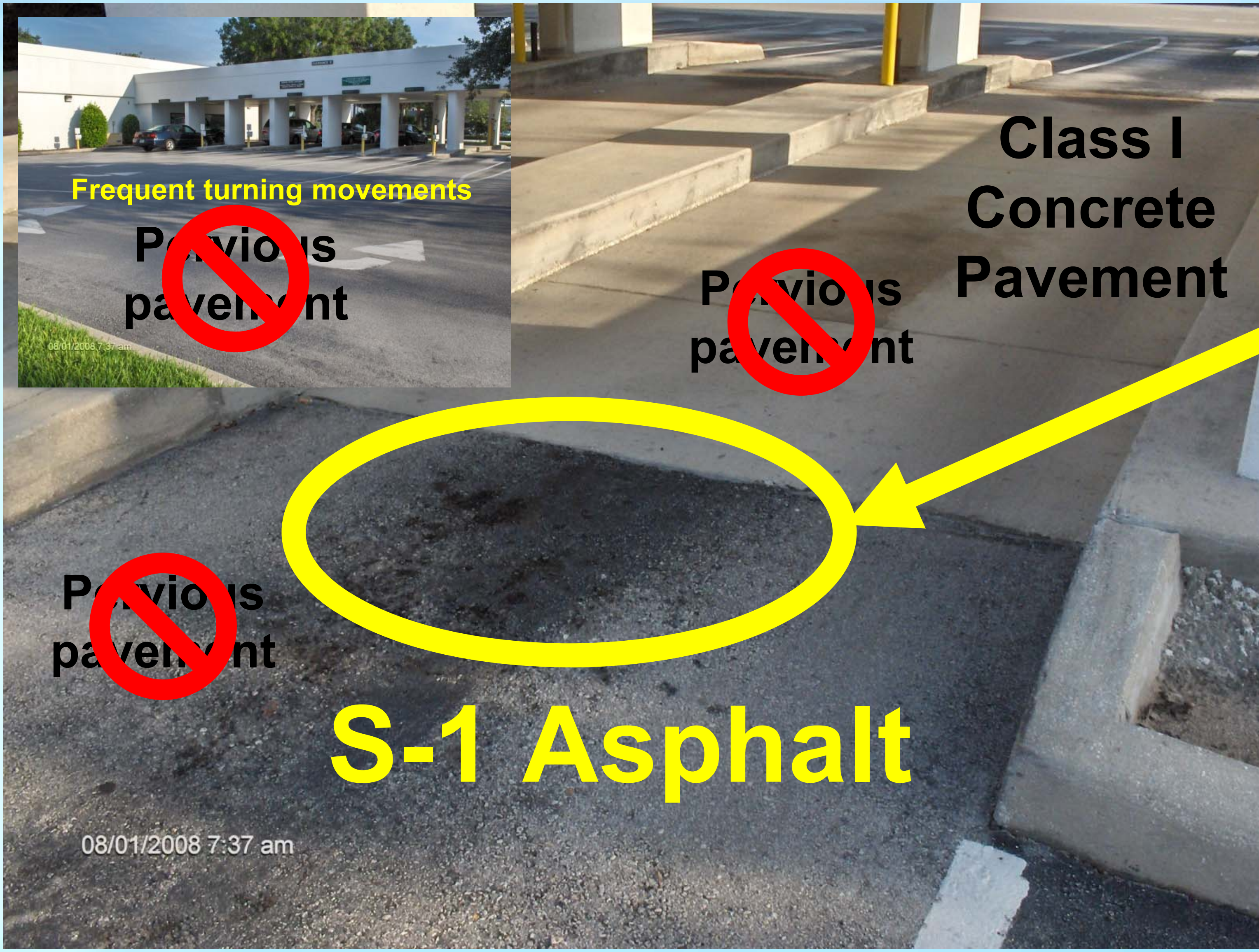


Another obvious place where pervious pavement should NOT be used.

Notice the structural failure where the S-1 asphalt joins to the Class I concrete - very common with high traffic volumes (regardless of wheel load).

Locating pervious pavement in the wrong location

Improper placement of pervious pavement in high traffic volume / heavy wheel load areas, or areas of frequent turning movements (regardless of wheel loads).



Notice the beginnings of structural failure where the S-1 asphalt joins to the Class I concrete - very common with high traffic volumes (regardless of wheel load).

Locating pervious pavement in the wrong location

Improper placement of pervious pavement in high traffic volume / heavy wheel load areas, or areas of frequent turning movements (regardless of wheel loads).

Class I concrete pavement for a fast food restaurant *"Drive Through"* pick-up window.

Locating pervious pavement in the wrong location

Improper placement of pervious pavement in high traffic volume / heavy wheel load areas, or areas of frequent turning movements (regardless of wheel loads).

Notice the structural failure where the S-1 asphalt joins to the Class I concrete - very common with high traffic volumes (regardless of wheel load).

Locating pervious pavement in the wrong location

Modular Concrete Pavers

(be careful about Federal ADA requirements)

Locating pervious pavement in the wrong location

Modular Concrete Pavers

(be careful about Federal ADA requirements)

Recommendations

Pervious Pavement should NOT be located in areas of:

- **Heavy wheel loads** – signage should be posted to inform users of this limitation.

- **Frequent turning movements** – regardless of wheel loads.

- **Heavy traffic volumes** – (greater than 100 vehicles a day *), regardless of wheel loads

- **Modular Concrete Pavers** – for expected use by the physically challenged, or people wearing high heeled shoes.

→ Modular Concrete Pavers ←

* Current North Carolina DENR requirement.

Recent Improvements - Pervious Pavement

Much better due to:

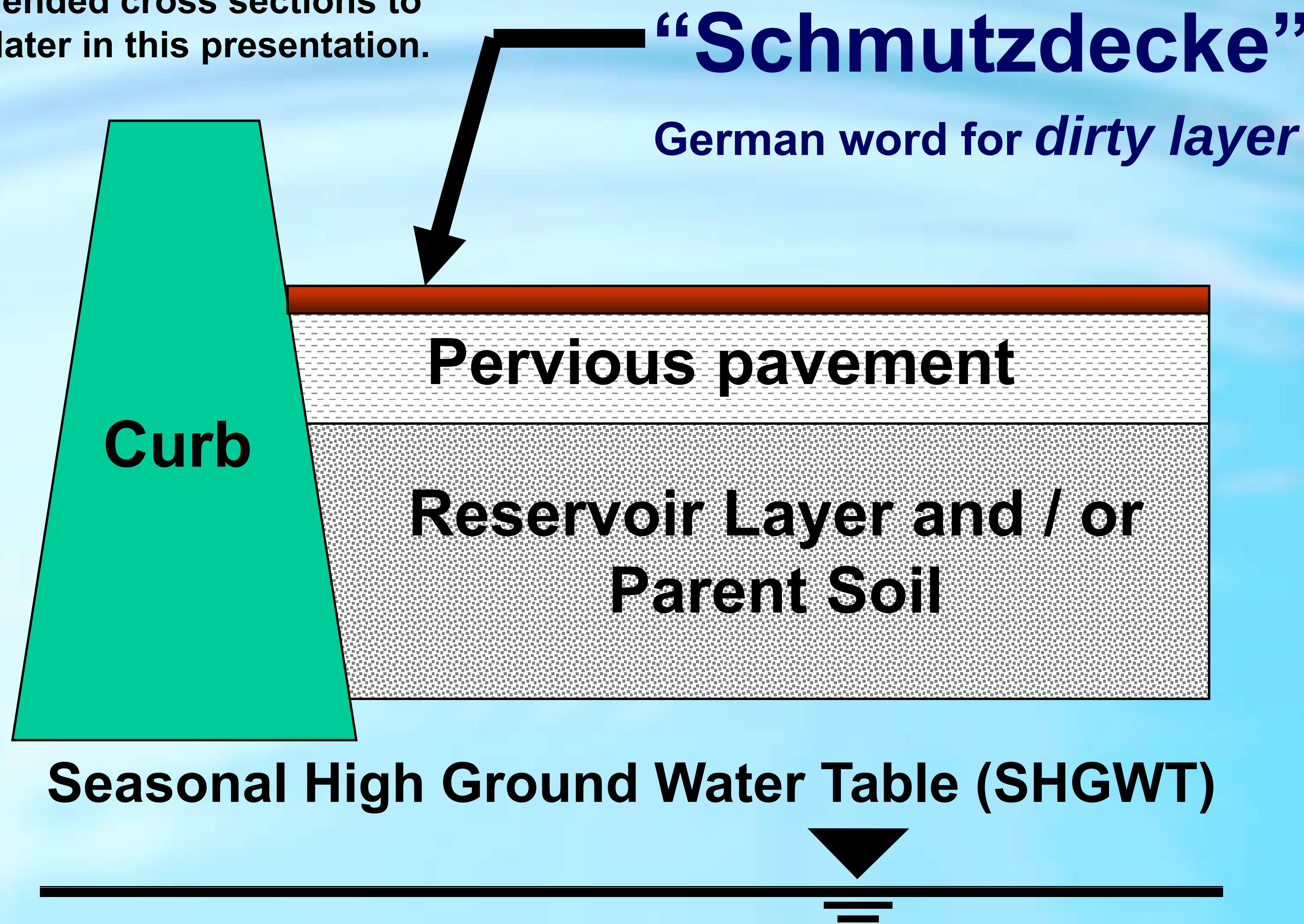
- **Improved Products**
- **Better construction supervision** (using specialized construction crews that are trained / certified by the product manufacturer).
- **Better designs and maintenance procedures** (through information / training sessions such as these, plus more University Research (i.e. the UCF Stormwater Management Academy)

UNIVERSITY OF CENTRAL FLORIDA Stormwater Management ACADEMY "Managed Stormwater is Good Water"

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

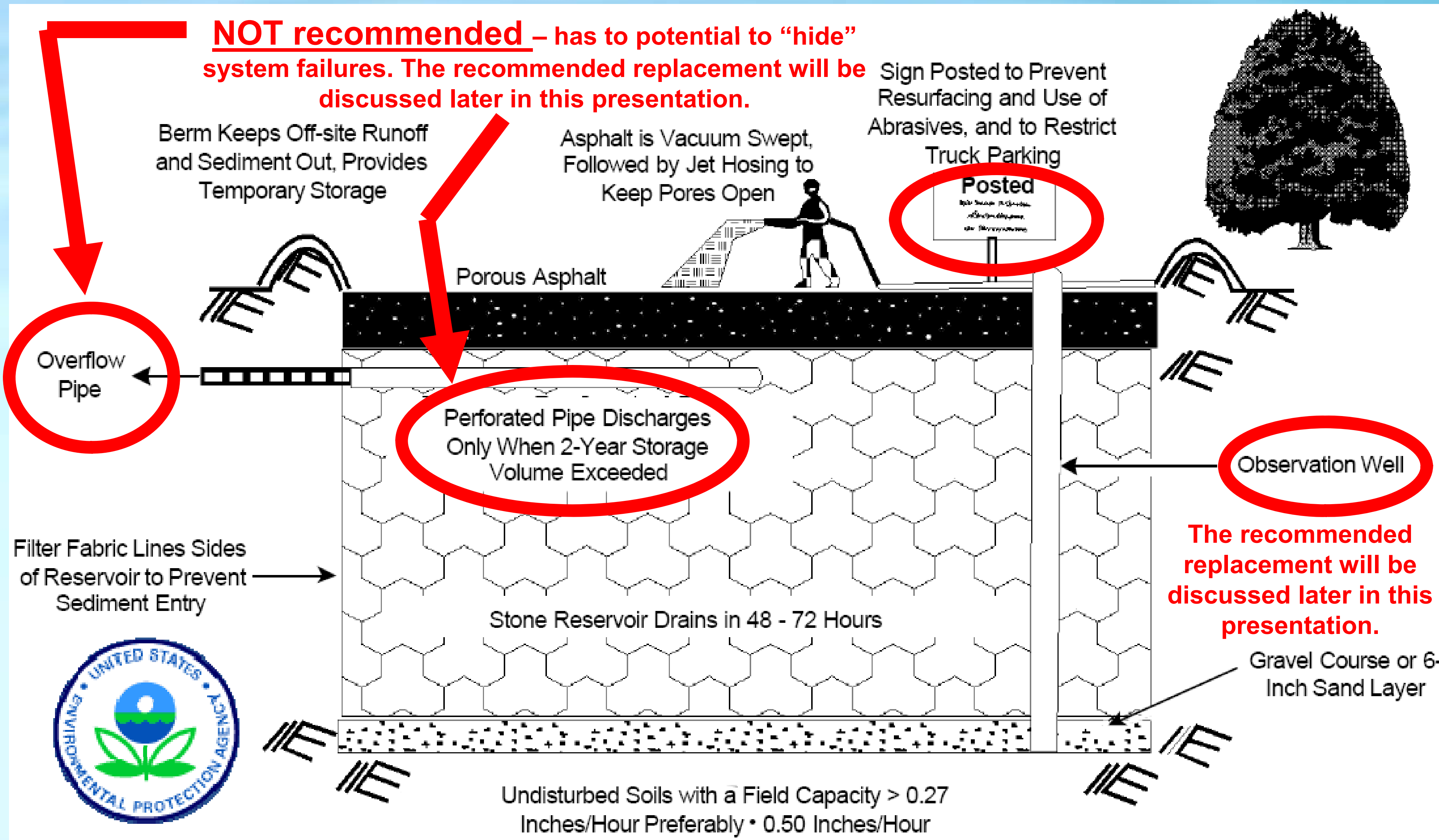
“Generic” Cross Section *

* Recommended cross sections to be shown later in this presentation.



Pervious Pavement Done Right

Typical Pervious Pavement Section



Source: Storm Water Technology Fact Sheet – Porous Pavement, EPA 832-F-99-023, September, 1999

http://yosemite.epa.gov/water/owrccatalog.nsf/9da204a4b4406ef885256ae0007a79c7/e60fc08b01f9edc385256d83004fd8ed!OpenDocument

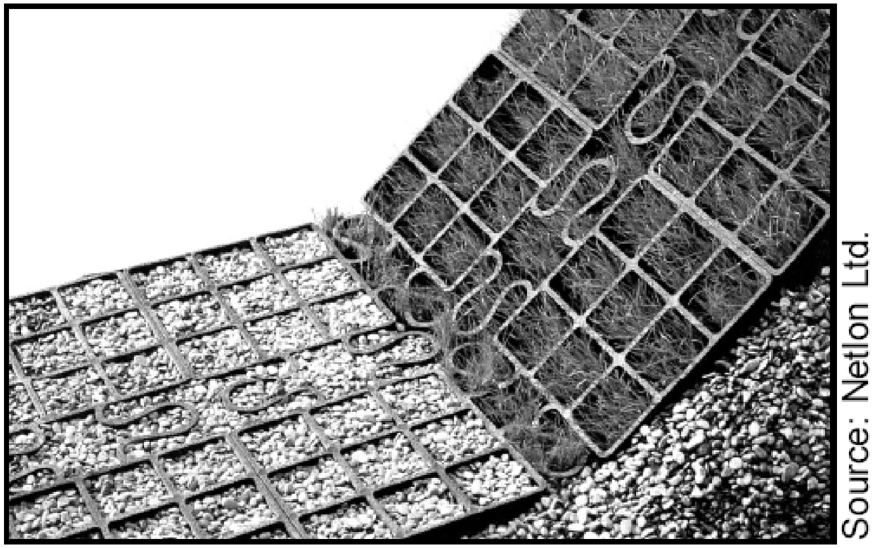
Typical Pervious Pavement Installation

Source of Graphic: Georgia Storm Water Management Manual, Section 3.3.7 – Porous Concrete

http://www.georgiastormwater.com/

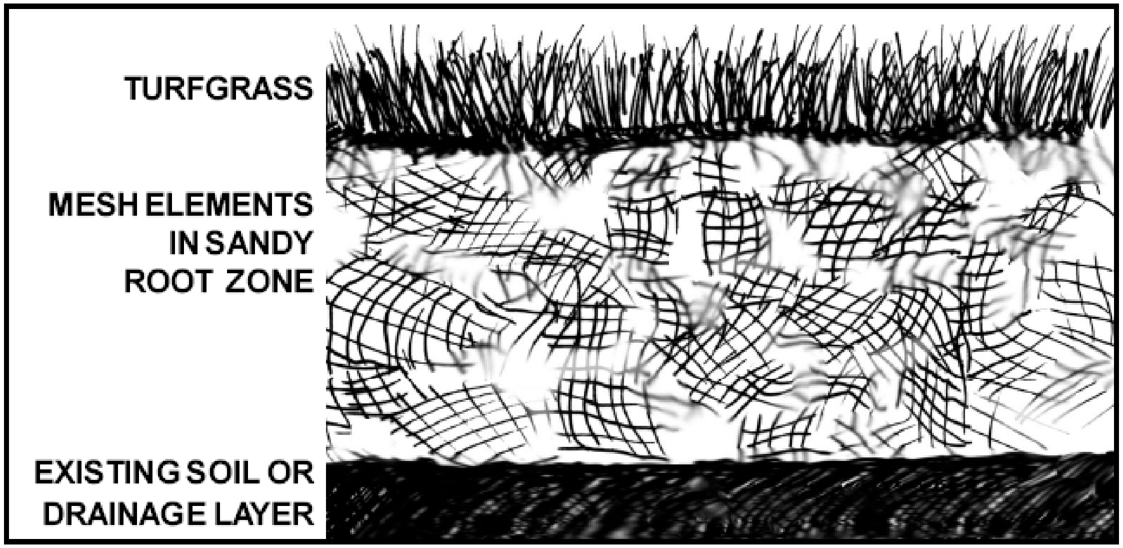
Additional Pervious Pavement System Installations

Figure 1



A modular polyethylene paving system, Netlon SG2000, shown with both gravel and turfgrass.*

Figure 2



Soil amendment technology: Synthetic mesh elements add load-bearing capacity to turf-covered areas.

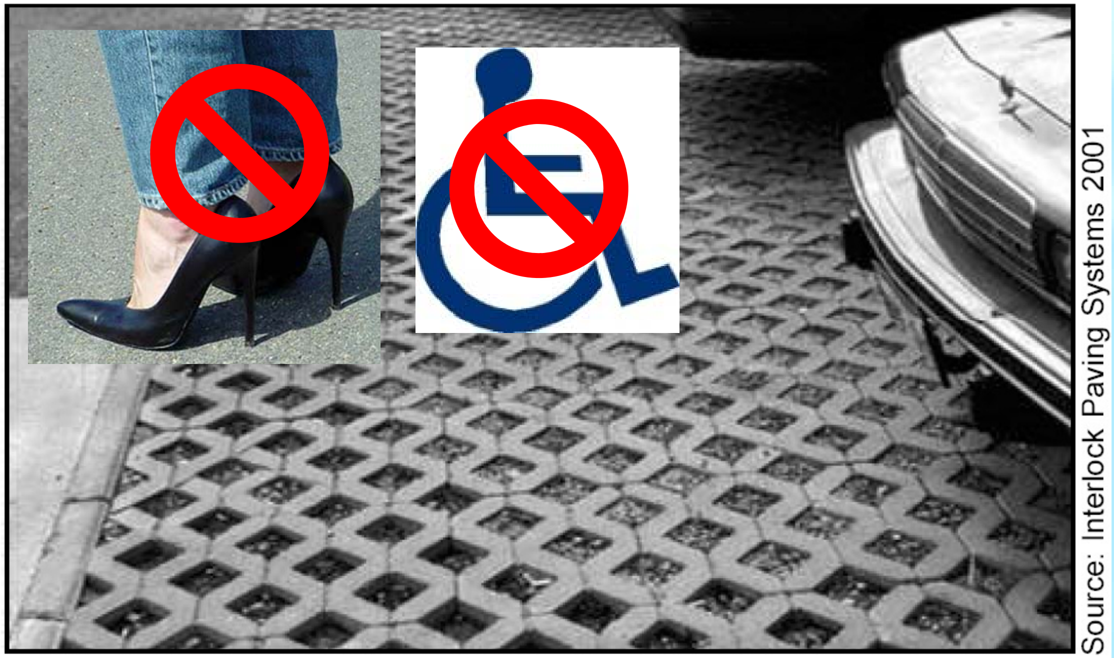


Figure 3: Modular Concrete Turfstone™ Pavers*

Source of Graphics: *Urban Small Sites Best Management Practice Manual – Turf Pavers*, from the Minnesota Urban Small Sites BMP Manual

http://www.metrocouncil.org/environment/Watershed/bmp/manual.htm

(be careful about Federal ADA requirements)

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

North Carolina DENR and NC State University publications

"To preserve, protect and enhance North Carolina's water..."

North Carolina DENR publications available at:

http://h2o.enr.state.nc.us/su/bmp_forms.htm
http://h2o.enr.state.nc.us/su/bmp_links.htm

NC State University publications available at:

http://www.bae.ncsu.edu/info/permeable-pavement/
http://www.bae.ncsu.edu/stormwater/pubs.htm
http://www.bae.ncsu.edu/stormwater/downloads.htm

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*", dated January, 2007

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

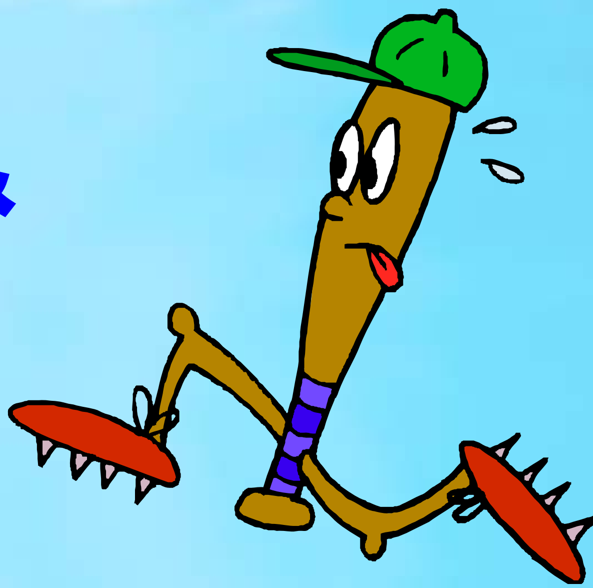
UCF research publications available at:

http://stormwater.ucf.edu/research_publications.asp

How & why pervious pavement will be important in the proposed statewide storm water Rule 62-347

Section 11.4 of FDEP's 03/05/08 *Stormwater Quality Applicant's Handbook*, available at:
http://www.dep.state.fl.us/water/wetlands/erp/rules/stormwater/rule_docs.htm

The carrot & stick approach.



Advantages of a “pervious pavement” design:

- One of the alternate Low Intensity Development (LID) “treatment train” methods to provide additional water quality retention volumes up-gradient of a wet detention pond.

- On small projects, can be used to retain the entire required water quality retention volume (additional construction costs $$$ may be incurred for this option).

- If additional $$$ are invested, can be used to reduce storm water runoff discharge rates (i.e. lower Curve Number or Rational “C” coefficient).

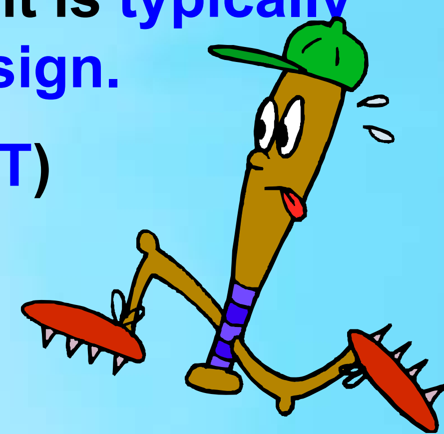
- An good LID choice for walkways, bike paths, pool / patio decks, etc.

- Can maximize land use and profit.

Disadvantages of a "pervious pavement" design:

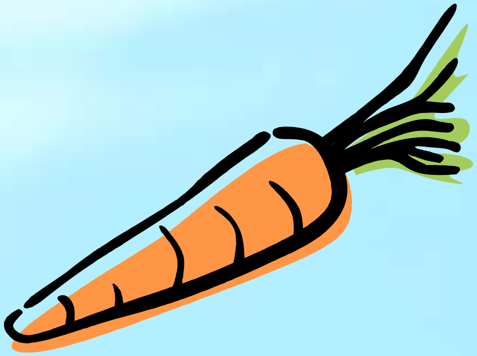
- **More costly** when compared to traditional asphalt & concrete pavements.
- **Difficult to build properly (specialized construction crews required).**
- **Requires more frequent maintenance** (sweeping & vacuuming of silts & sands to avoid plugging of pervious pavement void spaces).
- **Limited to "light duty" usages** (structural failures are more common with heavy wheel loads, or where lighter traffic makes frequent turning movements).
- **Off-site sediment** input must be minimized or eliminated.
- **Detention storage** (for flood control) **is more costly $$$.**
- Unless additional $$$ are invested, pervious pavement is **typically restricted to the same soil conditions as a "dry" pond design.**

  - i.e. **deep** Seasonal High Ground Water Table (**SHGWT**) **and confining unit** (clay / hardpan) **depths**.



Potential LID "treatment train" options to provide <u>additional</u> water quality retention volumes up-gradient of a wet detention pond.

See the next seven (7) slides



Missed Opportunity

Angled Parking lot for cars & light trucks

- ideal location for pervious pavement

Taking a Advantage of a LID Practice

Pervious pavement parking lot & driveway

Pervious concrete* pavement parking lot at the Florida Concrete Products Association facility in Orlando, Florida

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

http://www.fcpa.org/

Parking lot for cars & light trucks

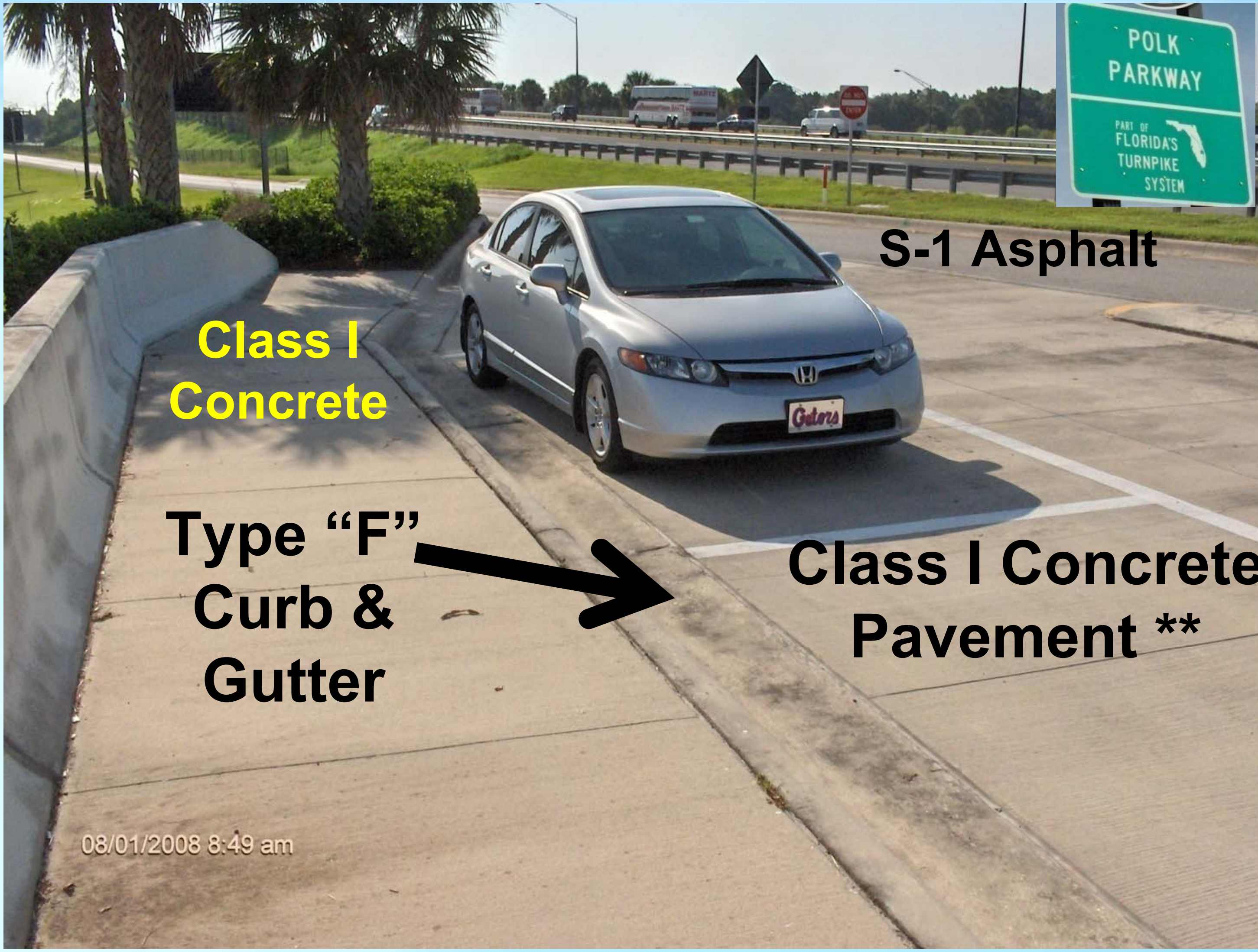
Potential** (Future) Opportunity

** If heavy wheel loads (or heavy traffic volumes) are expected, then pervious pavement is NOT a viable option.

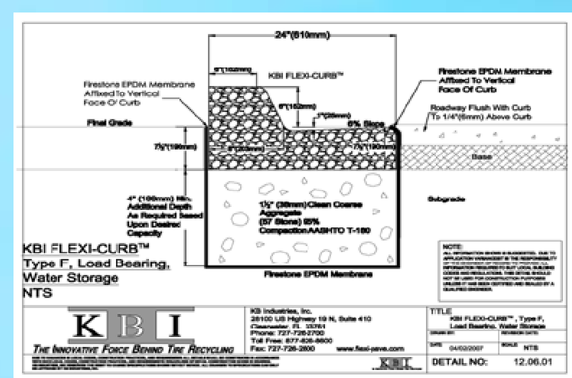
Access Ramp Parking Lot

- Potential ** location for pervious pavement

Potential** (Future) Opportunity



** If heavy wheel loads (or heavy traffic volumes) are expected, then pervious pavement is NOT a viable option.



Access Ramp Parking Lot

- Potential ** location for pervious pavement, pervious sidewalk and pervious curb & gutter *

http://www.kbius.com

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

Potential (Future) Opportunity

Current UCF research is showing that these pervious brick pavers are working well in terms of load bearing and infiltration.

Streetscape Projects

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

- ideal location for pervious brick pavers

Taking a Advantage of a LID Practice

Flexi™-Pave * is available in many colors
http://www.kbius.com

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

Pedestrian walks & Bicycle Trails

- ideal locations for pervious pavement

Taking a Advantage of a LID Practice

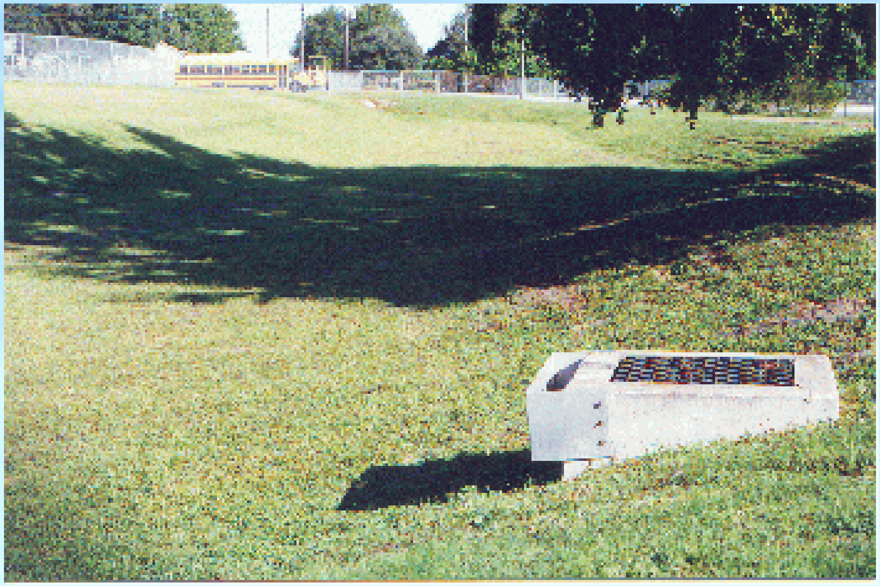
Flexi™-Pave * Sidewalk Installation

http://www.kbius.com

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

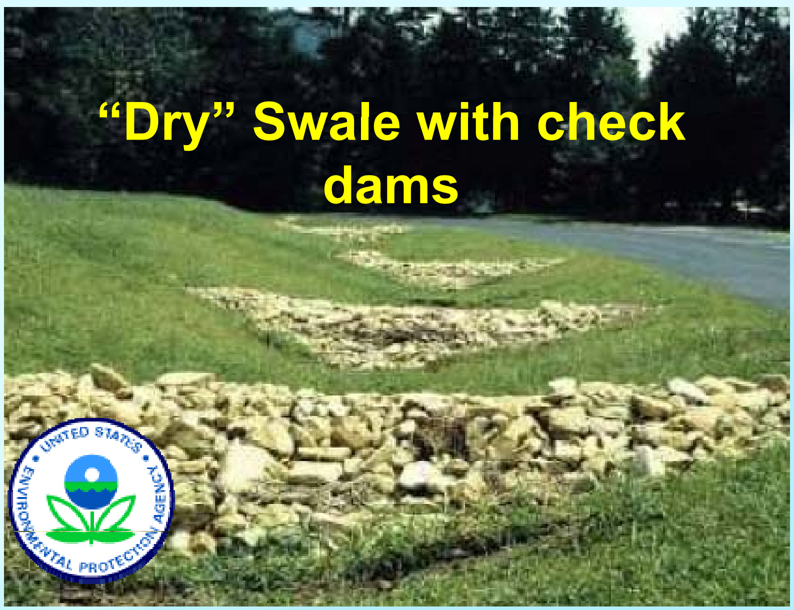
The Basics of Retention System Designs

Typical Retention System Designs

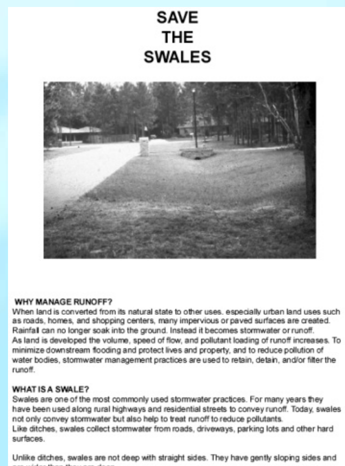


"Dry" storm water pond

Underground Exfiltration Trench



Storm water Best Management Practice Design Guide, Volume 2, Vegetative Bio-filters
http://www.epa.gov/ORD/NRMRL/pubs/600r04121/600r04121.htm



SAVE THE SWALES

WHY MANAGE RUNOFF?
When land is converted from its natural state to other uses, especially urban land uses such as roads, homes, and shopping centers, many impervious or paved surfaces are created. Rainfall can no longer soak into the ground. Instead it becomes stormwater or runoff.
As land is developed the volume, speed of flow, and pollutant loading of runoff increases. To minimize downstream flooding and protect lives and property, and to reduce pollution of water bodies, stormwater management practices are used to retain, detain, and/or filter the runoff.

WHAT IS A SWALE?
Swales are one of the most commonly used stormwater practices. For many years they have been used along rural highways and residential streets to convey runoff. Today, swales not only convey stormwater but also help to treat runoff to reduce pollutants.
Like ditches, swales collect stormwater from roads, driveways, parking lots and other hard surfaces.

Unlike ditches, swales are not deep with straight sides. They have gently sloping sides and are wider than they are deep.

"Save the Swales" brochure from FDEP

http://www.dep.state.fl.us/water/nonpoint/pubs.htm#Urban_Stormwater_BMP_Research_Reports

Four critical components for the successful <u>DESIGN</u> of a surface water management system

- **ACCURATE Topographic Survey**
- **ACCURATE Soils data (SHGWT, Kv, & Kh)**
- **ACCURATE Tailwater Information (Stage / Time data in receiving water body)**
- **ACCURATE identification of Hydric soils and wetlands**

The majority of storm water management system *DESIGN* FAILURES are due to:

- Improperly estimated Seasonal High Ground Water Table (SHGWT) depths
- Improperly estimated Tail Water elevations

First things First

Obtain ACCURATE Soils data

The *"Tail that wags the Dog"* in regard to designing retention systems.

SHGWT & confining unit depths, and horizontal & vertical hydraulic conductivity (Kv & Kh) rates at the correct depths.

Annual SWFWMD soils & SHGWT workshop

A cooperative training effort with the Federal Natural Resources Conservation Service (NRCS)

USDA NRCS
United States Department of Agriculture
Natural Resources Conservation Service

Proper identification of soils and estimation of Seasonal High Ground Water Table (SHGWT) depths are important tasks in the design of functional surface water management systems. Persons involved in geotechnical investigation and design of surface water management systems are invited to attend these workshops.

Web soil survey information is available at:
http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

Legacy (hard copy) soil surveys available at:
http://soils.usda.gov/survey/printed_surveys/

Since 1989, each workshop has covered the determination of SHGWT elevations in natural, pre-developed conditions.

2009 SWFWMD soils workshop

On-line registration for the 2009 workshops can be accessed through the following URL:

http://www.swfwmd.state.fl.us/calendar/conferences/

Conferences, Seminars & Workshops

21st Annual Workshop
Methods for Identifying Soils & Determining Seasonal High Groundwater Table Depth

Web registration available:
December 15, 2008 at 8 a.m.

Listings:

- Methods for Identifying Soils & Determining Seasonal High Groundwater Table Depth
- Growth Management, Energy, Climate Change and the Environment

View Meetings & Events Calendar

Agenda • Dates & locations • Registration • Misc. details • Questions

To be placed on our mailing list for next year's (2010) workshops, please contact the Strategic Program Office, Resource Regulation Division, at the District's Brooksville headquarters. The telephone numbers are:

800-423-1476, x4336 (Florida Only)
352-796-7211, x4336 (Local)
SunCom 628-4336

United States Department of Agriculture
Natural Resources Conservation Service

Additional source of information in estimating depths to the SHGWT

ESTIMATING THE NORMAL SEASONAL HIGH GROUNDWATER TABLE: A MIX OF ART & SCIENCE

by

Devo Seereeram, Ph.D., P.E.
Consulting Geotechnical Engineer; dseereeram1@cfl.rr.com
5500 Alhambra Drive, Orlando, Fl 32808
April 1993

The above paper is available at:

http://www.devoeng.com/memos/paper_on_estimating_SHWT.pdf

The above referenced paper is courtesy of Devo Seereeram, P.E., Ph.D.

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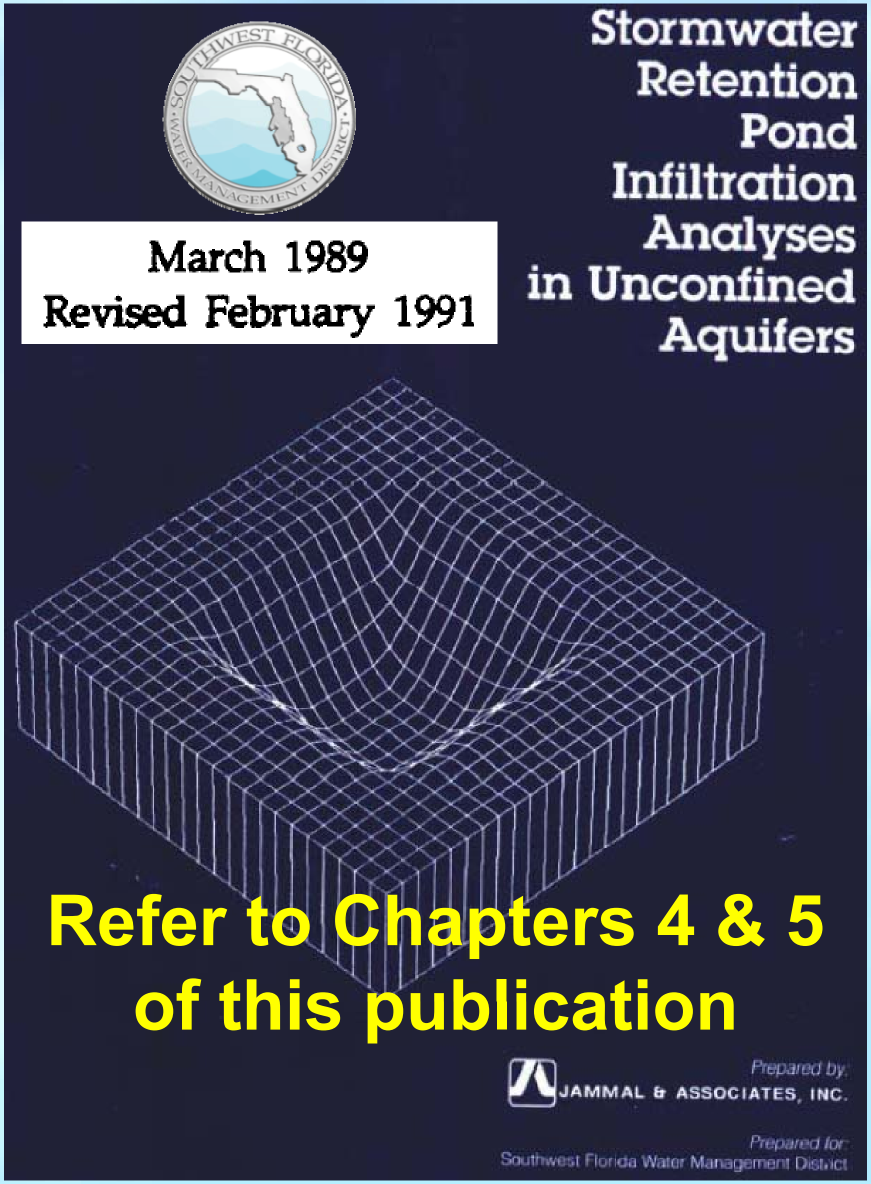
Mounding (recovery) analysis of the required retention volume

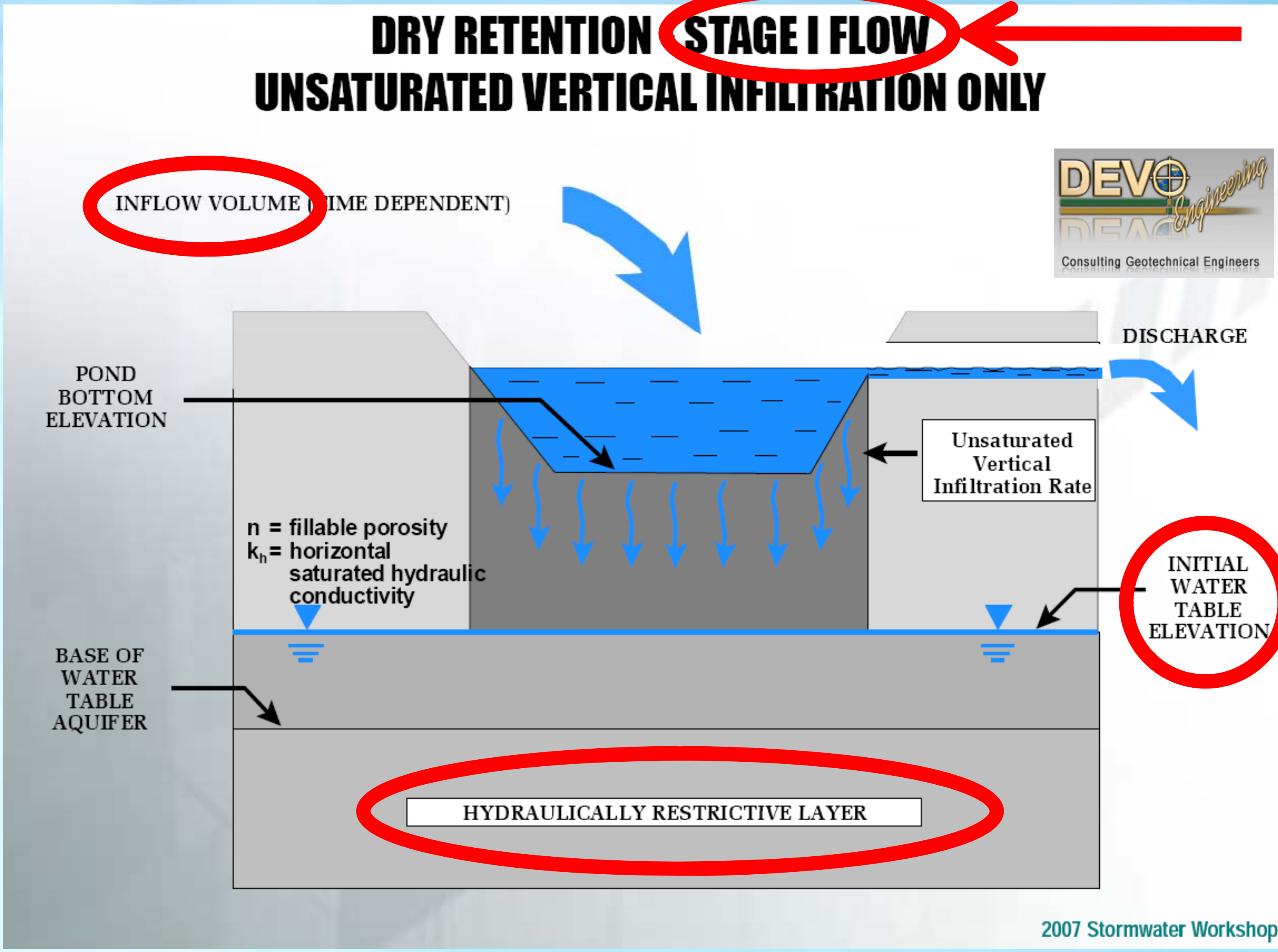


Refer to Chapters 4 & 5 of this publication

A significant percentage of engineering consultants utilize the PONDS© *, Modret© *, or ICPR© * software packages to perform this analysis.

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

Mounding (recovery) analysis of the required retention volume



"Dry" ponds & swales, underground exfiltration trenches and pervious pavement

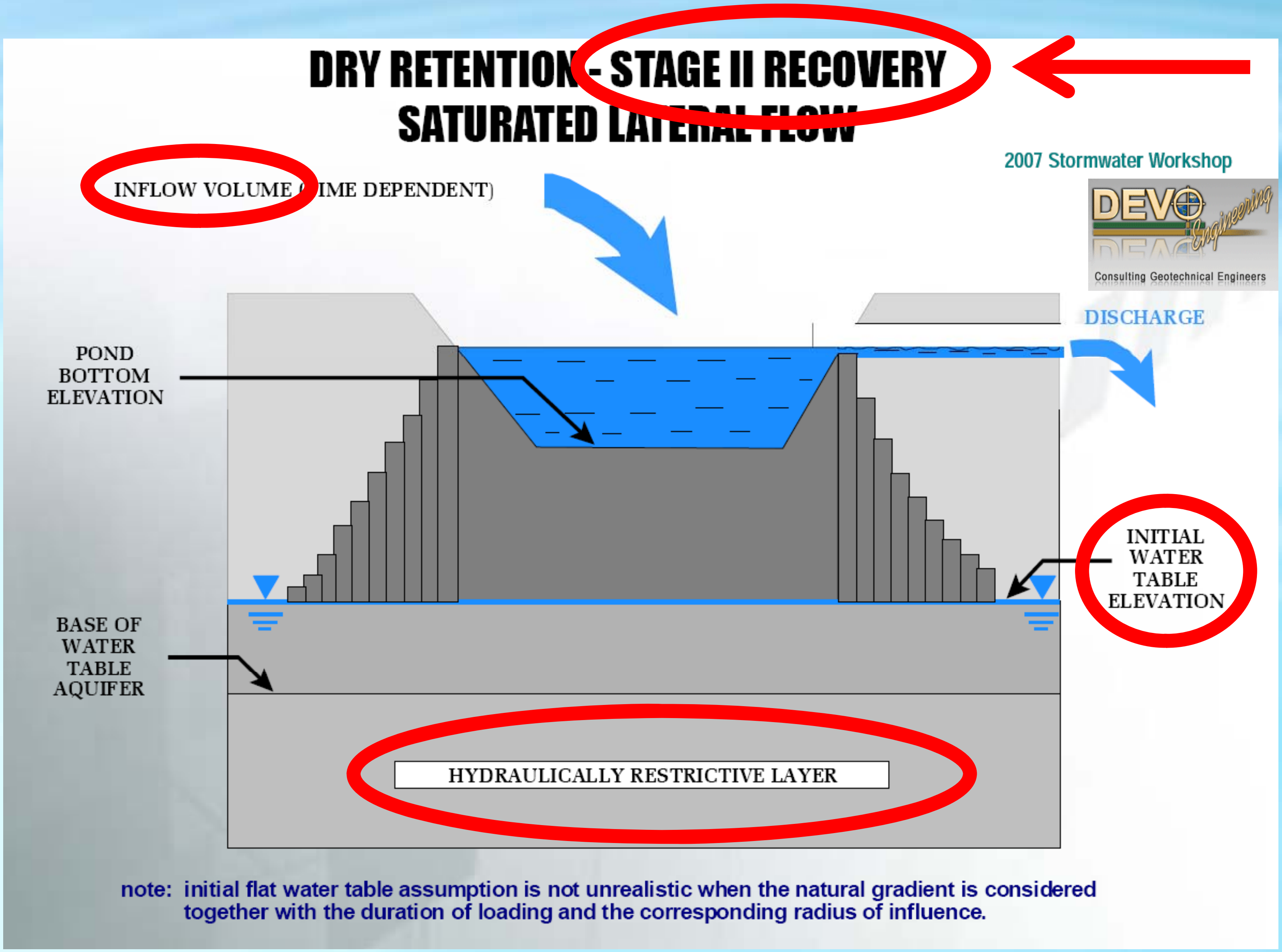
Graphic courtesy of Devo Seereeram, P.E., Ph.D.

– used with permission

Devo Engineering - Orlando, Florida

http://devoeng.com/

Mounding (recovery) analysis of the required retention volume



"Dry" ponds & swales, underground exfiltration trenches and pervious pavement

Graphic courtesy of Devo Seereeram, P.E., Ph.D.

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Devo Engineering - Orlando, Florida

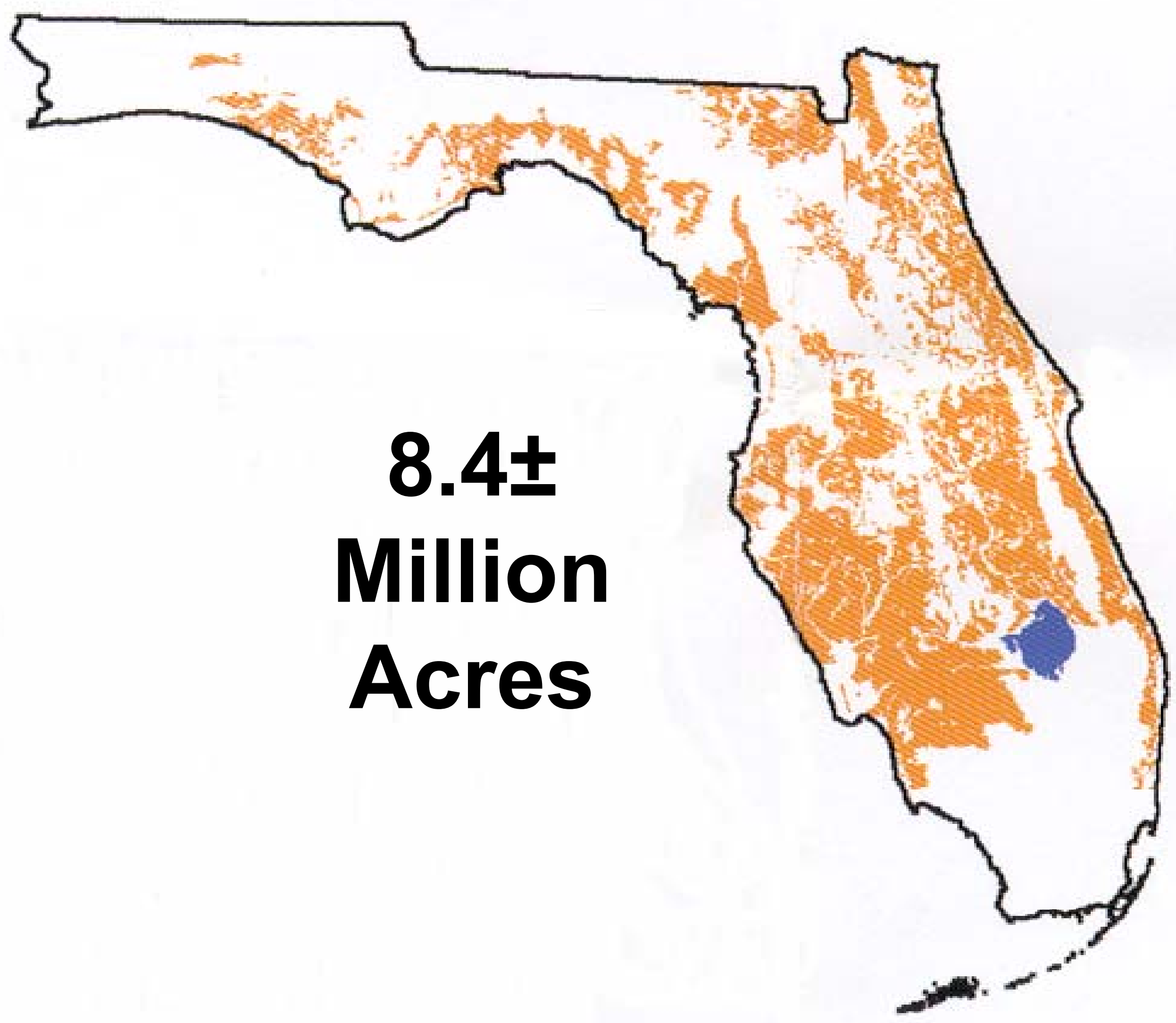
http://devoeng.com/

The issue of placing pervious pavement systems over HSG "B/D" soils.

For both storm water QUALITY and QUANTITY computations.

Generalized location map of Spodosols (i.e. Pine Flatwoods)

Not for site specific use. Refer to the County Soil Surveys for more detailed information.



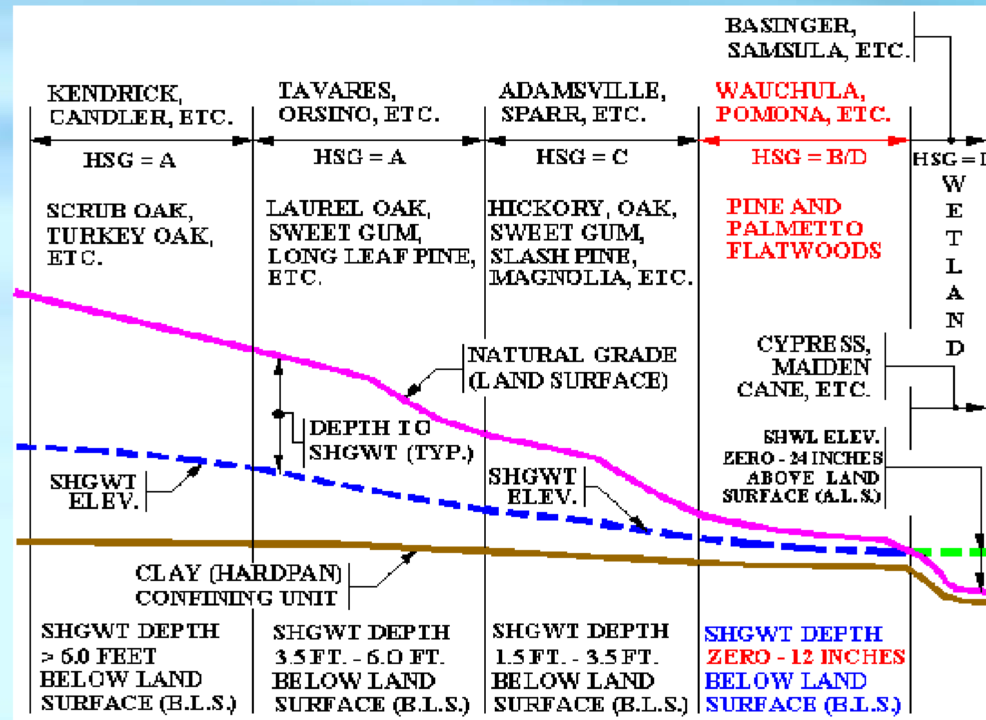
Most of the "good" land in central and south Florida has already been developed. What is left is wetlands, flood plains and Pine Flatwoods soils - with a SHGWT depth of 0" to 12" Below Land Surface (B.L.S.).

USDA NRCS
United States Department of Agriculture
Natural Resources Conservation Service

Pomona soil, HSG = B/D

SHGWT depth 0 inches - 12 inches Below Land Surface (B.L.S.)

Typical pine flatwoods soil. Pomona is a <u>poorly drained</u> soil, with a SHGWT elevation at (or near) the surface.



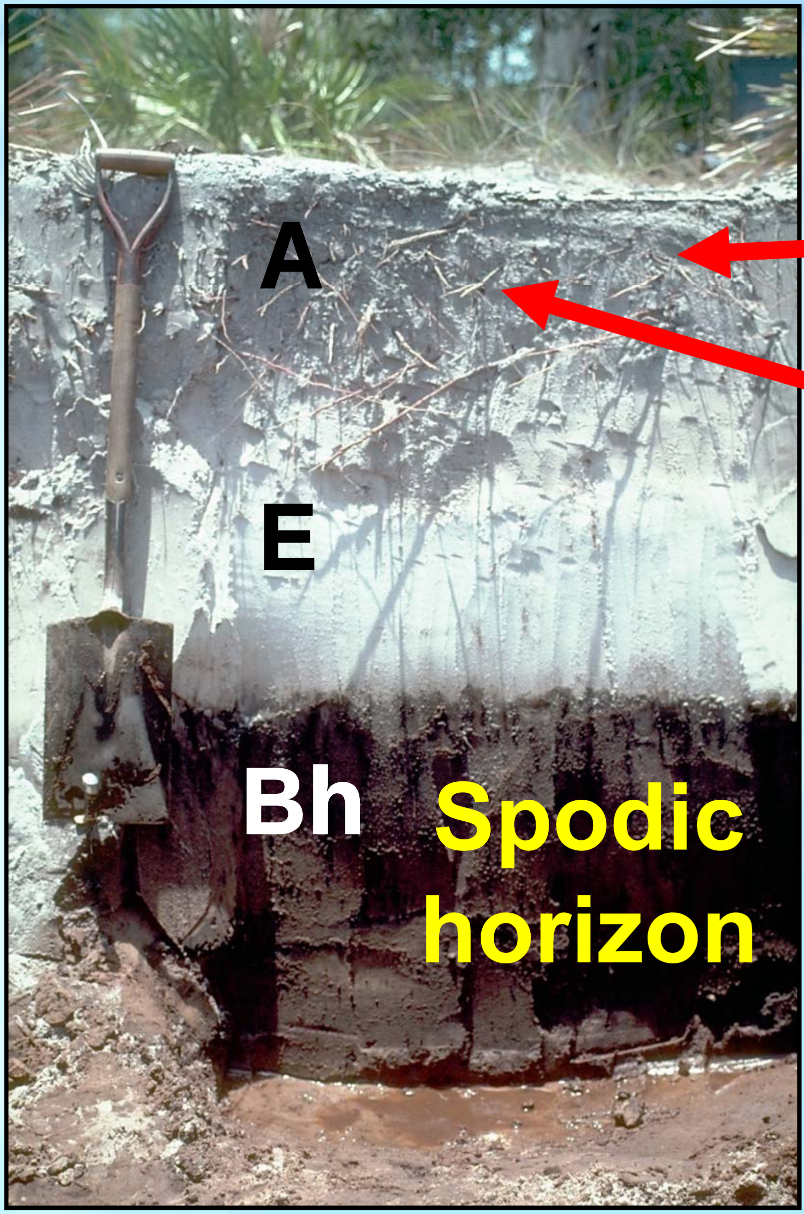
Moving farther down gradient in regard to landscape position.

Refer to the reference material handouts for a copy of the SWFWMD Training Memorandum entitled *"USDA- NRCS Hydrologic Soil Groups and Development Effects"*. <u>For the vast majority of cases, a B/D soil should be considered as a HSG = D</u>.

Immokalee sand, HSG = B/D

SHGWT depth 0 inches - 12 inches B.L.S.

Color soil profile



Notice that all of the roots are concentrated at the surface.

"Grey" colors indicate wetness.

A horizon: Surface layer containing organic matter.
E horizon: Leached horizon between the A and B horizons.
B horizon: Zone of accumulation of material leached from the A and B horizons.
C horizon: Layer not affected by soil forming processes.

Special Definition of Soils With Variable HSG Classifications (i.e. A/D, B/D, etc.)

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT
RESOURCE REGULATION
TRAINING MEMORANDUM

This document is subject to change. If in doubt, verify current status with Technical Services staff or the author(s).

DATE: January 15, 1997

SUBJECT: TM/ERP - 970116.b1
USDA-NRCS Hydrologic Soil Groups and Development Effects

TO: Surface Water Managers and Staff

FROM: Charlie H. Miller, P.E., Chief Regulation Engineer, Technical Services

THIS TRAINING MEMORANDUM MUST NOT BE CONSIDERED AS DISTRICT POLICY. PERMIT APPLICATIONS MUST BE ISSUED OR DENIED SOLELY ON DISTRICT RULE CRITERIA AND STATE STATUTE AUTHORITY. THE PURPOSE OF THIS DOCUMENT IS TO PROVIDE GENERAL GUIDANCE AND TRAINING FOR REGULATION REVIEW BY DISTRICT STAFF. THE GUIDELINES SET FORTH HEREIN MAY BE MODIFIED IN APPROPRIATE CIRCUMSTANCES.

District Training Memorandum

Refer to the next two slides for a copy of the SWFWMD Training Memorandum entitled *"USDA- NRCS Hydrologic Soil Groups and Development Effects"*. For the vast majority of cases, a B/D soil should be considered as a HSG = D.

Some soils are listed in the NRCS Soil Surveys as being in more than one HSG. Such soils (indicated as A/D or B/D) are in HSG D in their natural (pre-developed) condition because of high water table conditions that create drainage impedance. If these soils can be effectively drained (and properly maintained) they may be reclassified in a different HSG. For instance, an Ona soil is classified as HSG B/D. This indicates that effectively drained (and maintained) Ona soil can be reclassified as high as HSG B, but it can not be HSG A.

Special Definition of Soils With Variable HSG Classifications (i.e. A/D, B/D, etc.)

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT
RESOURCE REGULATION
TRAINING MEMORANDUM

> This document is subject to change. If in doubt, verify current status with Technical Services staff or the author(s).

DATE: January 15, 1997

SUBJECT: TM/ERP - 970116.b1
USDA-NRCS Hydrologic Soil Groups and Development Effects

TO: Surface Water Managers and Staff

FROM: Charlie H. Miller, P.E., Chief Regulation Engineer, Technical Services

---

THIS TRAINING MEMORANDUM MUST NOT BE CONSIDERED AS DISTRICT POLICY. PERMIT APPLICATIONS MUST BE ISSUED OR DENIED SOLELY ON DISTRICT RULE CRITERIA AND STATE STATUTE AUTHORITY. THE PURPOSE OF THIS DOCUMENT IS TO PROVIDE GENERAL GUIDANCE AND TRAINING FOR REGULATION REVIEW BY DISTRICT STAFF. THE GUIDELINES SET FORTH HEREIN MAY BE MODIFIED IN APPROPRIATE CIRCUMSTANCES.

BACKGROUND: This procedure provides guidelines to Surface Water Permitting staff regarding the identification of NRCS Hydrologic Soil Groups and interpretation of the effects or changes to soil drainage due to certain development practices.

DESCRIPTION:

Procedure - The NRCS classifies soils into Hydrologic Soil Groups (HSG's) according to their runoff producing characteristics. HSG's, indicated as A, B, C and D; are used along with hydrologic condition and land cover type in determining runoff curve numbers. HSG indicates the infiltration rate at which water enters bare, saturated soil; and transmission rate, the rate at which water moves within the soil. NRCS defines four HSG's as follows:

Group A Soils have a high infiltration rate when wet and have a low runoff potential. They are usually deep, well drained sands.

Group B Soils have moderate infiltration rates and consist mainly of moderately deep, moderately well drained and moderately fine textures.

Group C Soils have low infiltration rates when wet and largely include soils with a layer that restricts downward movement of water, along with soils having moderately fine to fine textures.

Group D Soils have a very slow infiltration rate and high runoff potential. They mainly include soils having a high water table, a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious material such as bedrock.

Some soils are listed in NRCS Soil Survey information as being in more than one HSG. Such soils, indicated as A/D or B/D, are naturally in HSG D because of high water table conditions that create drainage impedance. If these soils can be effectively drained, they may be reclassified in a different HSG. For instance, an Ona soil is classified as HSG B/D. This indicates that effectively drained Ona soil can be reclassified as high as HSG B, **but it can not be HSG A**.

Effective soil drainage means having positive surface drainage, without residual depression storage, together with a designed subsurface drainage system. The subsurface drainage system must have an adequate outlet which is properly installed and **maintained** with a removal rate of at least 0.5 inches/day for vegetable farming and 0.75 inches/day for citrus. Higher removal rates may be required for other land uses and site conditions.

Process - The following empirical guidelines, when applied cautiously, may be used to estimate changes in HSG resulting from effective soil drainage and lowering of the seasonal high ground water table (SHGWT).

Due to effective soil drainage, existing undrained A/D soils may change HSG as follows:

SHGWT effectively drained 2 to 3 feet below land surface may change HSG from D to C;

SHGWT effectively drained 3 to 4 feet below land surface may change HSG from D to B;

SHGWT effectively drained greater than 4 feet below land surface may change HSG from D to A.

Cautions: The above listed guidelines are limited as follows:

1. Changes in HSG classification due to effective soil drainage and lowering of the SHGWT must be justified on a site specific basis; and must be assured perpetually by proper design, construction, operation and **maintenance** of the surface water management system.

2. Effective soil drainage and lowering of the SHGWT must be designed to function in accordance with Basis of Review Section 3.2.1.6, Overdrainage and Water Conservation, and other applicable regulations.

3. Only soils listed with variable HSG's (i.e. A/D, B/D) can change HSG.

Special Definition of Soils With Variable HSG Classifications (i.e. A/D, B/D, etc.)

4. An effectively drained soil shall in no case be reclassified to exceed the fully drained classification; for example, a HSG B/D soil can be effectively drained to become no better than HSG B.

5. Where subsurface drain tubing is used to create effective drainage in soil containing iron, which has a high potential for plugging of subsurface drains (by iron ochre), the alphabetically next lower HSG should be used; unless specific assurances of proper subsurface drain operation and **maintenance** are adequately provided by the land/system owner. See the USDA-NRCS Florida Drainage Guide for soils in this category.

Conversely, filling an effectively drained development site having existing HSG A soil with fill soil having native HSG B or lower (i.e., C or D) could cause the post-development filled site soil to be reclassified HSG B, C or D, depending on the fill soil(s) native HSG. Such filling should normally be avoided.

REFERENCES:

1. Chapters 120.54(8), 373.004. 373.046, 373.113. 373.171, and 373.414, Florida Statutes

2. Rule 40D-4.091(1), "Basis of Review."

3. USDA-NRCS, Technical Release 55, "Urban Hydrology for Small Watersheds" - June 1986.

4. USDA-NRCS, ENG - TECHNICAL RELEASE NO. 55 - Appendix A, June 1, 1989.

5. USDA-NRCS, "Florida Drainage Guide" - October 1980.

6. USDA-NRCS, "National Engineering Handbook, Section 4 - Hydrology" - 1964.

STATUS: Reclassified and revised in format only: formerly IOP/SWP-031 and SWP-021under similar names.

DISTRIBUTION: Executive, General Counsel, Resource Regulation Directors, Technical Services, Processing and Records, Permit Records & Data, Administrative Supervisors, Permit Coordinators, Central Records

AUTHOR: **Charlie Miller, P.E., Chief Regulation Engineer, Technical Services**

(seal)

Original document was signed and sealed on 01/15/97

____

Charles H. Miller, P.E.
Florida Registration No. 13205
Date: __________

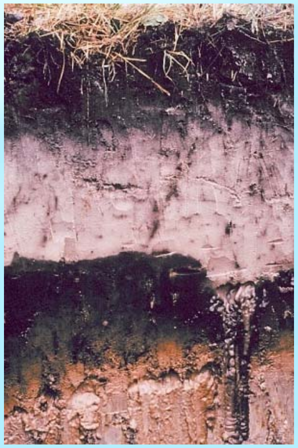
WordPerfect® file name: TM970116-b1-USDA-NRCS-hydrologic-soil-groups-and-development-effects.wpd

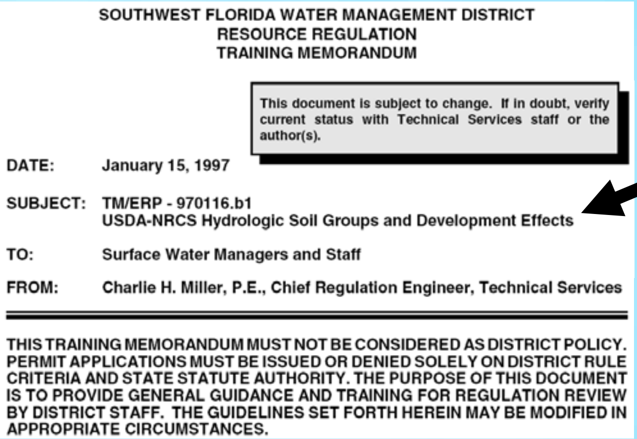
District Training Memorandum on B/D soils

Importing HGS "A" soils over HSG "B/D" soils

to provide additional clearance from the proposed finished grades to the historical SHGWT elevations.

B/D soils





SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT
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District Training Memorandum

Fluctuation of the SHGWT in HSG "B/D" Soils

Water Table Fluctuation in Representative Immokalee and Zolfo Soils of Florida

by **Adam G. Hyde and Richard D. Ford (former or current NRCS Soil scientists). This is an excellent paper detailing the fluctuation of the SHGWT in Florida Pine Flatwoods soils from 1977 to 1986.**

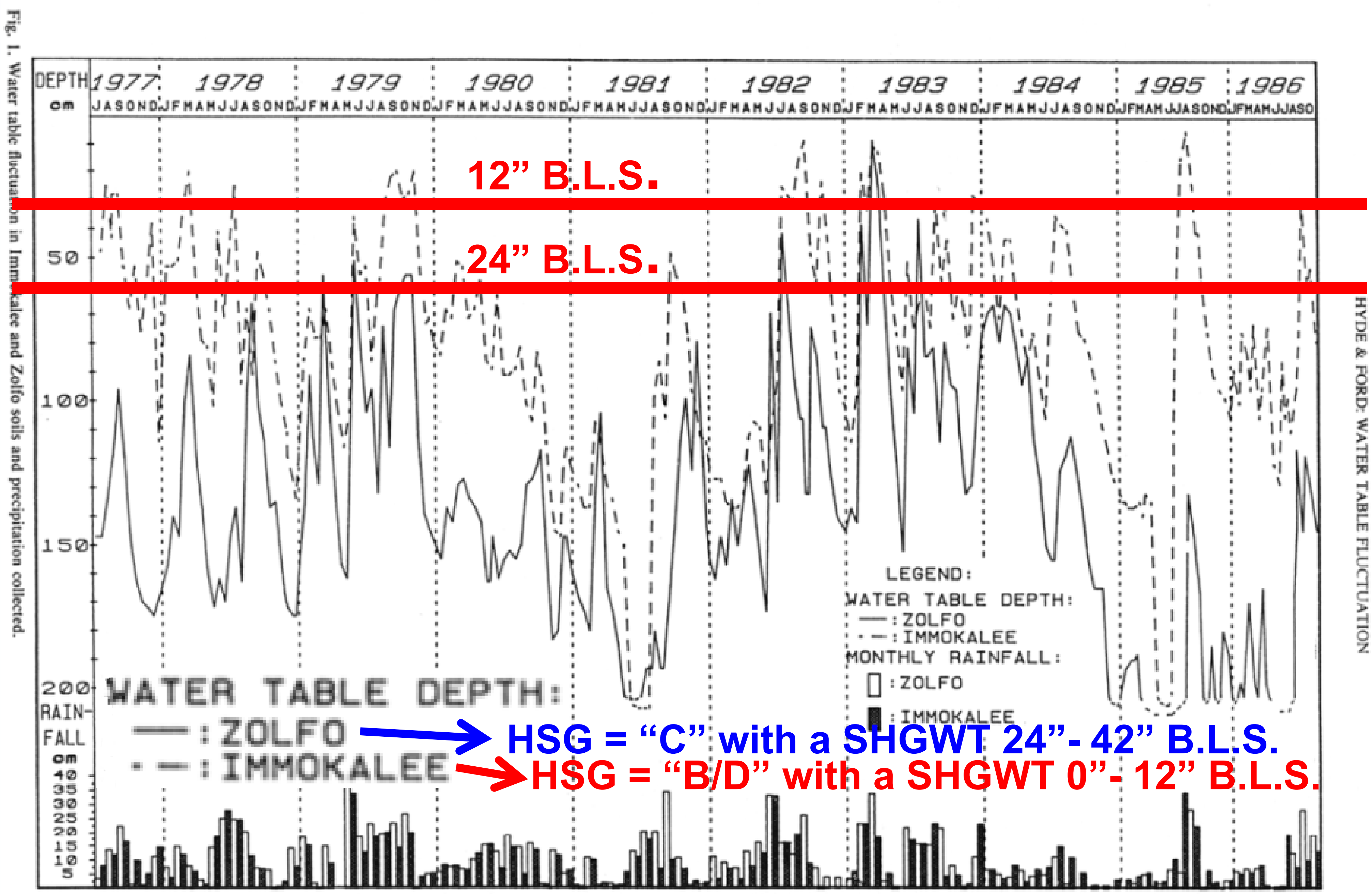
Available on line at:

http://soil.scijournals.org/cgi/content/abstract/53/5/1475

Zolflo are somewhat poorly drained soils, HSG = "C" with a SHGWT depth of 24"- 42" B.L.S.

Immokalee are poorly drained soils, HSG = "B/D" with a SHGWT depth of 0"- 12" B.L.S.

Fluctuation of the SHGWT in HSG “B/D” Soils



Shallow Monitoring Well,

Embedded Ring Infiltrometer Kit (ERIK),

Potential Pervious Pavement Cross Sections

and Recommendations

Shallow monitoring well (for groundwater levels) at the edge of the pervious pavement test sites

The concrete block is used to cover (and protect) the PVC well casing.

AutoCAD® drawing of the Monitoring Well

Insert this drawing (when available) from Erik Stuart (UCF)

http://stormwater.ucf.edu/

Embedded Rings in the pervious pavement

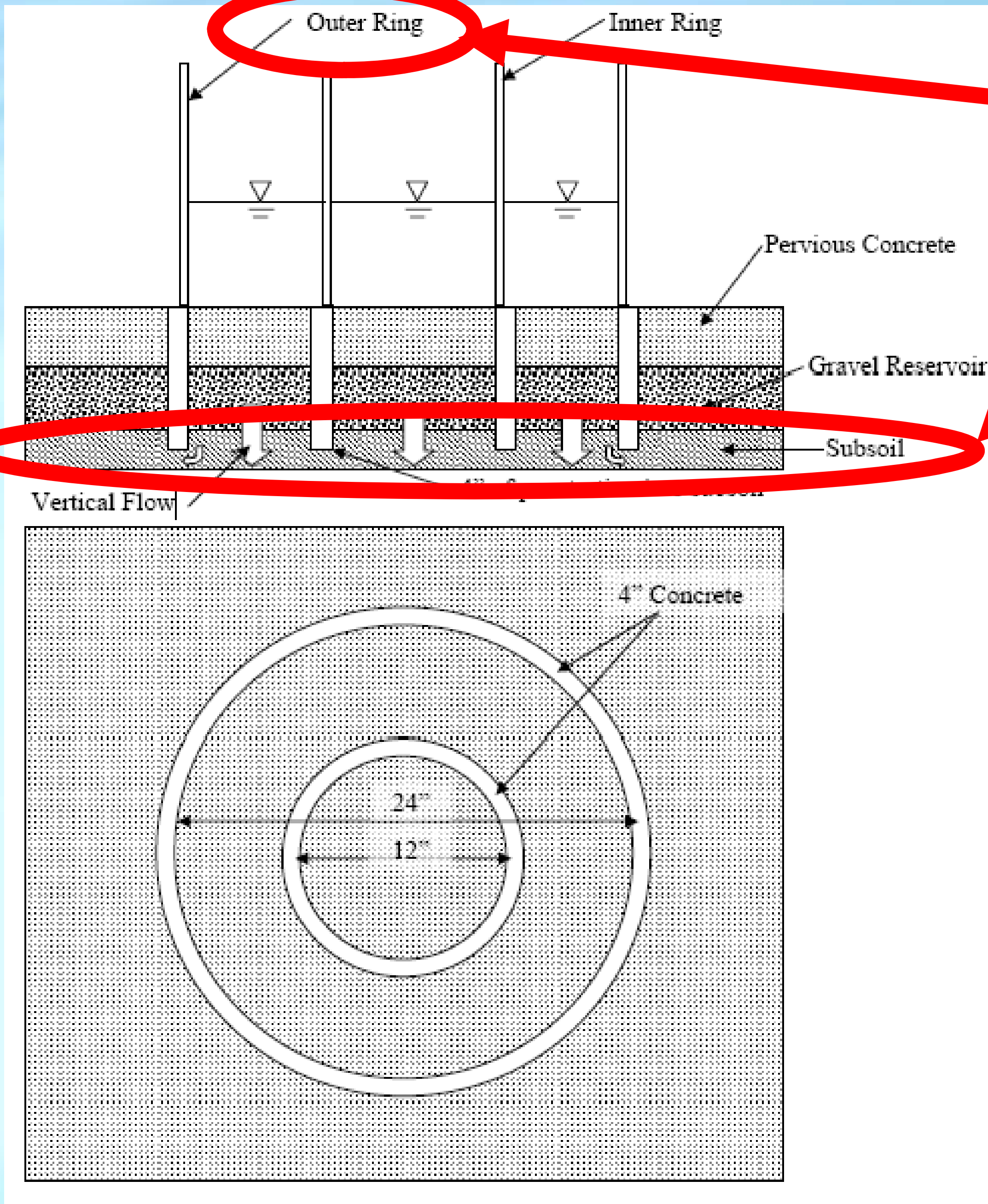
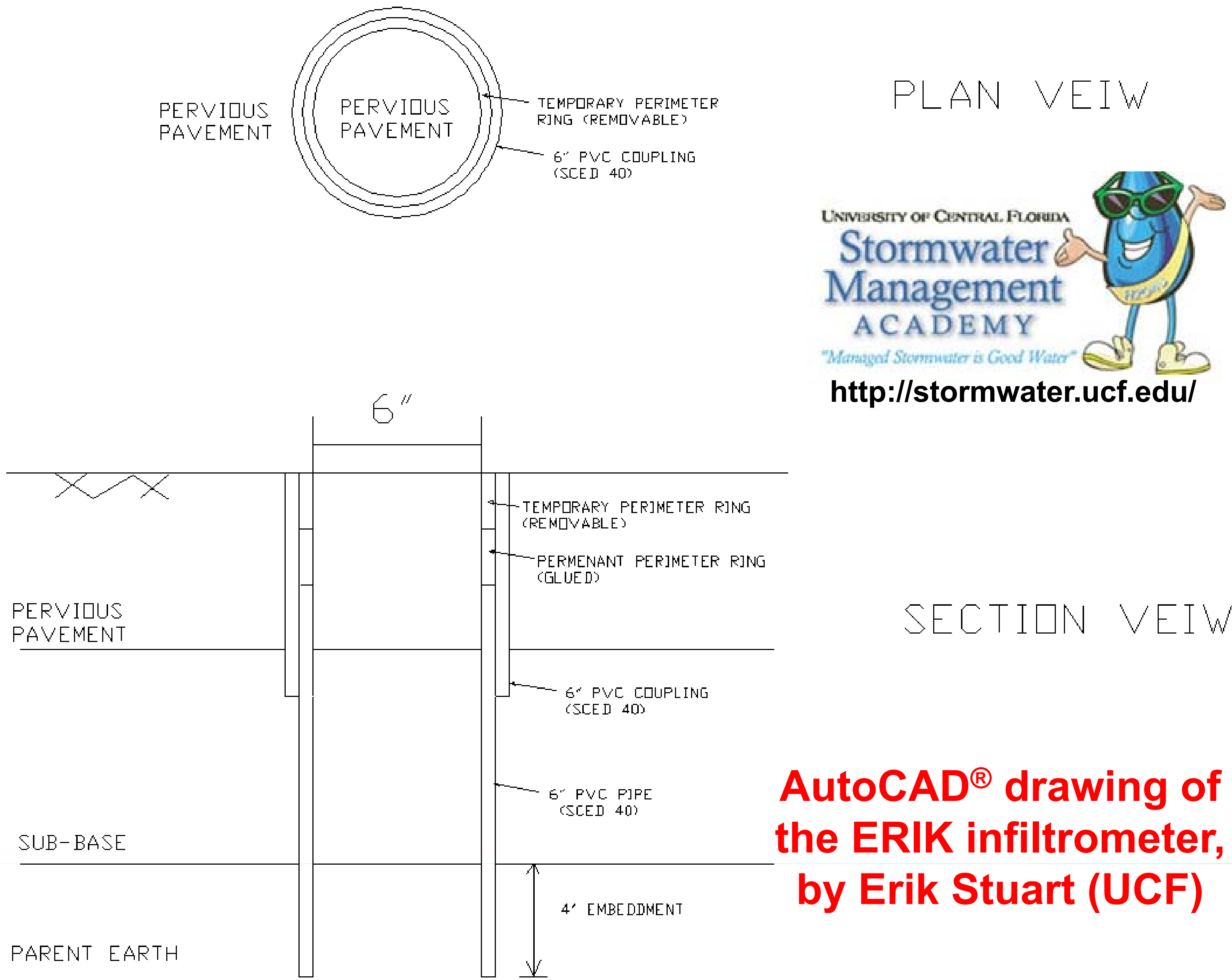


Figure 42: Design profile for Embedded Infiltrometer installation

A single ring ERIK infiltrometer is acceptable provided that is embedded into the subsoil as shown in Figure 42 (see the next slide for additional information).

For more information on this in-situ infiltration monitor (ERIK), refer to the UCF research paper entitled "*Construction and Maintenance Assessment of Pervious Concrete Pavements - Final Draft*", dated January, 2007, available at: http://stormwater.ucf.edu/research_publications.asp

Embedded (ERIK) infiltrometer in the pervious pavement



University of Central Florida Stormwater Management Academy "Managed Stormwater is Good Water"

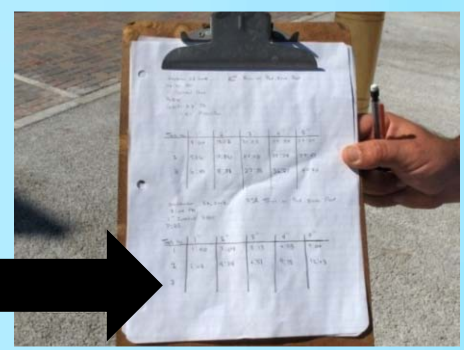
http://stormwater.ucf.edu/

AutoCAD® drawing of the ERIK infiltrometer, by Erik Stuart (UCF)

Embedded Ring Infiltrometer Kit (ERIK)

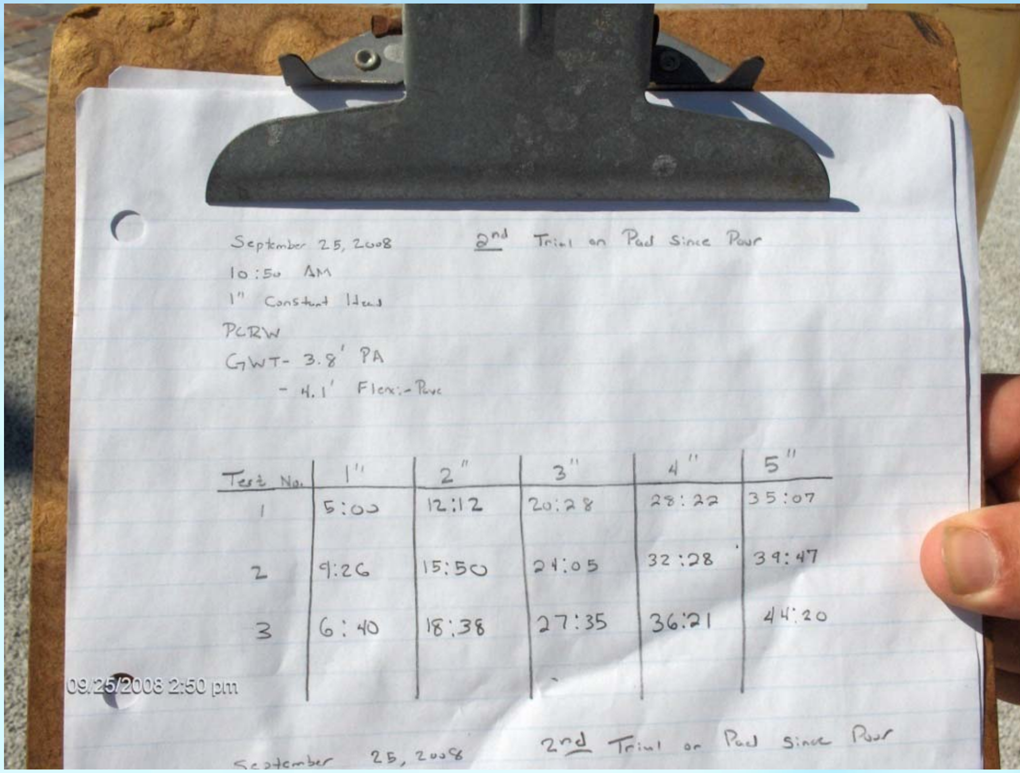
University of Central Florida
Stormwater Management ACADEMY
"Managed Stormwater is Good Water"

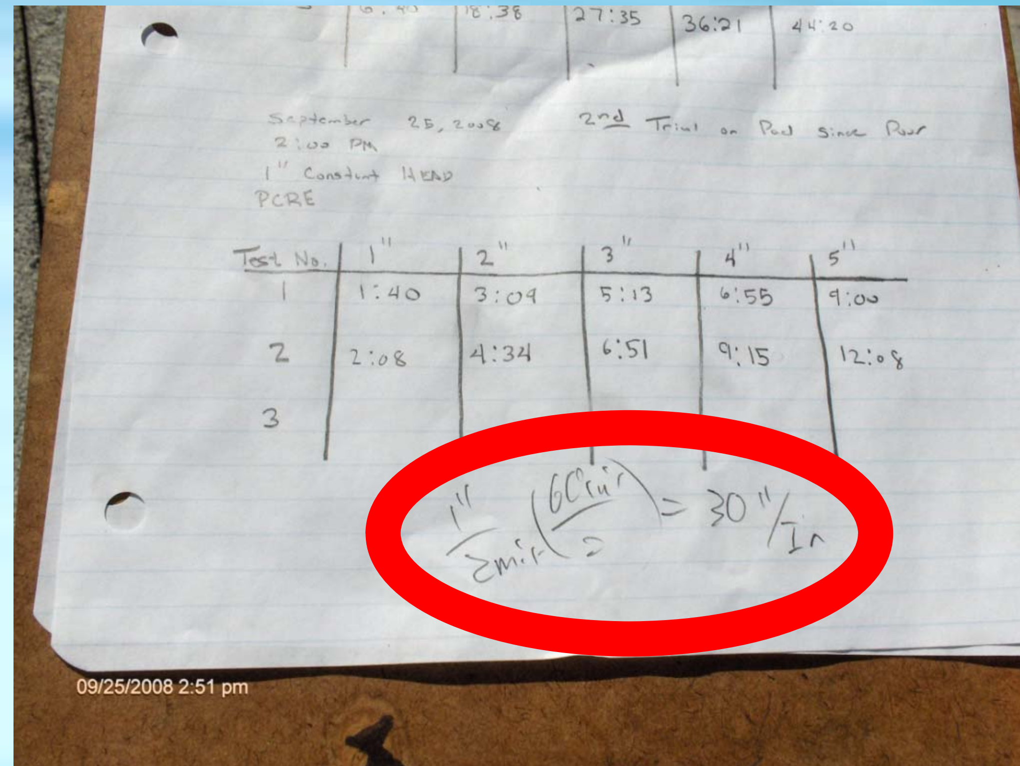
See the next slide for the results of this test on 09/25/08.

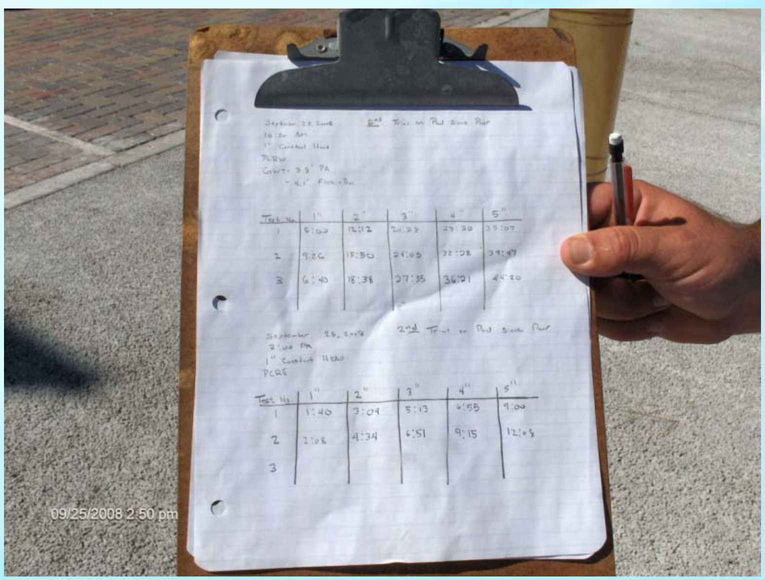


http://stormwater.ucf.edu/

Results from an ERIK device test







09/25/08 test date.

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Additional Embedded Ring Infiltrometer Kits (ERIKs)

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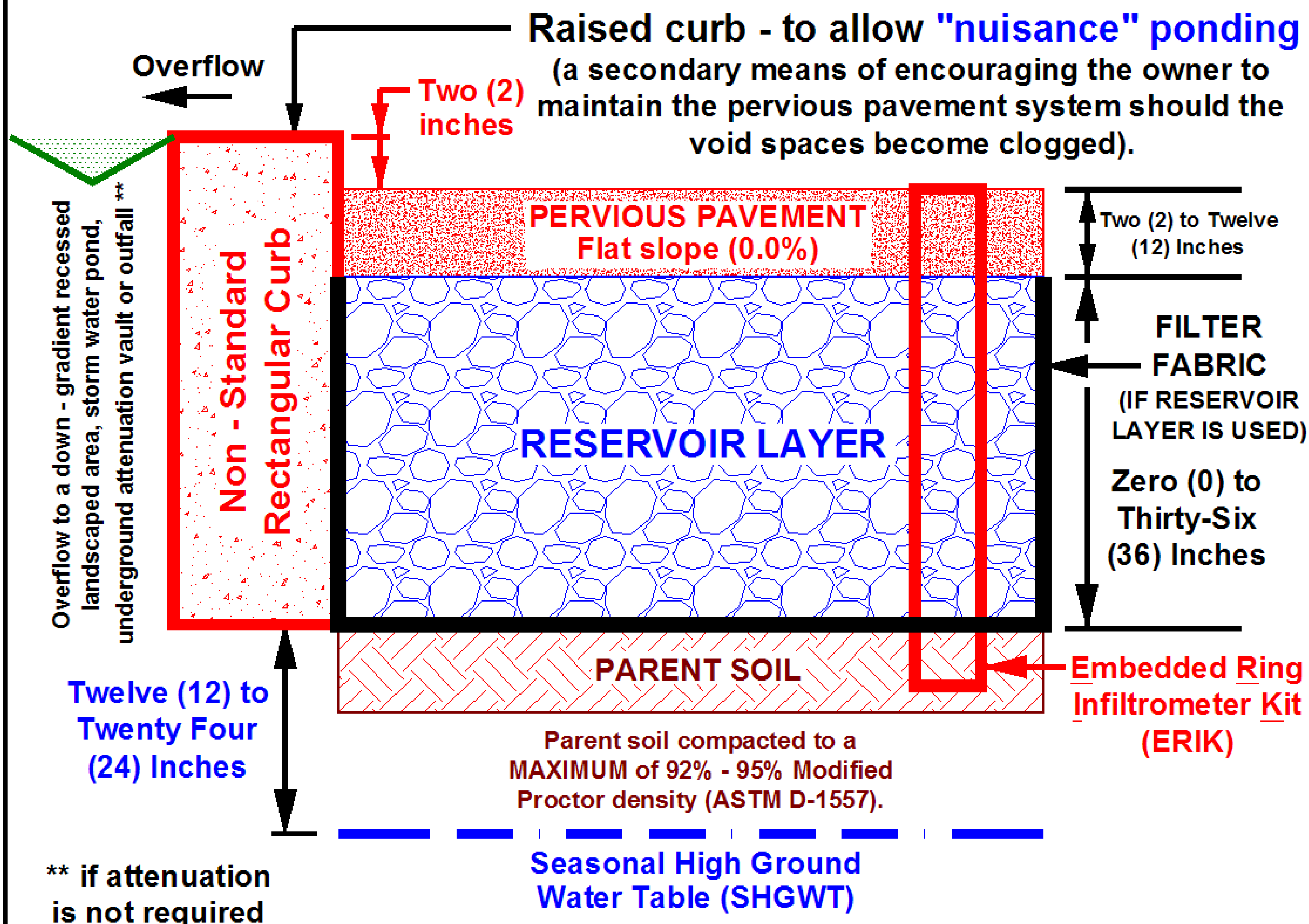
Stormwater Management ACADEMY
"Managed Stormwater is Good Water"

http://stormwater.ucf.edu/

AutoCAD® drawing of the ERIK infiltrometer

Insert this drawing (when available) from Erik Stuart (UCF)

http://stormwater.ucf.edu/



Potential Pervious Pavement Cross Section #1

Scale: None

Refer to previous slides for information on the ERIK device.

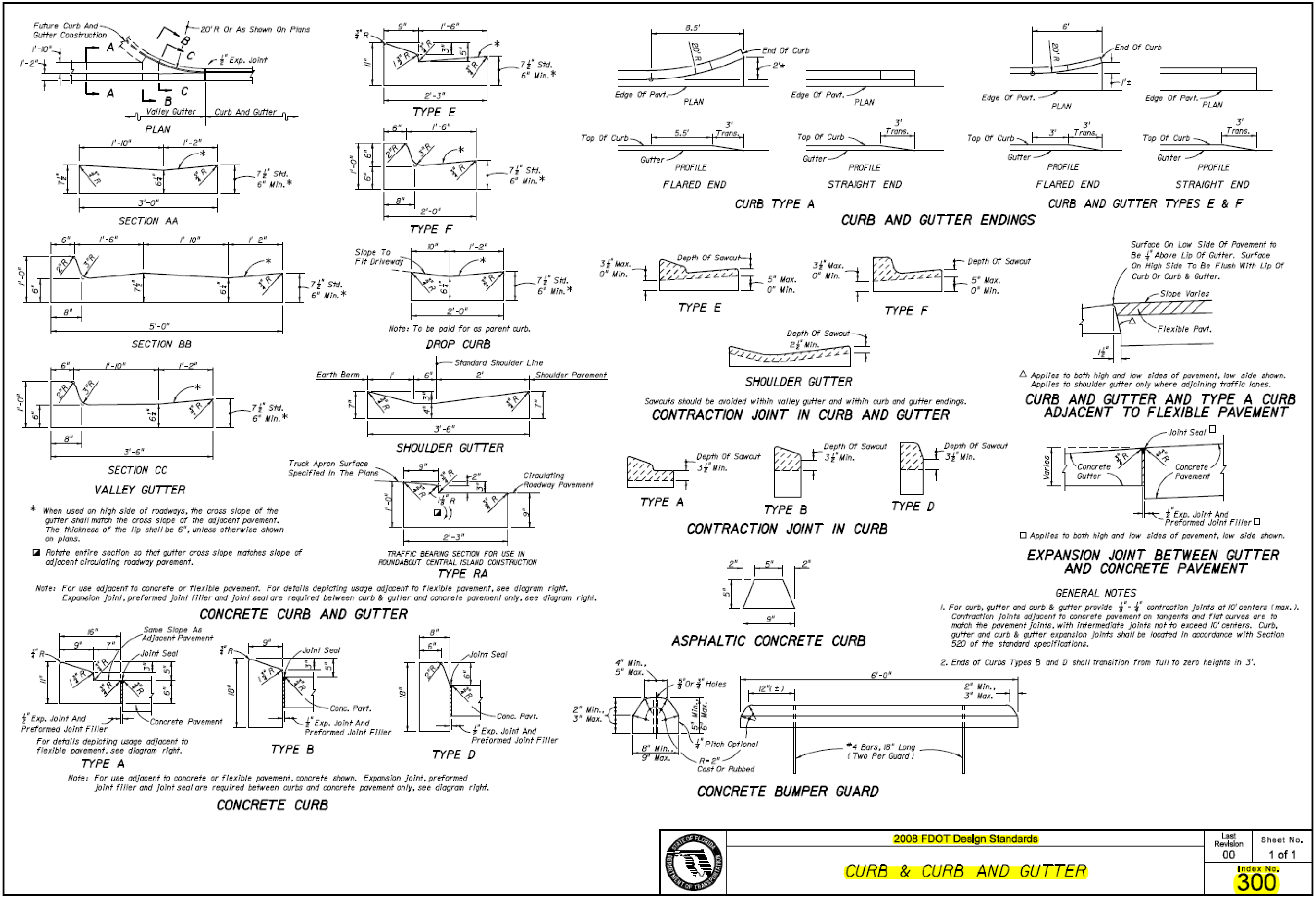
“Typical” curb machines*

http://www.edgemaster.net/extrusion.html

http://www.millerspreader.com/1050Main.html

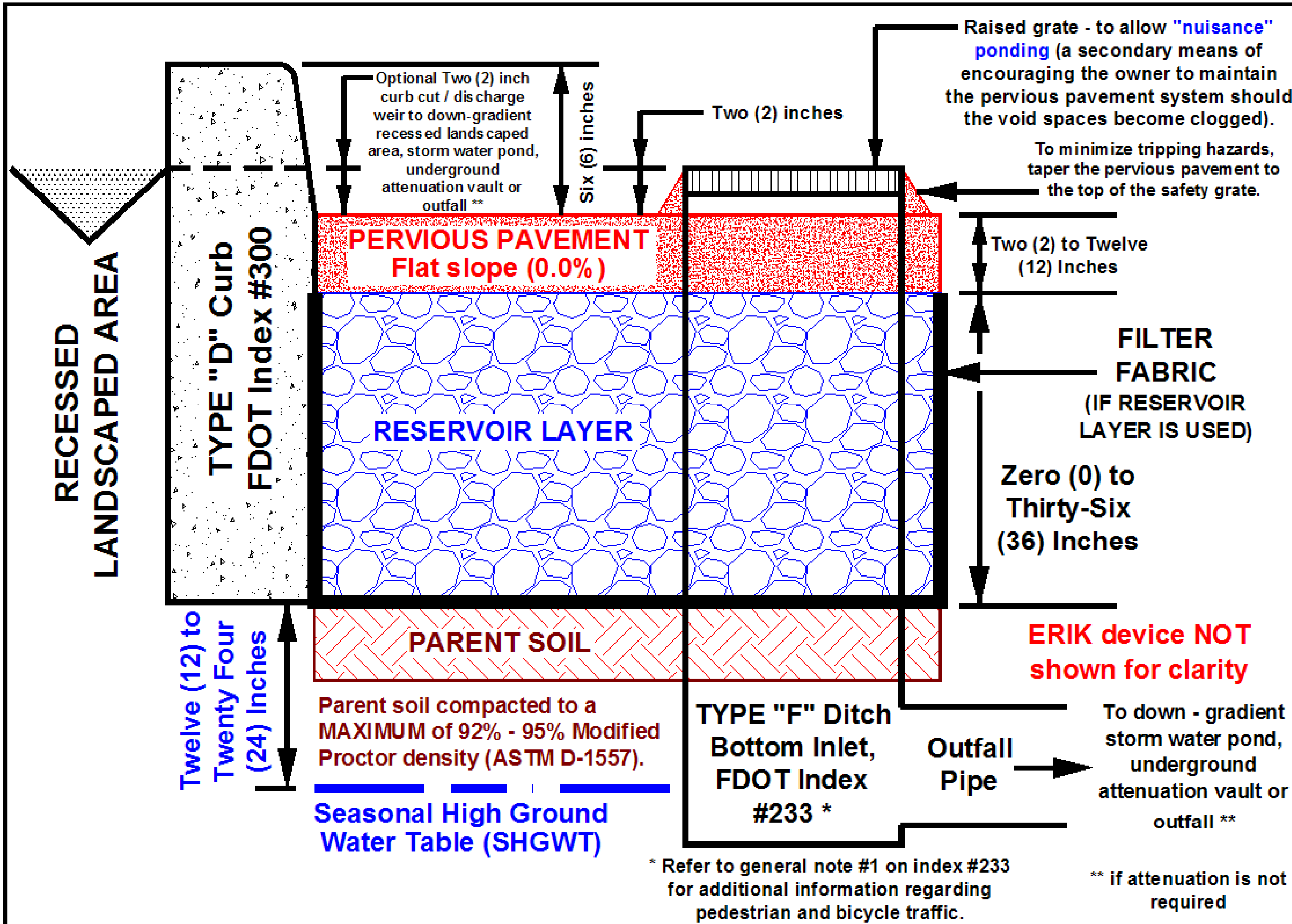
** This mention does not constitute an endorsement of product.*

To save $$$, many site contractors prefer to utilize extruding curb machines in lieu of hand forming & placement.



FDOT design standards (index drawings), available at:

http://www.dot.state.fl.us/rddesign/rd/RTDS/08/2008Standards.htm



Potential Pervious Pavement Cross Section #2

Scale: None

ERIK device NOT shown for clarity.

FDOT design standards (index drawings), available at: http://www.dot.state.fl.us/rddesign/rd/RTDS/08/2008Standards.htm

“Flush” Non – Standard Rectangular Curbs

along the edges of the portland cement * pervious pavement sections at the UCF Engineering Field Lab

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

UNIVERSITY OF CENTRAL FLORIDA Stormwater Management ACADEMY "Managed Stormwater is Good Water"

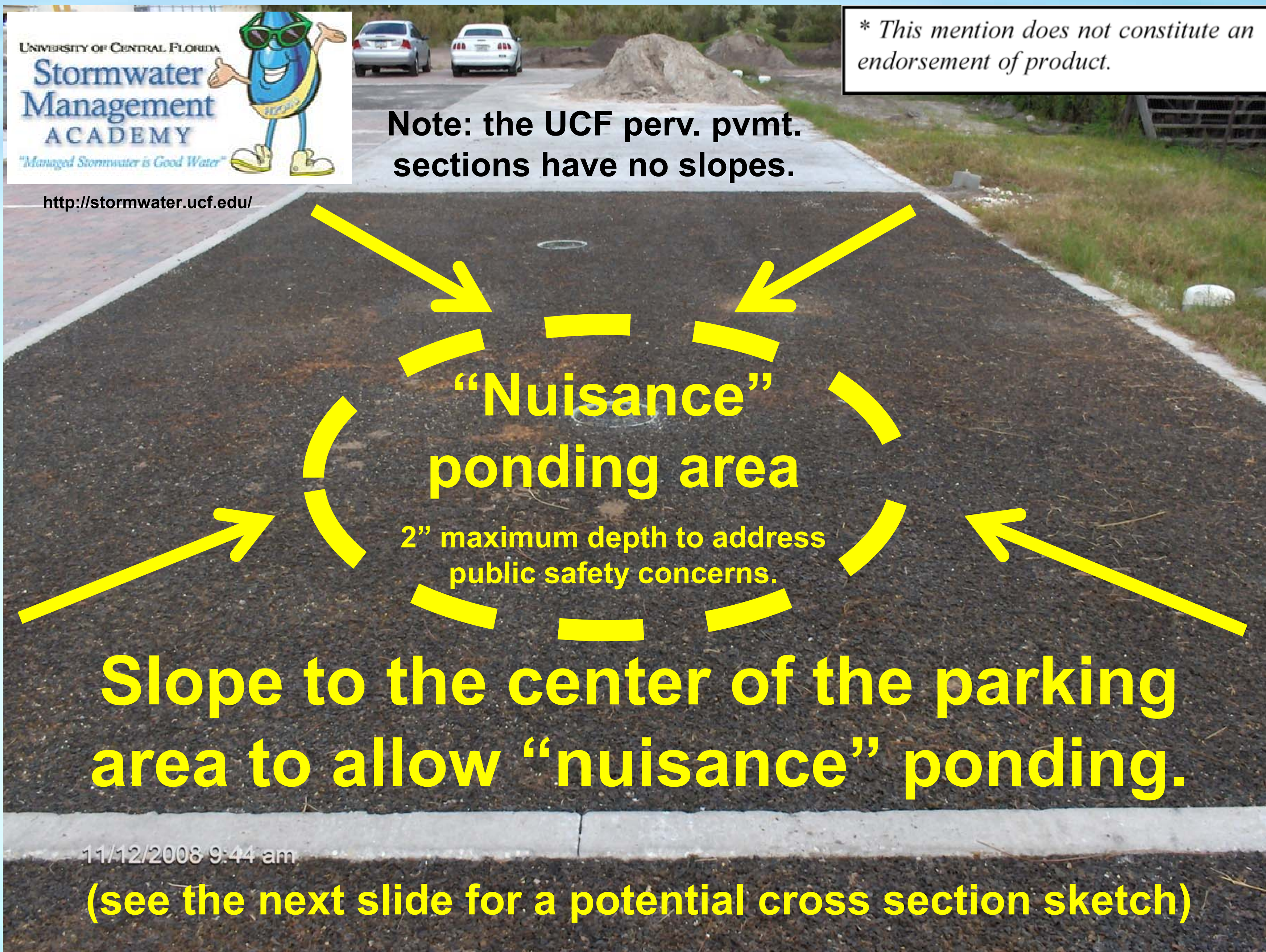
http://stormwater.ucf.edu/

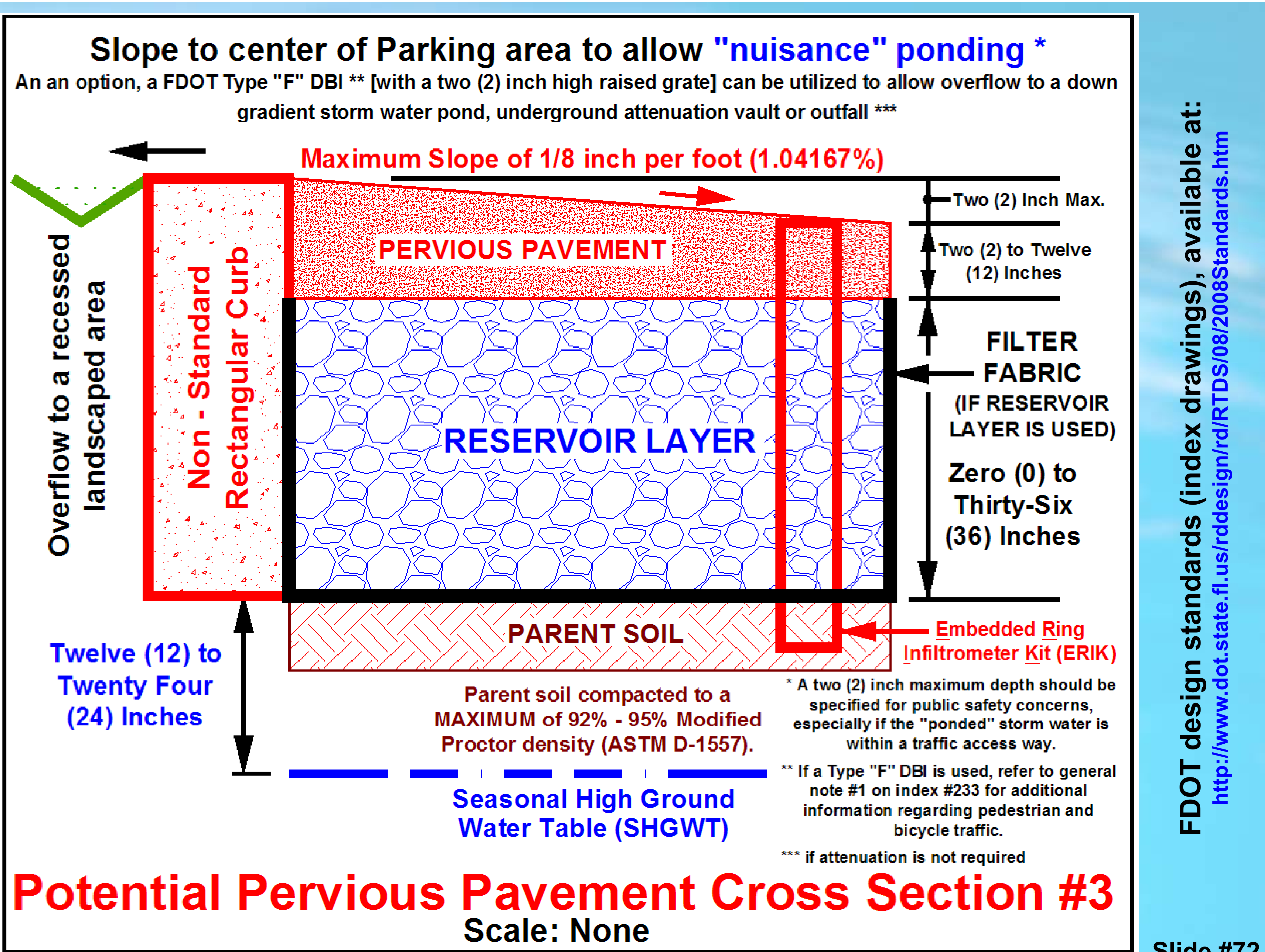
Photography provided by Dr. Manoj Chopra, P.E. from the UCF Storm Water Management Academy

As noted on a previous slide, many site contractors prefer to utilize extruding curb machines in lieu of hand forming & placement (to save $$$).

“Flush” Non – Standard Rectangular Curbs

Flexi-Pave® * pervious pavement section at the UCF Engineering Field Lab





Slope to center of Parking area to allow "nuisance" ponding *
An an option, a FDOT Type "F" DBI ** [with a two (2) inch high raised grate] can be utilized to allow overflow to a down gradient storm water pond, underground attenuation vault or outfall ***
Maximum Slope of 1/8 inch per foot (1.04167%)
Overflow to a recessed landscaped area
Non - Standard Rectangular Curb
PERVIOUS PAVEMENT
Two (2) Inch Max.
Two (2) to Twelve (12) Inches
RESERVOIR LAYER
FILTER FABRIC
(IF RESERVOIR LAYER IS USED)
Zero (0) to Thirty-Six (36) Inches
PARENT SOIL
Embedded Ring Infiltrometer Kit (ERIK)
Twelve (12) to Twenty Four (24) Inches
Parent soil compacted to a MAXIMUM of 92% - 95% Modified Proctor density (ASTM D-1557).
Seasonal High Ground Water Table (SHGWT)
* A two (2) inch maximum depth should be specified for public safety concerns, especially if the "ponded" storm water is within a traffic access way.
** If a Type "F" DBI is used, refer to general note #1 on index #233 for additional information regarding pedestrian and bicycle traffic.
*** if attenuation is not required
Potential Pervious Pavement Cross Section #3
Scale: None
FDOT design standards (index drawings), available at:
http://www.dot.state.fl.us/rddesign/rd/RTDS/08/2008Standards.htm

Recommendations – pervious pedestrian walks & bicycle paths



- **For water quality credit on HSG = "B/D" soils (SHGWT depth of 0" to 12" below the bottom of the pervious pavement system): 80% (credit) of the pervious pedestrian walk & bike path areas can be subtracted from the total contributing area when computing the storm water treatment volume.**

- **For water quality credit on HSG = "A", "B" or "C" soils (SHGWT depth of greater than 24" below the bottom of the pervious pavement system): 100% (credit) of the pervious pedestrian walk & bike path areas can be subtracted from the total contributing area when computing the storm water treatment volume.**

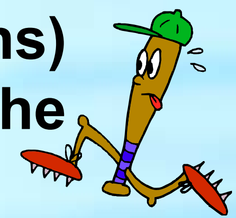
- **Perimeter curbs will NOT be required for pervious walks & bike paths.**

- **Unless there are public safety concerns, slopes should not be an issue for pervious pedestrian walks & bike paths.**

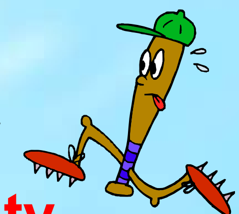
Proposed Requirements – pervious pavement parking lots and access drives

- Consider these types of applications as dry "retention systems" for up – gradient treatment train credit.

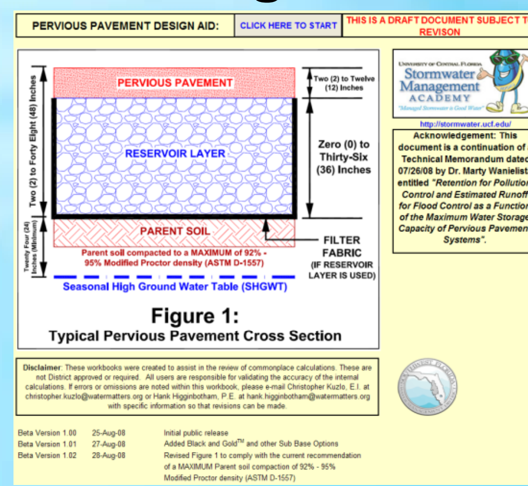
- For water quantity credit (Curve Number (CN) or Rational "C" coefficient computations) the SHGWT <u>shall</u> be greater that 24" below the <u>bottom of the</u> pervious pavement <u>system</u>).



- A mounding analysis will be required to demonstrate that the Required Treatment Volume (RTV) shall recover (to the <u>bottom of the</u> pervious pavement <u>system</u>) within seventy two (72) hours, with a safety factor of two (2.0)



Pervious Pavement "Design Aid"



This "Design Aid" will be discussed later in this presentation.

The Basics of Pervious Pavement Construction

Pervious concrete* parkinglot installation at the Florida Concrete Products Association (FCPA) facility in Orlando, Florida

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

Forming

Photography provided by Deep Tu, P.E. at the Florida Concrete Products Association

http://www.fcpa.org/

Pervious concrete* parking lot installation at the Florida Concrete Products Association (FCPA) facility in Orlando, Florida

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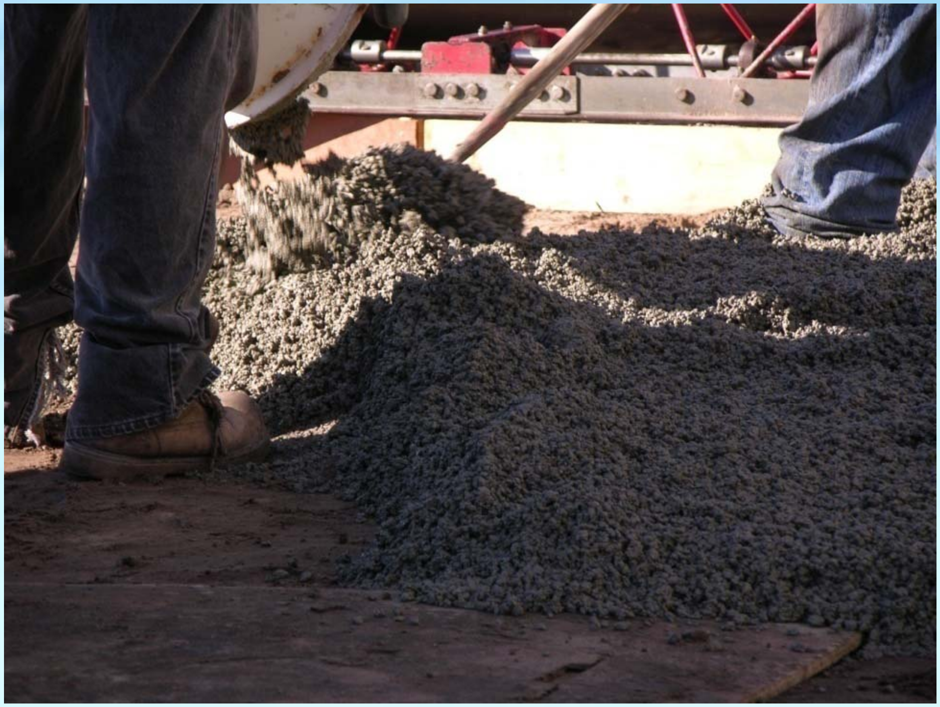

Placement & Screeding

Photography provided by Deep Tu, P.E. at the Florida Concrete Products Association

http://www.fcpa.org/

Pervious concrete* parking lot installation at the Florida Concrete Products Association (FCPA) facility in Orlando, Florida

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Screeding & Rolling

Photography provided by Deep Tu, P.E. at the Florida Concrete Products Association

http://www.fcpa.org/

Pervious concrete* parking lot installation at the Florida Concrete Products Association (FCPA) facility in Orlando, Florida

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

Cross Rolling

Screeding & Rolling

Photography provided by Deep Tu, P.E. at the Florida Concrete Products Association

http://www.fcpa.org/

Pervious concrete* parking lot installation at the Florida Concrete Products Association (FCPA) facility in Orlando, Florida

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

Scoring & Curing

Photography provided by Deep Tu, P.E. at the Florida Concrete Products Association

http://www.fcpa.org/

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* This mention does not constitute an endorsement of product.

Curing

Photography provided by Deep Tu, P.E. at the Florida Concrete Products Association

http://www.fcpa.org/

Florida Concrete* Products Association facility in Orlando, Florida

* This mention does not constitute an endorsement of product.

http://www.fcpa.org/

Pervious pavement parking lot & driveway

Finished Installation

Florida Concrete* Products Association facility in Orlando, Florida

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

http://www.fcpa.org/

Standard Asphalt Entrance Roadway

Pervious pavement parking lot & driveway

Finished Installation

UCF Engineering Field Lab visit 11-09-07

Standard Class I concrete pavement

- driveway entrance with frequent vehicle turning movements

Rinker MATERIALS *

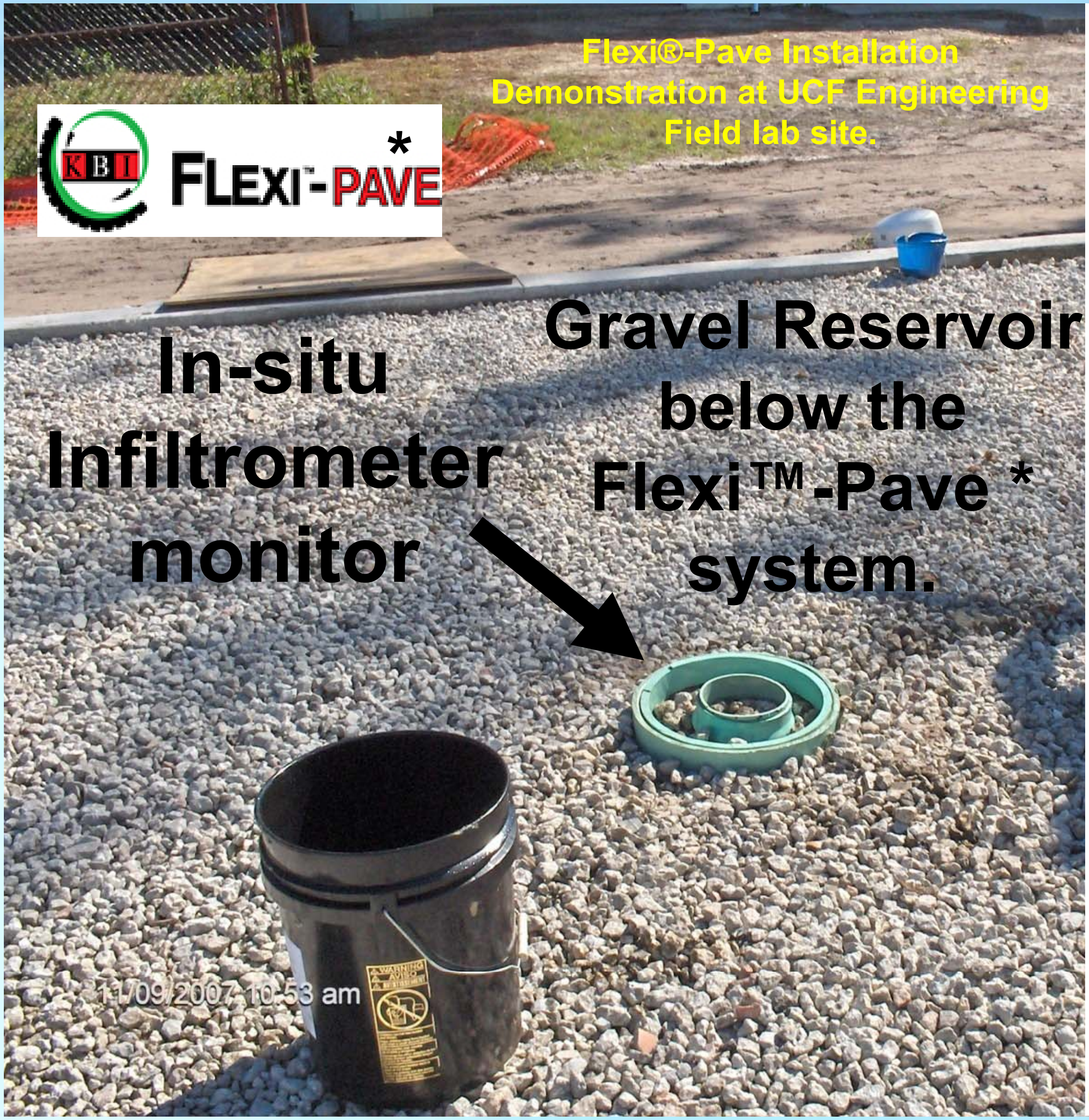
Flexi™-Pave * Pervious Pavement

KBI FLEXI-PAVE *

Flexi™-Pave * Installation Demonstration at UCF Engineering Field lab site.

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

UCF Engineering Field Lab visit 11-09-07



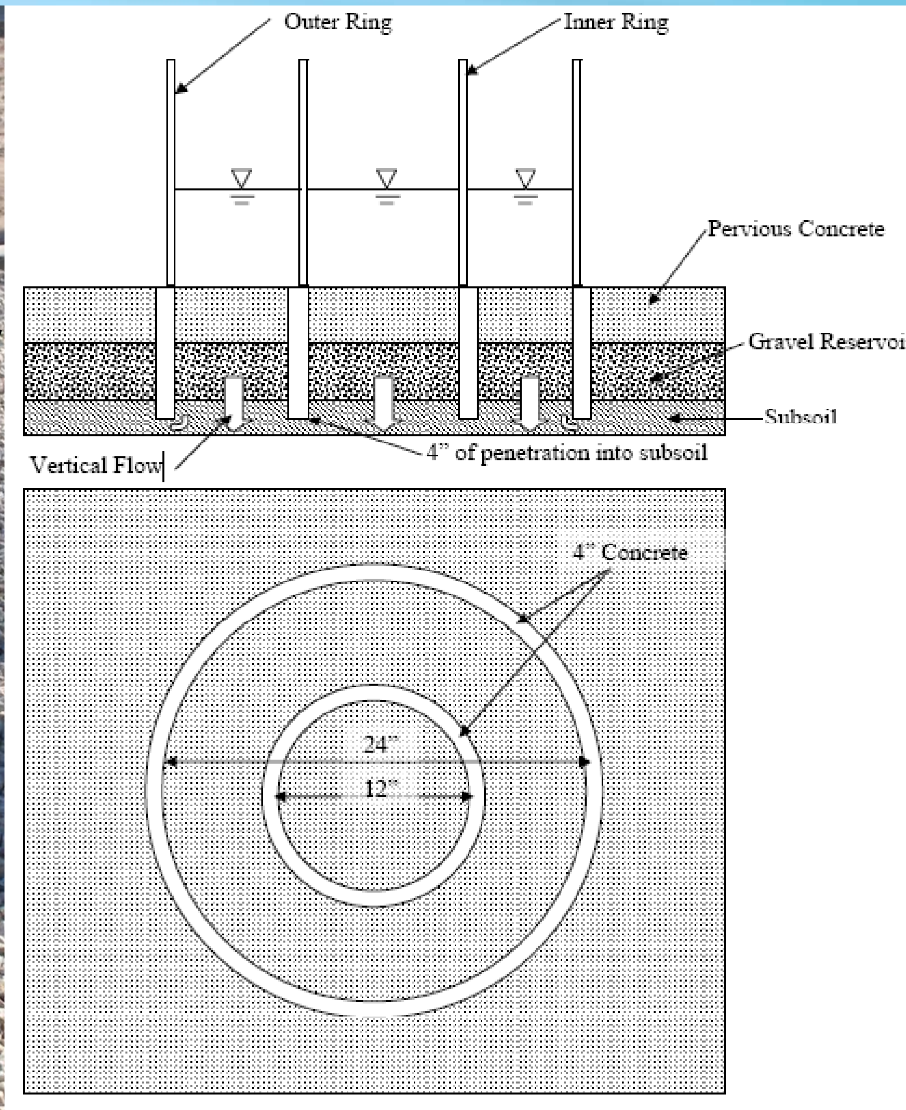


Figure 42: Design profile for Embedded Infiltrometer installation

For information on this in-situ infiltration monitor, refer to the UCF research paper entitled "*Construction and Maintenance Assessment of Pervious Concrete Pavements - Final Draft*, dated January, 2007 ", available at:
http://stormwater.ucf.edu/research_publications.asp

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

UCF Engineering Field Lab visit 11-09-07

Installation contractors of Flexi™-Pave * must be certified by the manufacturer

(K.B. Industries, Inc.).

KBI FLEXI™-PAVE *

www.kbius.com

Raw materials stockpile.

Flexi™-Pave * Installation Demonstration at UCF Engineering Field lab site.

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

UCF Engineering Field Lab visit 11-09-07

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KBI FLEXI™-PAVE *

www.kbius.com

← Mixer operation for the raw materials.

Flexi™-Pave * Installation Demonstration at UCF Engineering Field lab site.

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KBI FLEXI-PAVE *

www.kbius.com

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Flexi™-Pave *Installation Demonstration at UCF Engineering Field lab site.

Additional Pervious Pavement System Installations

KBI FLEXI-PAVE *

Photography provided by K.B. Industries, Inc. *

http://www.kbius.com

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

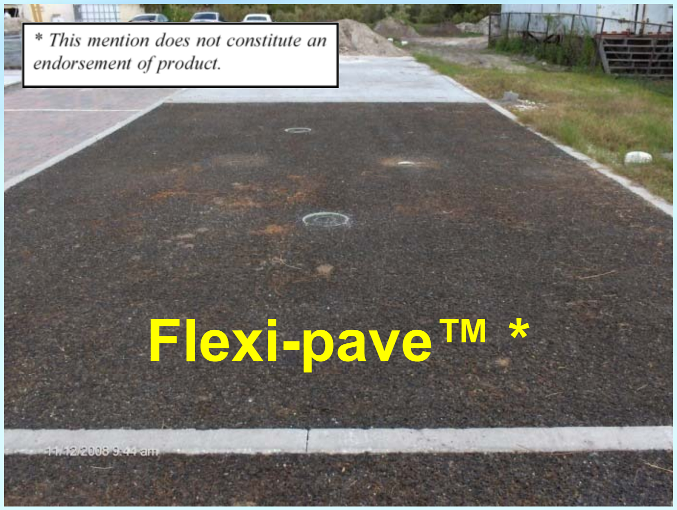
Current & Ongoing Pervious Pavement Research

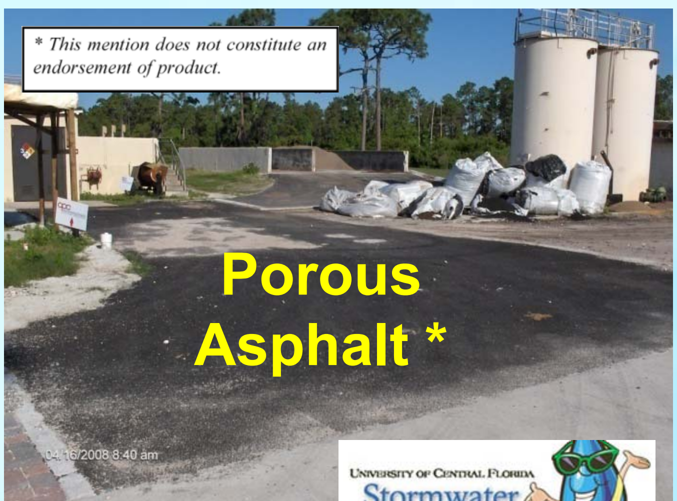
at the UCF Stormwater Management Academy.

http://stormwater.ucf.edu/

Location - Stormwater Academy Research Laboratory at UCF,

adjacent to the erosion & Sediment Control Lab and Rainfall Simulator





University of Central Florida
Stormwater Management Academy
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http://stormwater.ucf.edu/

UCF Rainfall Simulator

Types of Pervious Pavements *

Type		Area (sf)
Pervious Concrete		1500
Flexipave		1500
Pervious Pavers	 	660, 600
Porous Asphalt		1500

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

Pervious Pavement Installations

UNIVERSITY OF CENTRAL FLORIDA
Stormwater Management ACADEMY
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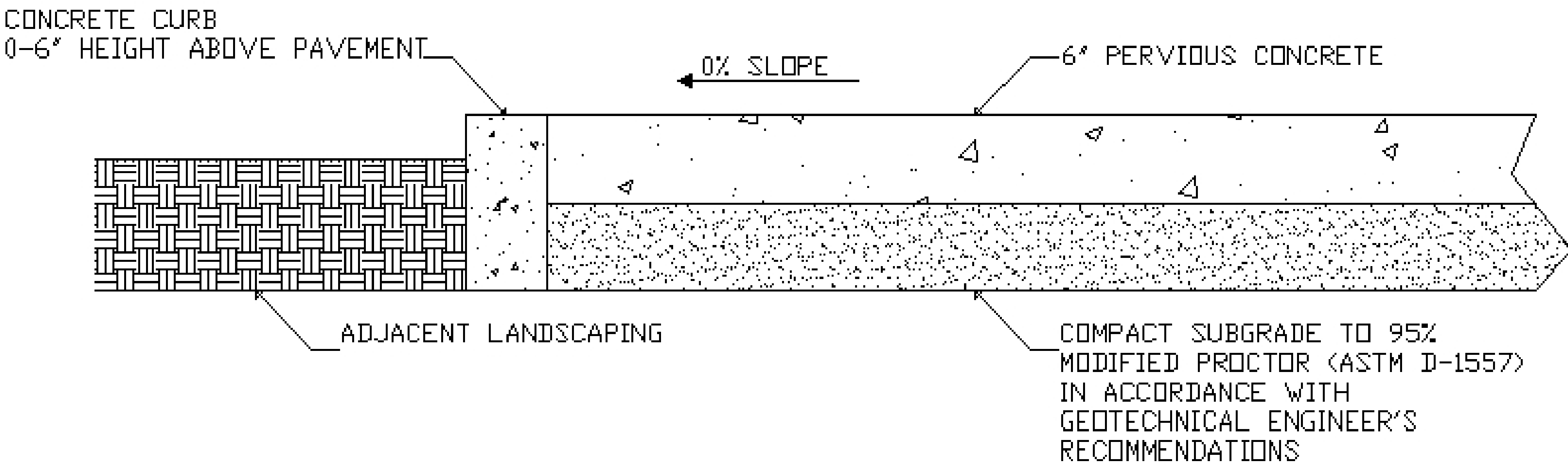
http://stormwater.ucf.edu/

Pervious Concrete * Design Section



TYPICAL PERVIOUS CONCRETE PAVEMENT SECTION

N.T.S.

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

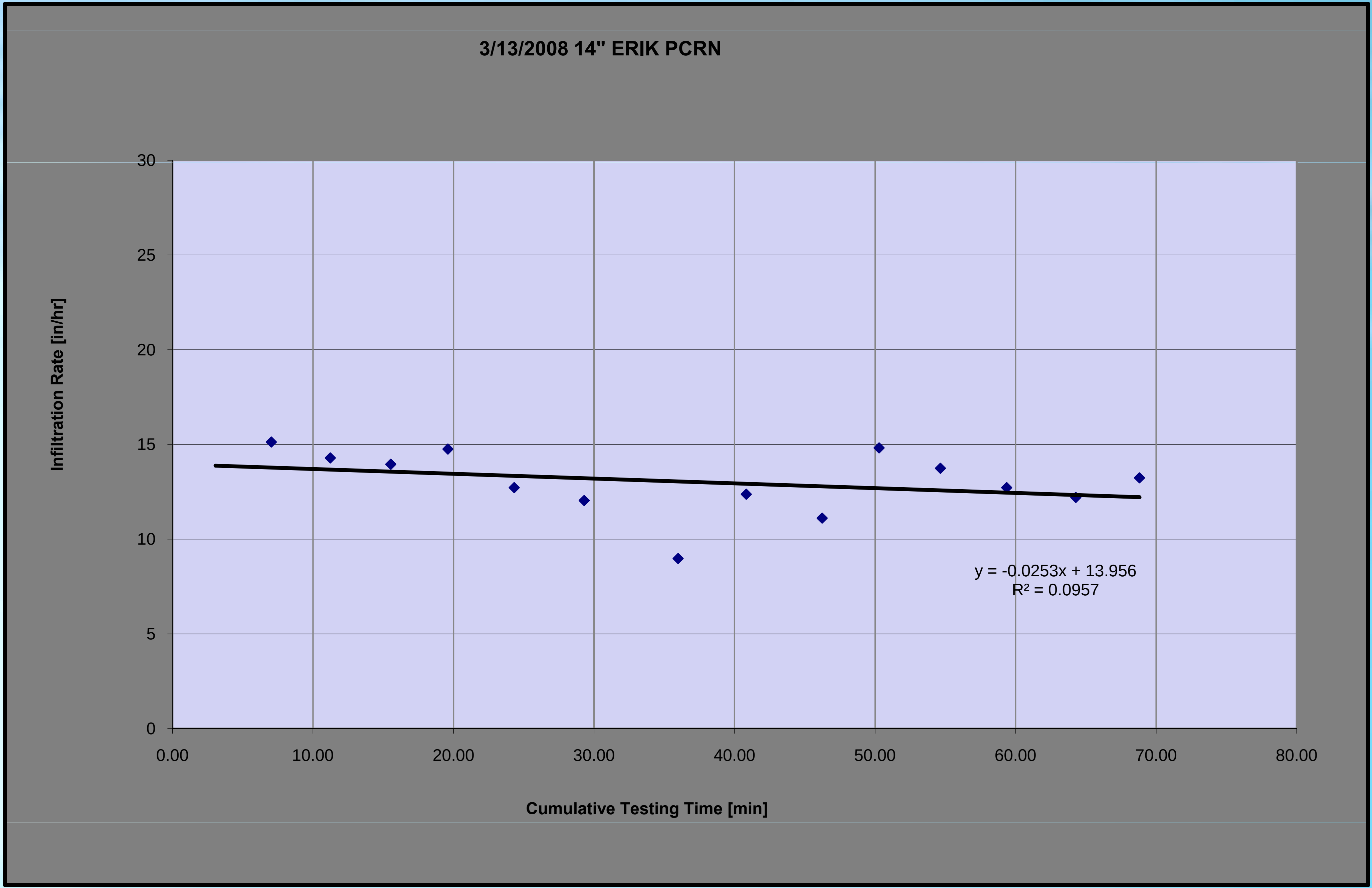
Pervious Concrete * Pavement

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

Pervious Concrete* Pavement

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

Infiltration Rate of Pervious Concrete Pavement



Flexipave™ *

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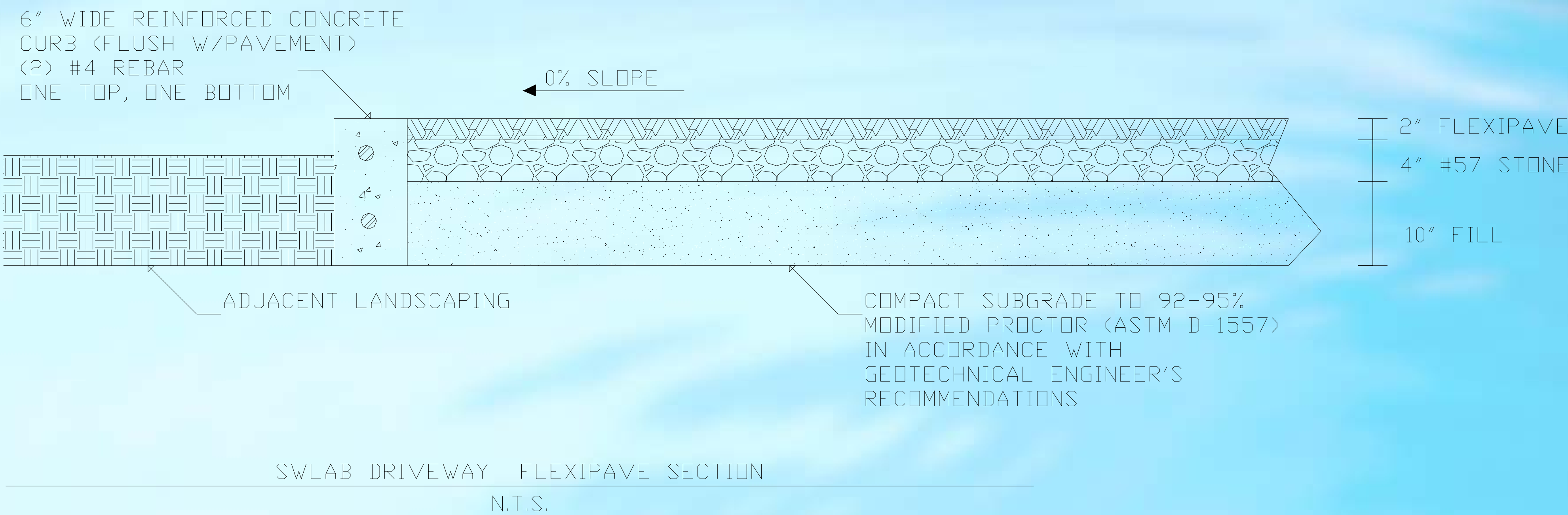
Flexipave™ * Design Section



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Flexipave™ *

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

Flexipave™ *

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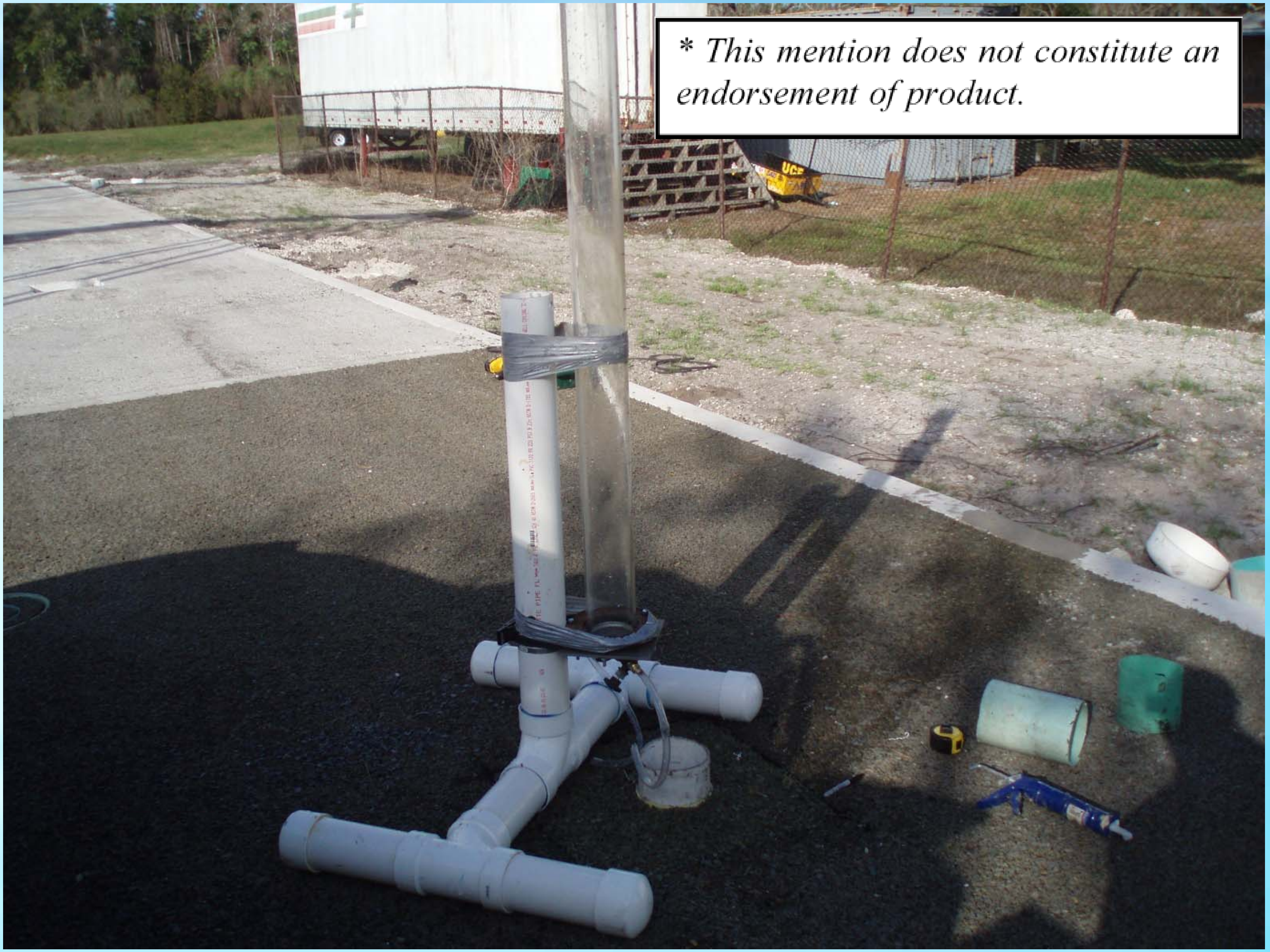
Flexipave™ *

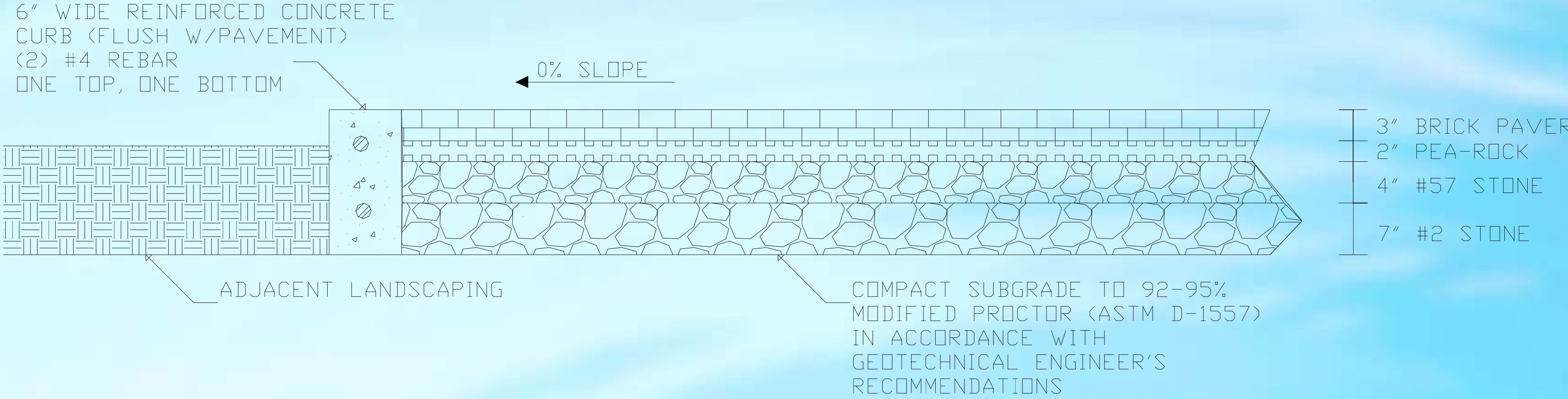


* This mention does not constitute an endorsement of product.

Pervious Brick Pavers *

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

Pervious Pavers * Design Section with Stone Reservoir

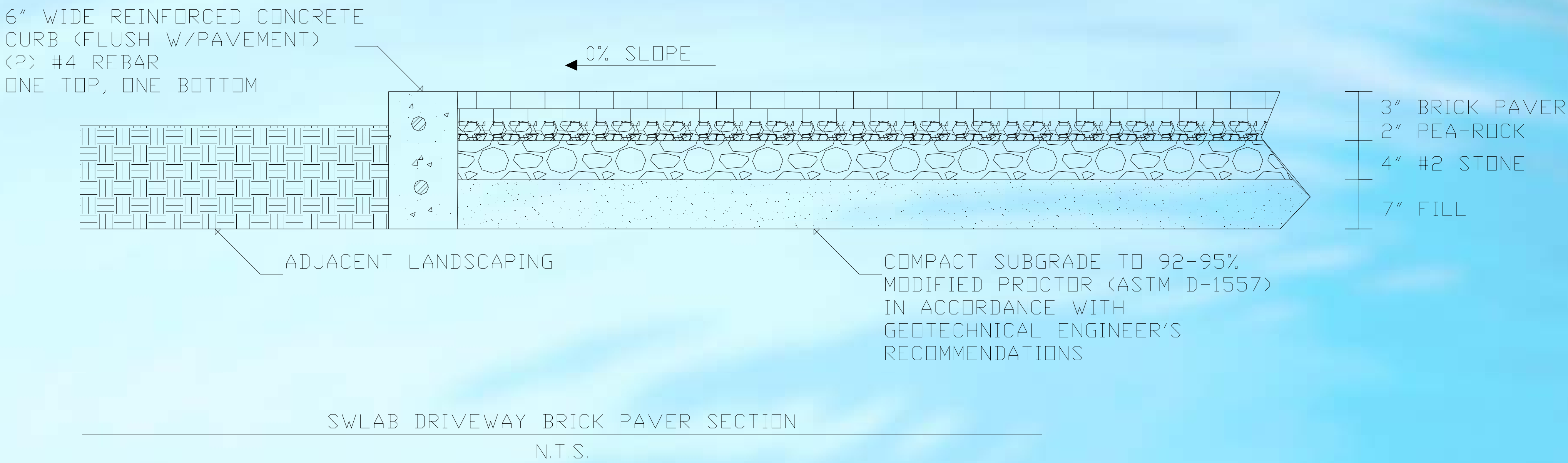


SWLAB DRIVEWAY BRICK PAVER SECTION (w/ ROCK RES.)

N.T.S.

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

Pervious Pavers * Design Section **without** Stone Reservoir



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

Pervious Brick Pavers *

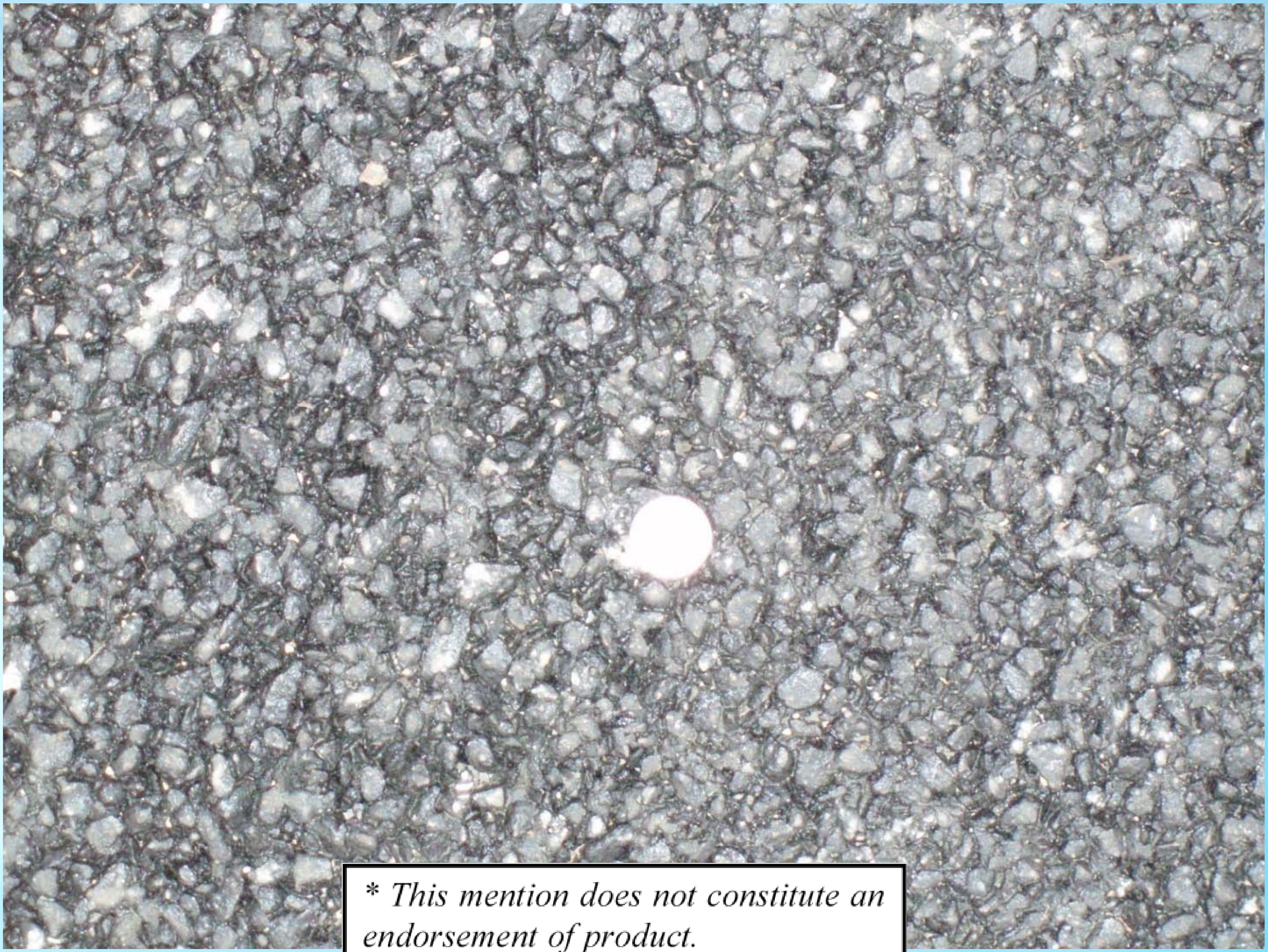
** This mention does not constitute an endorsement of product.*

Pervious Brick Pavers *

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

Water Quality Sampling

Porous Asphalt * Pavement



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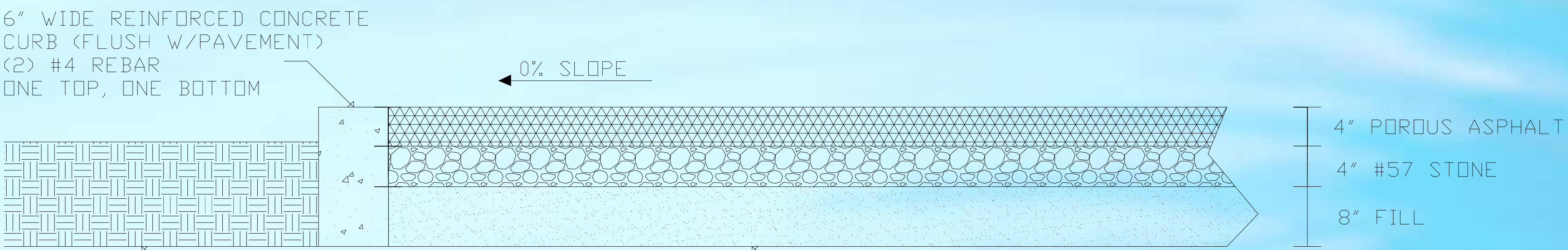
Porous Asphalt * Design Section



SWLAB DRIVEWAY POROUS ASPHALT SECTION

N.T.S.

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Porous Asphalt * Pavement

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Porous Asphalt * Pavement

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Load Testing for Structural Failure

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Load Testing for Structural Failure

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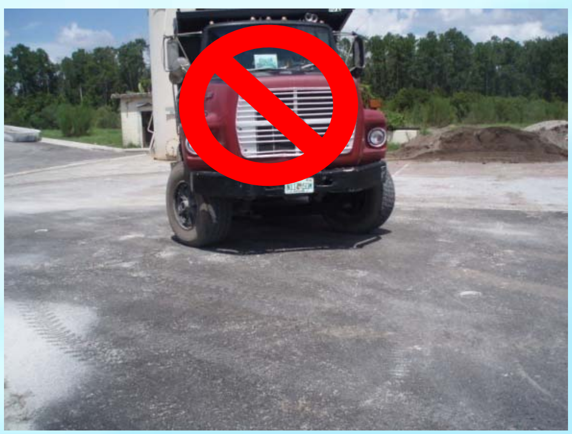
Load Testing for Structural Failure



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Turning movements under heavy wheel loads

Load Testing for Structural Failure

Load Testing for Structural Failure

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Premature structural failure of the pervious pavement surface

Load Testing for Structural Failure

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Premature structural failure of the pervious pavement surface

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Structural failure of the pervious pavement surface

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Premature structural failure of the pervious pavement surface

Sedimeent Clogging & Rejuvenation Studies with sandy soils

Rejuvenation Studies

- Sediment (sandy soil) was spread (1-2 inch of poorly graded sand) on top of the pavement surface
- Wet and compacted with Bobcat
- Conducted vacuum sweeping using Elgin MV Truck – 3-4 passes with some overlap
- Rate of sweeping under 2-4 mph (with 1” sediment) and under 5-7 mph for light sweep
- Followed by a second sweep over the entire area
- Measure infiltration rates pre and post-cleaning

Rejuvenation Studies - Wet

- Some of the studies were conducted on saturated pavement surfaces (PCRS)
- Surface wetting hindered the dislodging of particles due to suction forces
- Water was sprayed at 80 gallons/min until pavement was saturated and runoff occurred
- Surface was then vacuum swept
- It was noted that rate decreased after wet tests indicating finer particles may have migrated deeper and water was preventing the suction of these particles

Deliberate clogging of Pervious Concrete *

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Deliberate clogging of Flexi-Pave™ *

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Deliberate clogging of Pervious Pavers *

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Deliberate clogging of Porous Asphalt *

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

Adding Insult to Injury

by wetting the contaminates over the pervious pavements

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Adding Insult to Injury

by compacting the wetted the contaminates over the pervious pavements

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Final Surface Ready for Testing & Sweeping

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ERIK Testing prior to vacuum sweeping

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Typical Vacuum Sweeping Truck

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"DRY" Vacuum Sweeping Operations

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“DRY” Vacuum Sweeping Operations

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"Dry" Vacuum Sweeping Disposal

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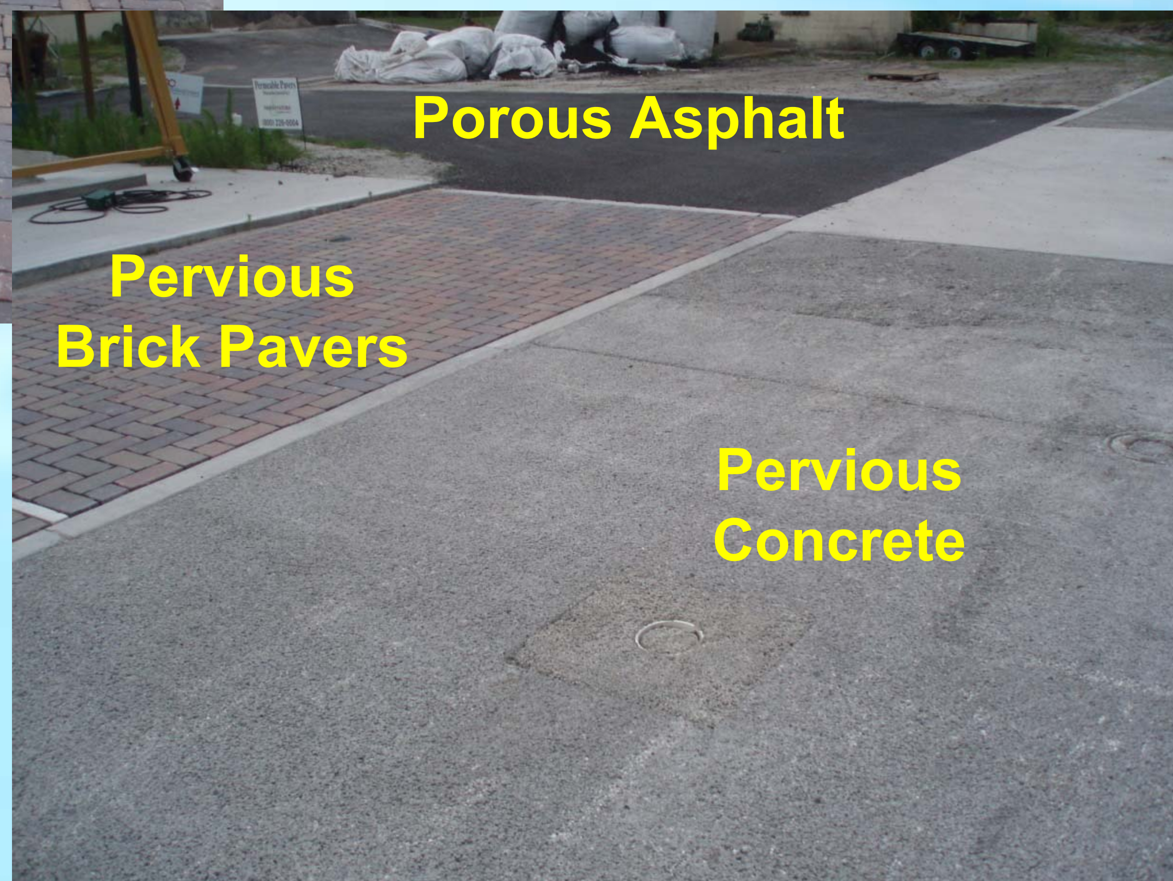
Visual Results After “DRY” Vacuum Sweeping Operations



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"Wet" Vacuum Sweeping Operations

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“Wet” Vacuum Sweeping Operations

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Visual Results After Initial "Wet" Vacuum Sweeping Operations

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"Wet" Vacuum Sweeping Disposal

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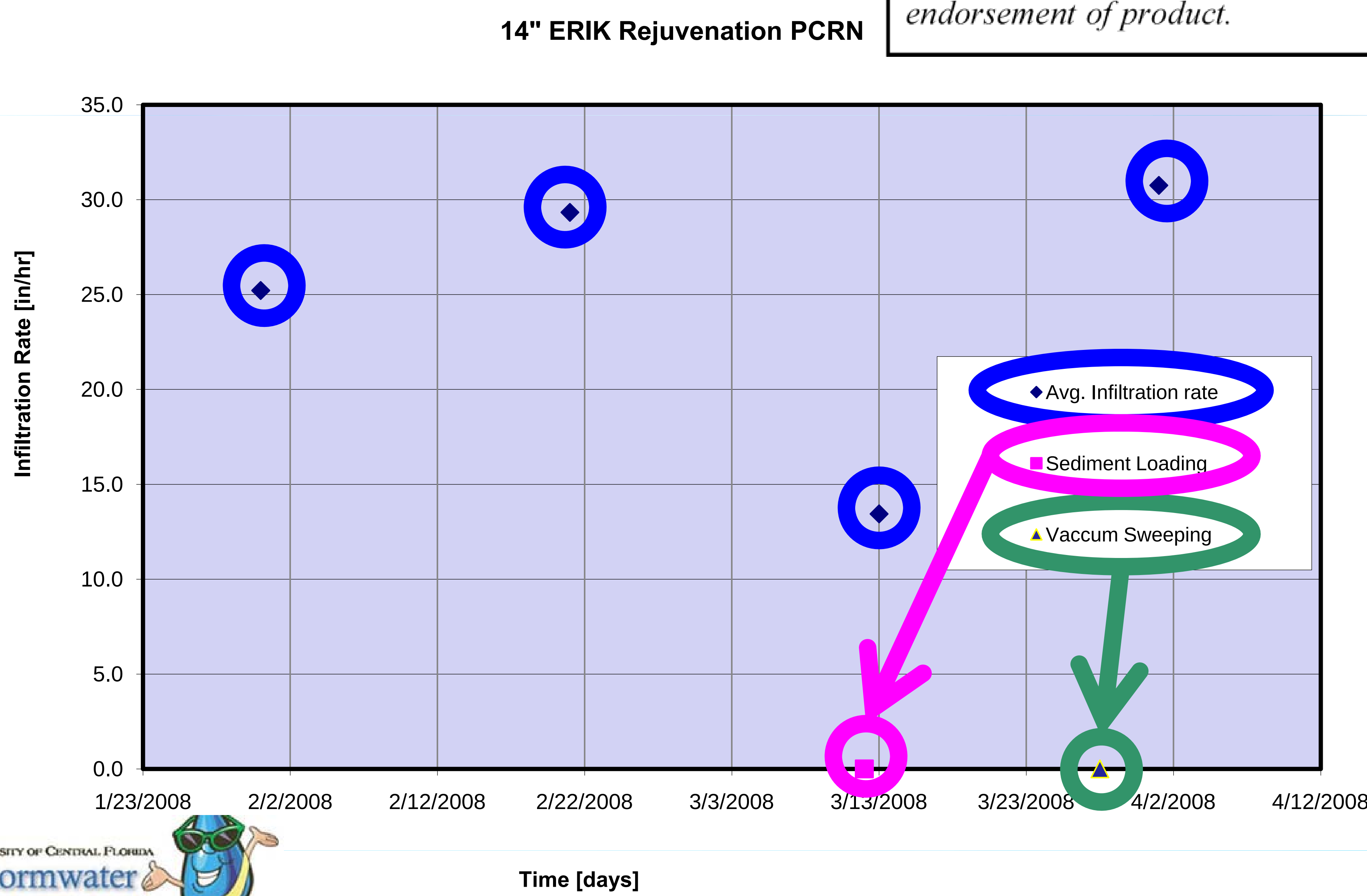
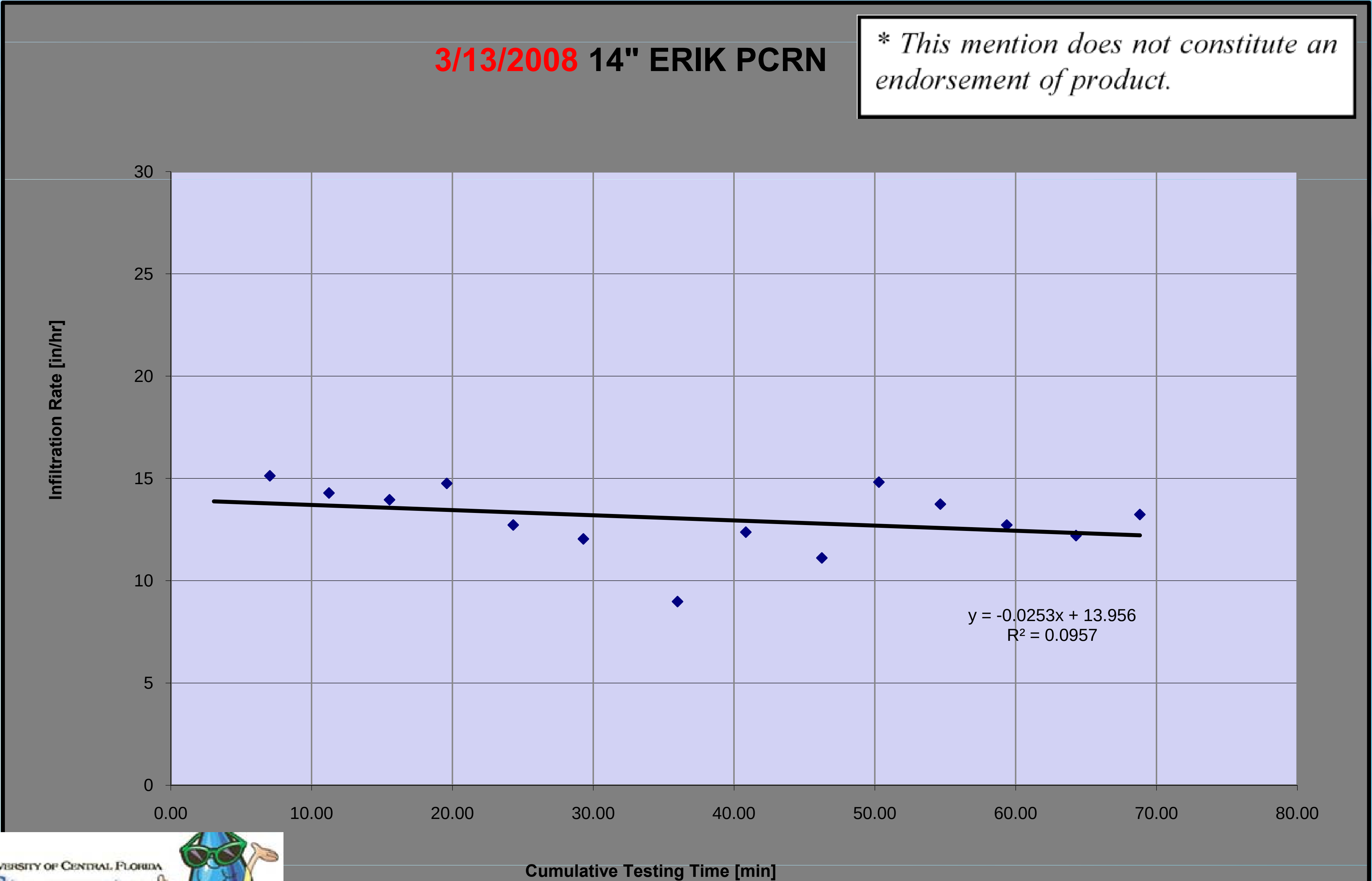
Rejuvenation Results of Pervious Concrete * Pavement

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



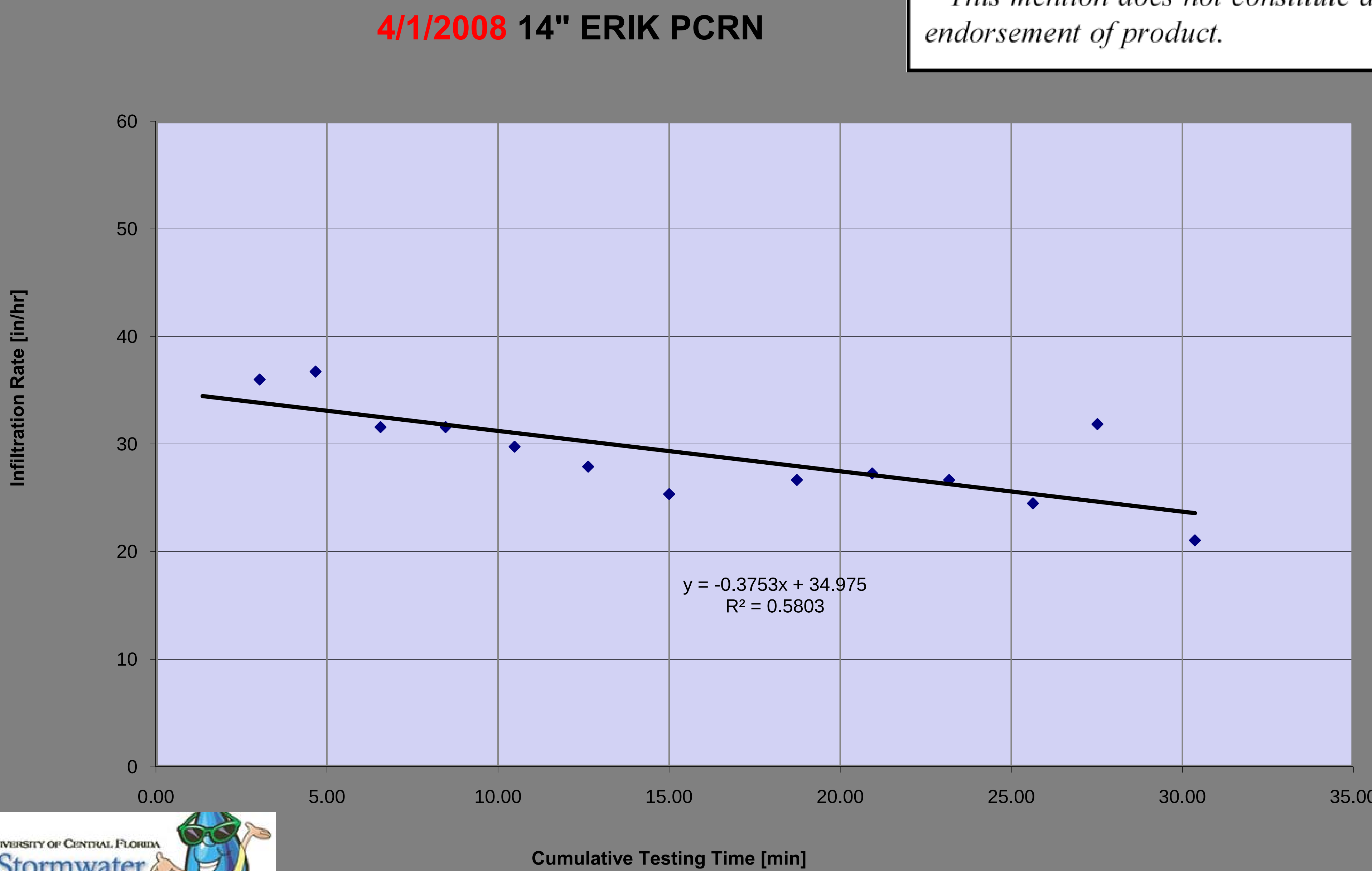
Rejuvenation Results of Pervious Concrete * Pavement



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

Rejuvenation Results of Pervious Concrete * Pavement

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



Sedimen t Clogging & Rejuvenation Studies with silty fines (limerock)

http://stormwater.ucf.edu/

Deliberate clogging of Porous Asphalt *

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Deliberate clogging of Porous Pavers *, Pervious Concrete * and Flexi-Pave™ * with limerock (subsequently crushed and compacted)

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Adding Insult to Injury

by wetting the crushed limerock over the pervious pavements

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Adding More Insult to Injury

Tropical Storm Fay (about 14" of Rain in 48 hours) during August, 2008

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Adding More Insult to Injury

Tropical Storm Fay (about 14" of Rain in 48 hours) during August, 2008

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“Wet” Vacuum Sweeping Operations

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"Wet" Vacuum Sweeping Operations

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"Wet" Vacuum Sweeping Disposal

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Visual Results After "Wet" Vacuum Sweeping Operations

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Add the Rejuvenation Results (infiltration rates) here when they become available from the UCF Stormwater Academy

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http://stormwater.ucf.edu/

Excel© *"Design Aid"* Examples for Pervious Pavement

Using Beta Version 1.03 dated 09/29/08

The Excel© *"Design Aid"* is available from the following URL:

http://www.dep.state.fl.us/water/wetlands/erp/rules/stormwater/rule_docs.htm

Statewide Stormwater Treatment Rule Development Documents

TAC Meeting Minutes and Presentations

TAC Meeting Locations and Topics

TAC meeting, November 12, 2008
» Notice PDF (27 kb)
» Agenda PDF (36 kb)

TAC meeting #6, October 1 & 2, 2008
» Notice PDF (27 kb)
» Agenda PDF (55 kb)
» Minutes PDF (175 kb)
» Wet Detention Systems Presentation PDF (856 kb)
» Legacy Pollutants and Altered Hydrology Issues PDF (525 kb)
» Urban Redevelopment Issues PDF (591 kb)
» Impacts of Natural Communtities Monitoring Data PDF (561 kb)
» **TAC Comments**
  » Devo Comments on Redevelopment, Altered Hydrology and Legacy Pollutants PDF (108 kb)
  » Devo Comments on Open Swales Design Criteria PDF (67 kb)
  » Devo Comments on Wet Detention Design Criteria PDF (132 kb)

TAC Meeting #5, September 15 & 16, 2008
» Agenda PDF (45 kb)
» Minutes PDF (364 kb)
» Low Impact Design BMPs PDF (288 kb)
» Pervious Pavement Design Aid Excel (490 kb)
» Green Roofs PDF (3.0 mb)
» Stormwater Reuse PDF (4.6 mb)
» Natural Communities Monitoring Project PDF (9.6 mb)
» **Karst Sensitive/Ground Water Protection Revisited**
  » Karst Sensitive Area Recommendations PDF (10.4 MB)
  » Aquifer Vulnerability PDF (10.4 MB)

» **TAC Comments**
  » LID Recommendations PDF (128 kb)
  » Devo Seereeram Reuse Comments PDF (195 kb)

TAC Meeting #4, July 9, 2008
» Agenda PDF (34 kb)
» Summary PDF (85 kb)
» Minutes PDF (116 kb)
» Wet Detention Issues Presentation PDF (526 kb)
» Wet Detention Systems Presentation PDF (853 kb)
» Use of Wetlands for Stormwater Treatment Presentation PDF (1.0 mb)
» Methodology List of Issues (rev 07/08) PDF (24 kb)
» Karst Sensitive/Ground Water Protection Issue Paper PDF (48 kb)
» Wet Detention Ponds Issue Paper PDF (13 kb)
» **TAC Comments**

July 26, 2008

Technical Memorandum: Retention for Pollution Control and Estimated Runoff for Flood Control as a Function of the Maximum Water Storage Capacity of Pervious Pavement Systems

The objectives of this report are to demonstrate and present data in support of calculations for pervious pavement systems that are used to satisfy the mass removal pollution objectives of the Statewide Stormwater Rule and to further expand pervious pavement design for flood control. The design procedure must start with a known retention volume needed for annual percent removal effectiveness and it is understood that it can be obtained for any area in the State. Then it is postulated that the design of the pervious pavement section can be specified to achieve the annual pollution effectiveness as well as the reduction in runoff volume.

Pollution Control Effectiveness

It is important to emphasize or repeat important facts related to the definition of pervious pavement systems. First, a pervious pavement system is defined as the pervious pavement and the reservoir, if one exists. Next the data and results reported in this memorandum are good for pervious pavement section installation completed by certified contractors. Next, the permeability of parent soils and reservoir materials meet a required storage recovery time.

All materials and depth of each used within the reservoir and the pervious pavement must be specified to estimate the storage within the system. The depth to the seasonal high water table must also be specified. Typically when the pervious pavement system storage exceeds 1.15 inches and the rate of infiltration through the section is greater than 1.5 inches per hour, the system will function on a yearly basis to remove 80% or better of the rainfall for the average year. This is shown in Figure 1 for various maximum storage capacities. The assumptions on parent and aquifer conductivity were limiting ones encountered in sampling existing systems (Wanielista and Chopra, Hydraulic Performance of Pervious Concrete, BD521-02, FDOT, 2007).

In Figure 1 provided are additional estimates of average annual rainfall removal as a function of infiltration rates. As an example, if the limiting rate is 3 inches per hour and the storage is about 1.7 inches, the average annual removal is 95%. The limiting infiltration rate must be determined using an Embedded Ring Infiltrometer Kit (ERIK). Testing of pervious pavement sections to date has shown that the rates of infiltration do commonly exceed 3 inches/hour.

The annual mass percent reduction shown in Figure 1 as a function of system (surface measured infiltration rate) did not significantly change with increased storage above 2.2 inches. Thus additional storage above 2.2 inches does not affect the annual mass reduction at any of the limiting infiltration rates shown in Figure 1. However, additional storage does affect the volume of storage within the pervious pavement system and thus the amount and rate of runoff from the pervious pavement section.

There are many combinations of pervious pavement and reservoir materials and depth that can achieve many storage values above a minimum storage of 0.80 inches used in Figure 1. As one example, pervious pavement at a depth of 6 inches with no storage reservoir typically holds 0.90 inches. Other designs specify reservoir depth or increased pavement thickness to support high traffic loads and thus storage has been estimated at up to 6 inches. The use of Figure 1 is considered valid for all practical pavement and reservoir depths. The additional storage affects the runoff volume and thus there is a trade-off between the storage within the pervious pavement system and the storage of water off-site of the pervious pavement that is used for flood control.

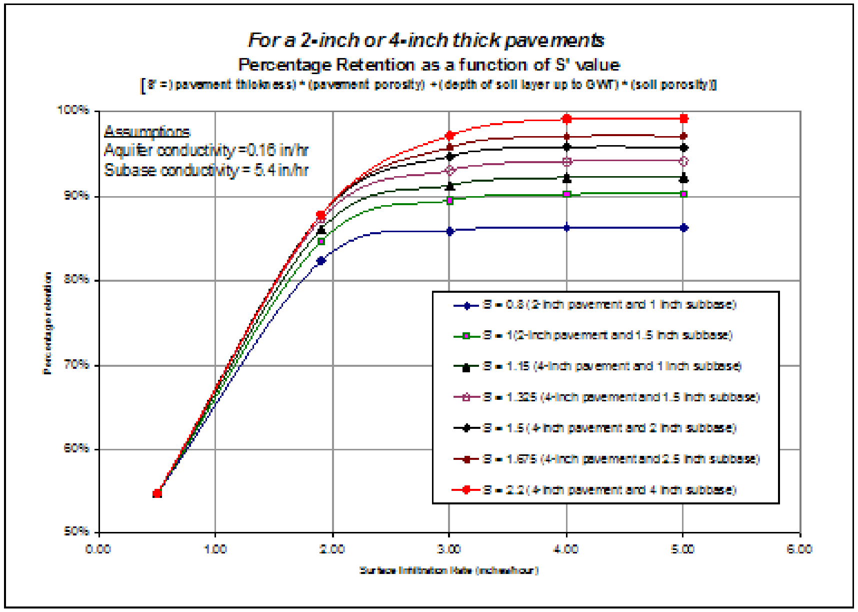

Figure 1. Average Annual Removal Mass as a Function of Surface Infiltration

The Value of Pervious Pavements for Flood Control Using a Design Storm

As noted, a pervious pavement section can be used to reduce flood control storage volume needed off-site of the pervious pavement, thus the importance of calculating runoff volume from pervious pavements resulting from a design storm. In addition, that runoff volume can be determined from the rainfall excess formulas of the curve number method and the ratio of rainfall excess to rainfall volume. The runoff coefficient is defined as the ratio of rainfall excess to precipitation. The governing equations are:

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

Figure 2 illustrates the best mathematical fit relationship between the runoff coefficient and the maximum storage of water in a pervious pavement system given a rainfall design volume. Thus for various sections of pervious

Slide #160

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pavement systems which includes the pavement and the reservoir storage, the runoff coefficient can be determined for a design storm volume. Similar curves can be developed for other design rainfall depths.

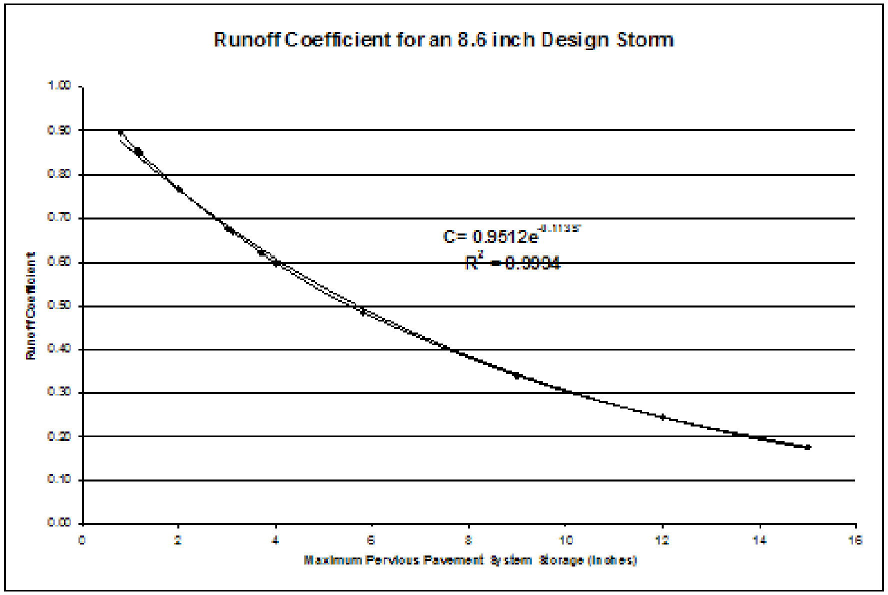

Figure 2. Runoff Coefficient Curve for Pervious Pavements as a Function of Storage and for an 8.6 inch Design Storm Event.

Example Problem

To illustrate the use of Figures 1 and 2, consider an area in the State of Florida where retention of 2.5 inches is needed for a specified mass loading reduction. For this example, a design section is specified that is a 6 inch deep pervious pavement with water holding capacity of 0.15 inch per inch depth, and a reservoir that is 8 inches deep with a water holding capacity of 0.2 inch per inch depth. The seasonal high water table is 24 inches below the reservoir. The reservoir can recover within the stated time period. The water holding capacity of the section is 2.5 inches (0.9 + 1.6). This storage capacity with parent and aquifer conductivities is sufficient to capture at least 80% of the annual rainfall and the pollution mass at a minimum 1.5 inches per hour infiltration rate, and over 95% at a limiting infiltration rate of 3.0 inches per hour (see Figure 1).

The runoff coefficient for an 8.6 inch storm event and 2.5 inches of storage (Figure 2) is estimated at over 0.70 and calculated using the formula as 0.72. Thus 72% of 8.6 inches is runoff or 6.19 inches. Most pervious pavement sections are designed for greater storage because of greater depth of the reservoir, or thicker pervious pavements, thus less rainfall excess results for a design storm. For this example pavement section, if there were an additional 12 inches of reservoir storage at 0.20 inch of storage per inch depth (20 inch deep reservoir), the resulting storage would be 4.9 inches. Thus the runoff coefficient would be reduced to 0.55 and runoff volume to 4.73 inches.

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Other Considerations

Runoff volumes can be calculated using the Curve Number Method. The curve number is calculated directly from the maximum storage using CN=1000/(S'+10). For a maximum storage of 2.5 and 4.9 inches as in the example problem, the Curve Numbers are 80 and 67 respectively.

The runoff volume calculation requires an assumption of initial abstraction. The initial abstraction used is typically set at 20% of the total storage, and 20% was assumed in the development of Figure 2. As additional experimental data are obtained, the typical value may be verified or a new initial abstraction may be recommended.

Frequent infiltration tests using the ERIK are being conducted at the UCF Stormwater Management Academy laboratory to further document the hydrologic operations of five different pervious pavements systems. These tests include the loading of the pervious pavement sections with sand, limestone, and debris. The infiltration rates are measured with the ERIK device before and after loading. When completed, results of these tests will be published as another technical memorandum.

The amount of water stored in the pervious pavement system is estimated from the storage voids within the pervious pavement sections. After the pervious system is loaded with sand, limestone, and debris, the sustainable water storage capacities will be determined for each material based on the extreme soil and debris loadings at the laboratory. When completed, results of these tests will also be published as another technical memorandum.

Marty Wanielista: July 26, 2008

Example Problem #1

The above photograph provided by Deep Tu, P.E.
at the Florida Concrete * Products Association
http://www.fcpa.org/

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

Completed pervious concrete* parking lot at the Florida Concrete Products Association (FCPA) facility in Orlando, Florida

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

Example Problem #1

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

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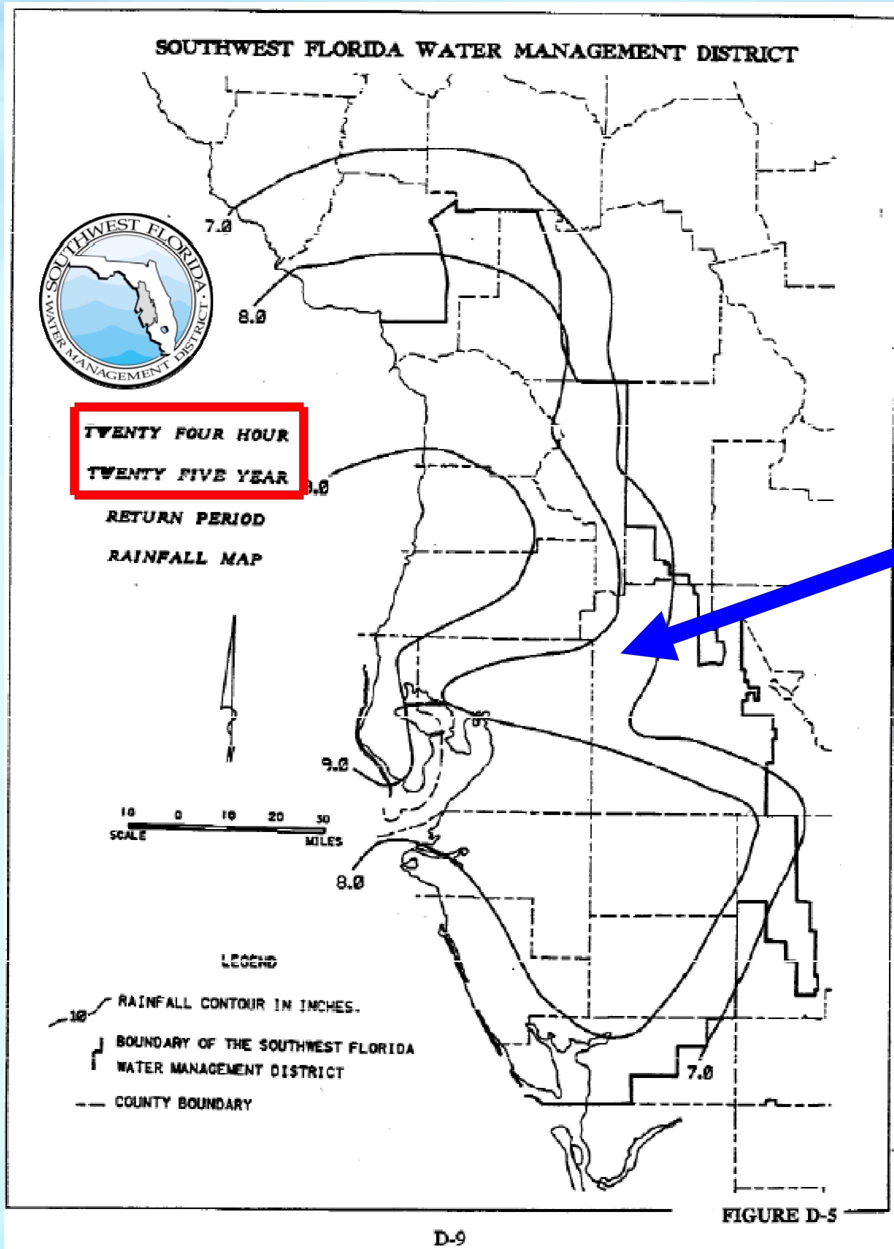

24 hour, 25 year rainfall depth ≈ 7.5 inches

Project Location: Lakeland, FL

Assignment: Determine the pervious pavement Curve Number (CN) and the Rational "C" Coefficient for this rainfall depth.

Example Problem #1

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

PERVIOUS PAVEMENT DESIGN AID: CLICK HERE TO START | THIS IS A DRAFT DOCUMENT SUBJECT TO REVISON

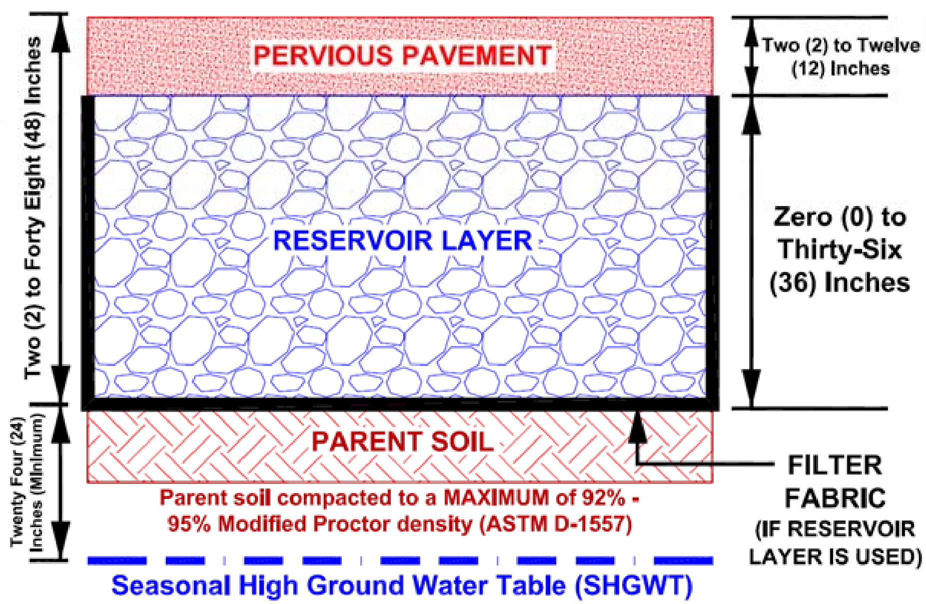

Figure 1:
Typical Pervious Pavement Cross Section

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Acknowledgement: This document is a continuation of a Technical Memorandum dated 07/26/08 by Dr. Marty Wanielista entitled *"Retention for Pollution Control and Estimated Runoff for Flood Control as a Function of the Maximum Water Storage Capacity of Pervious Pavement Systems".*

Disclaimer: These workbooks were created to assist in the review of commonplace calculations. These are not District approved or required. All users are responsible for validating the accuracy of the internal calculations. If errors or omissions are noted within this workbook, please e-mail Christopher Kuzlo, E.I. at christopher.kuzlo@watermatters.org or Hank Higginbotham, P.E. at hank.higginbotham@watermatters.org with specific information so that revisions can be made.

Beta Version 1.00	25-Aug-08	Initial public release
Beta Version 1.01	27-Aug-08	Added Black and Gold™ and other Sub Base Options
Beta Version 1.02	28-Aug-08	Revised Figure 1 to comply with the current recommendation of a MAXIMUM Parent soil compaction of 92% - 95% Modified Proctor density (ASTM D-1557)
Beta Version 1.03	29-Sep-08	Revised recommended effective porosity in the storage calculator per Dr. Chopra's 09/15/08 presentation to the statewide storm water Rule Technical Advisory Committee (TAC).

Be sure to enable the Excel© Macros prior to starting.

This Excel© "Design Aid" is available from the 09/15/08 TAC meeting summary available at: http://www.dep.state.fl.us/water/wetlands/erp/rules/stormwater/rule_docs.htm

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

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

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

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

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

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
	0	15	0
	0	25	0
	0	25	0
#4 rock	0	30	0
Recycled (crushed) concrete	0	25	0
Black and Gold™	0	9	0
Other Sub Base (see Note #1 above)	0	20	0

Drop-down menu:
- Click to select Perv. Pvmt. Section
- Concrete Pervious Pavement
- Porous Asphalt Pavement
- Flexi Pave®
- Permeable Pavers®

Blue Numbers	= Input data
Red Numbers	= Answers

Pull down menu for the type of pervious pavement

Example Problem #1

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

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	20	1.2
Other Perv. Pvmt. (see Note #1 above)	0	15	0
#57 rock	0	25	0
#89 pea rock	0	25	0
#4 rock	0	30	0
Recycled (crushed) concrete	0	25	0
Black and Gold™	0	9	0
Other Sub Base (see Note #1 above)	0	20	0

Blue Numbers	= Input data
Red Numbers	= Answers

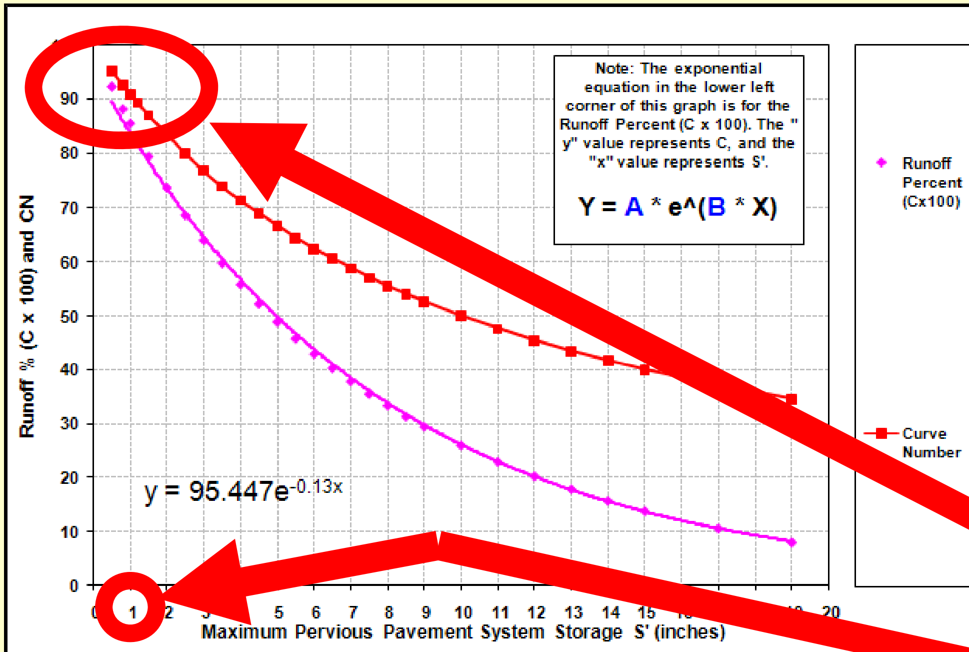
Note #1: For other pervious pavement sections, the User must supply the appropriate certified "Sustainable Void space percentages" from a licensed geotechnical laboratory.

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

Example Problem #1

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

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



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

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	20	1.2
Other Perv. Pvmt. (see Note #1 above)	0	15	0
#57 rock	0	25	0
#89 pea rock	0	25	0
#4 rock	0	30	0
Recycled (crushed) concrete	0	25	0
Black and Gold™	0	9	0
Other Sub Base (see Note #1 above)	0	20	0

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

S' =	1.2
CN =	89
C =	0.82

Y = A * e^(B * X)

A value:	B value:
95.447	-0.1299

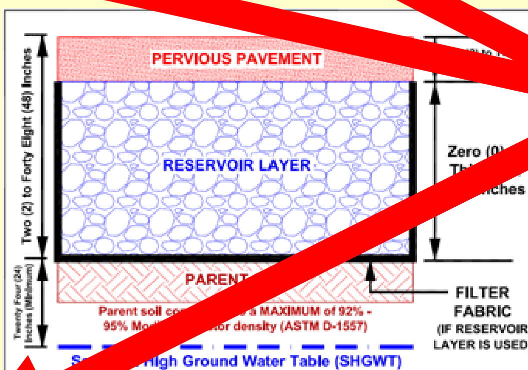


Figure 1:
Typical Pervious Pavement Cross Section

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') = 1.2"

CN = 89

Rational "C" = 0.82

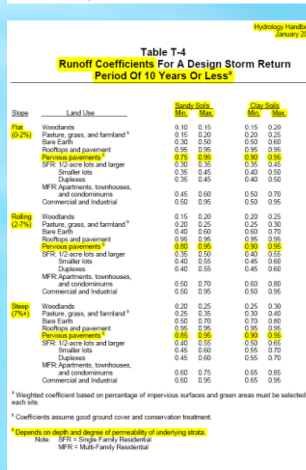
Example Problem #1

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

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

Slope	Land Use	Sandy Soils Min.	Sandy Soils Max.	Clay Soils Min.	Clay Soils Max.
Flat (0-2%)	Woodlands	0.10	0.15	0.15	0.20
	Pasture, grass, and farmland [b]	0.15	0.20	0.20	0.25
	Bare Earth	0.30	0.50	0.50	0.60
	Rooftops and pavement	0.95	0.95	0.95	0.95
	Pervious pavements [c]	0.75	0.95	0.90	0.95
	SFR: 1/2-acre lots and larger	0.30	0.35	0.35	0.45
	Smaller lots	0.35	0.45	0.40	0.50
	Duplexes	0.35	0.45	0.40	0.50
	MFR: Apartments, townhouses, and condominiums	0.45	0.60	0.50	0.70
	Commercial and Industrial	0.50	0.95	0.50	0.95

[c] Depends on depth and degree of permeability of underlying strata.



Hydrology Handbook
January 2004

Table T-5
Design Storm Frequency Factors For Pervious Area Runoff Coefficients *

Return Period (years)	Design Storm Frequency Factor, X_T
2 to 10	1.0
25	1.1
50	1.2
100	1.25

Reference: Wright-McLaughlin Engineers (1969).

* DUE TO THE INCREASE IN THE DURATION TIME THAT THE PEAK OR NEAR PEAK DISCHARGE RATE IS RELEASED FROM STORMWATER MANAGEMENT SYSTEMS, THE USE OF THESE SHORT DURATION PEAK RATE DISCHARGE ADJUSTMENT FACTORS IS NOT APPROPRIATE FOR FLOOD ROUTING COMPUTATIONS.

For a 25 year design storm, the FDOT range for Rational "C" values are:

1.1 x 0.75 = 0.83

1.1 x 0.95 = 1.05 (use 1.0)

From the previous slide, the Rational "C" = 0.82

Similar results for sandy soils

The FDOT Drainage Hydrology Handbook is available at:
http://www.dot.state.fl.us/rddesign/dr/Manualsandhandbooks.htm

Example Problem #2

Installation at the UCF Engineering Field Lab on 11-09-07

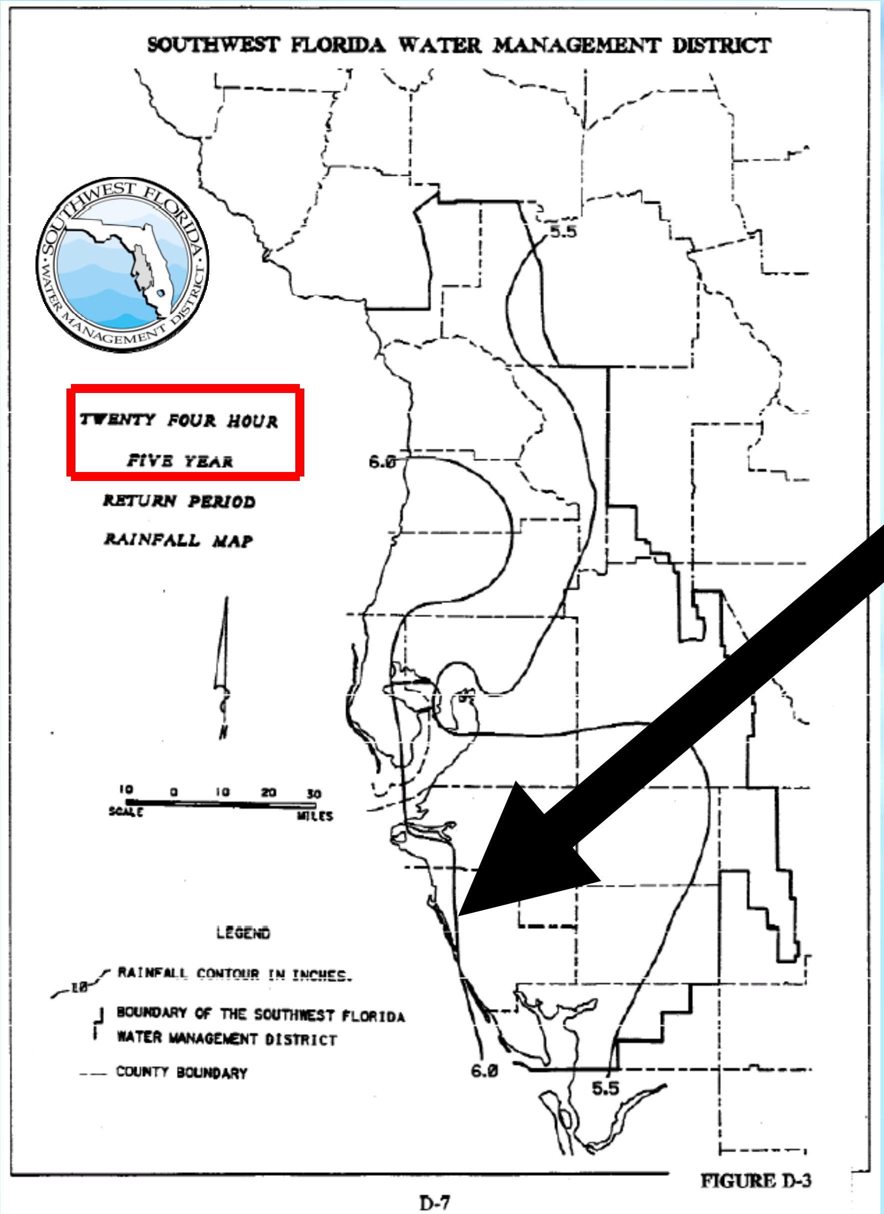
** This mention does not constitute an endorsement of product.*

Two (2) inches of Flexi™-Pave * placed over a twenty-four (24) inch #57 stone storage reservoir.

Example Problem #2

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

Two (2) inches of Flexi™-Pave * placed over a **twenty-four (24) inch #57 stone storage reservoir.**



Project Location: Sarasota, FL

Please note that most of Sarasota County consists of pine flatwoods soils, HSG = "B/D", with a SHGWT from 0" to 12" B.L.S.

24 hour, 5 year rainfall depth ≈ 6.0 inches

Assignment: Determine the pervious pavement Curve Number (CN) and the Rational "C" Coefficient for this rainfall depth.

Example Problem #2

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

Two (2) inches of Flexi™-Pave * placed over a twenty-four (24) inch #57 stone storage reservoir.

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). **6.00**

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, 5 year rainfall depth ≈ 6.0 inches.

S'	CN	C * 100	Ln (runoff %)
0.5	95	90.65	4.507
0.8	93	85.61	4.450
1	91	82.45	4.412
1.2	89	79.45	4.375
1.5	87	75.21	4.320
2	83	68.77	4.231
2.5	80	63.02	4.143
3	77	57.86	4.058
3.5	74	53.20	3.974
4	71	48.99	3.892
4.5	69	45.16	3.810
5	67	41.67	3.730
5.5	65	38.48	3.650

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 #2

* This mention does not constitute an endorsement of product.

Two (2) inches of Flexi™-Pave * placed over a twenty-four (24) inch #57 stone storage reservoir.

Calculator for Pervious Pavement Section Storage (S')			
Layer	Thickness (in)	SUSTAINABLE Void Space (%)	Storage (in)
Click to select Perv. Pvmt. Section	0	0	0
	0	15	0
	0	25	0
	0	25	0
#4 rock	0	30	0
Recycled (crushed) concrete	0	25	0
Black and Gold™	0	9	0
Other Sub Base (see Note #1 above)	0	20	0

Click to select Perv. Pvmt. Section
Concrete Pervious Pavement
Porous Asphalt Pavement
Flexi Pave®
Permeable Pavers®

Blue Numbers	= Input data
Red Numbers	= Answers

Pull down menu for the type of pervious pavement

Example Problem #2

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

Two (2) inches of Flexi™-Pave * placed over a twenty-four (24) inch #57 stone storage reservoir.

Calculator for Pervious Pavement Section Storage (S')			
Layer	Thickness (in)	SUSTAINABLE Void Space (%)	Storage (in)
Flexi Pave®	2	18	0.36
Other Perv. Pvmt. (see Note #1 above)	0	15	0
#57 rock	24	25	6
#89 pea rock	0	25	0
#4 rock	0	30	0
Recycled (crushed) concrete	0	25	0
Black and Gold™	0	9	0
Other Sub Base (see Note #1 above)	0	20	0

Blue Numbers	= Input data
Red Numbers	= Answers

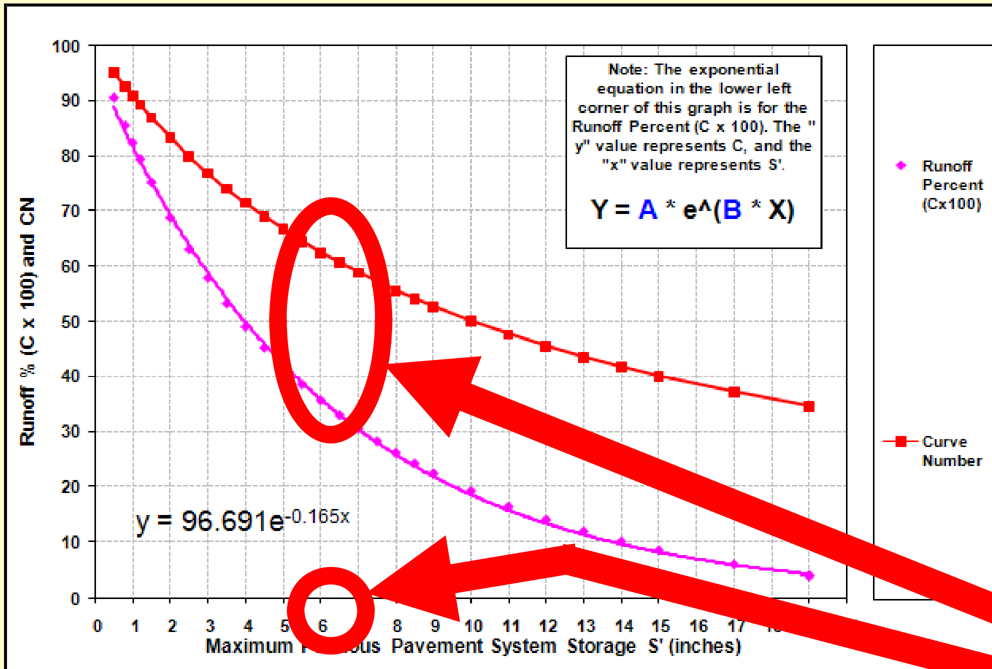
Note #1: For other pervious pavement sections, the User must supply the appropriate certified "Sustainable Void space percentages" from a licensed geotechnical laboratory.

Enter the 24 inches of #57 stone

Example Problem #2

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

Runoff Percent and Curve Number(CN) for the: 6.00 inch Design Storm Event



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

For two (2) inches of Flexi™-Pave * placed over a twenty-four (24) inch #57 stone storage reservoir, with a 6.0 inch rainfall depth:

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)
Flexi Pave®	2	18	0.36
Other Perv. Pvmt. (see Note #1 above)	0	15	0
#57 rock	24	25	6
#89 pea rock	0	25	0
#4 rock	0	30	0
Recycled (crushed) concrete	0	25	0
Black and Gold™	0	9	0
Other Sub Base (see Note #1 above)	0	20	0

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:
96.691	-0.1651

S' =	6.36
CN =	61
C =	0.34

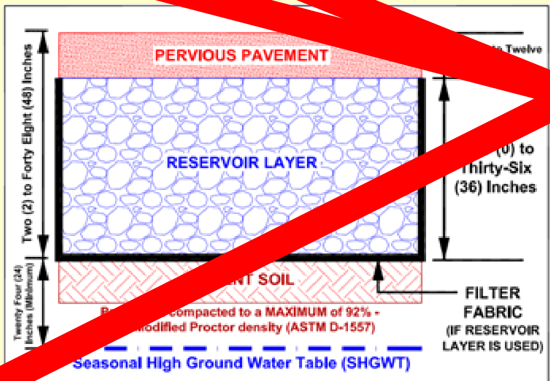


Figure 1:
Typical Pervious Pavement Cross Section

System Storage (S') = 6.36"

CN = 61

Rational "C" = 0.34

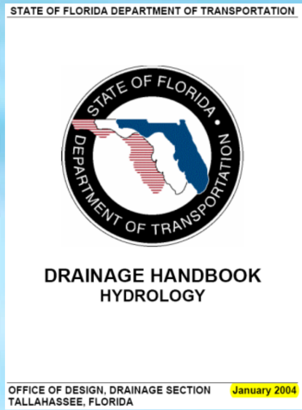
Example Problem #2

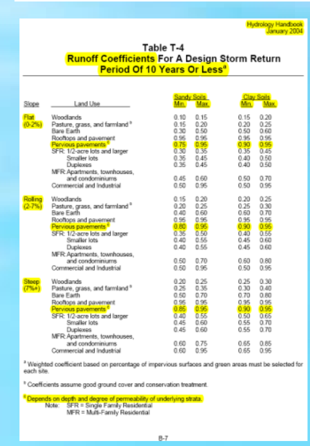
** This mention does not constitute an endorsement of product.*

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

Slope	Land Use	Sandy Soils Min.	Sandy Soils Max.	Clay Soils Min.	Clay Soils Max.
Flat (0-2%)	Woodlands	0.10	0.15	0.15	0.20
	Pasture, grass, and farmland [b]	0.15	0.20	0.20	0.25
	Bare Earth	0.30	0.50	0.50	0.60
	Rooftops and pavement	0.95	0.95	0.95	0.95
	Pervious pavements [c]	0.75	0.95	0.90	0.95
	SFR: 1/2-acre lots and larger	0.30	0.35	0.35	0.45
	Smaller lots	0.35	0.45	0.40	0.50
	Duplexes	0.35	0.45	0.40	0.50
	MFR: Apartments, townhouses, and condominiums	0.45	0.60	0.50	0.70
	Commercial and Industrial	0.50	0.95	0.50	0.95

[c] Depends on depth and degree of permeability of underlying strata.





For a 5 year design storm, the FDOT range for Rational "C" values are:

0.75
0.95

From the previous slide, the Rational "C" = 0.34

The results are different because the underlying strata is significantly different (a 24" thick #57 stone reservoir).

The FDOT Drainage Hydrology Handbook is available at:
http://www.dot.state.fl.us/rddesign/dr/Manualsandhandbooks.htm

Excel© "*Design Aid*" for Pervious Pavement

Using Beta Version 1.03 (dated 09/29/08), available at:
http://www.dep.state.fl.us/water/wetlands/erp/rules/stormwater/rule_docs.htm

Fictitious Example for a Small Pervious Pavement Project that Discharges Into Waters that Meet Water Quality Standards

(Using the District's presumptive criteria)

Note: **As this is a fictitious project for storm water <u>quality</u> review, no attempt was made to ensure that the example problems meet the other local codes of Sarasota County (i.e. flood control, land use intensity computations, landscaping requirements, minimum # of parking spaces, etc.).**

Soil Boring Recommendations

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT
RESOURCE REGULATION
TRAINING MEMORANDUM

DATE: December 04, 1996

> This document is subject to change. If in doubt, verify current status with Technical Services staff or the author(s).

SUBJECT: TM/ERP - 961212.e
Determination of Vertical Permeability (K_V) and Horizontal Permeability (K_H) in Surfacewater Management System Soil

TO: Surface Water Managers and Staff

FROM: Charlie H. Miller, P.E., Chief Regulation Engineer, Technical Services

THE PURPOSE OF THIS DOCUMENT IS TO PROVIDE GENERAL GUIDANCE FOR REGULATION REVIEW BY DISTRICT STAFF. THE GUIDELINES SET FORTH HEREIN MAY BE MODIFIED IN APPROPRIATE CIRCUMSTANCES.

Refer to the next five (5) slides for a copy of the above referenced SWFWMD Training Memorandum

Section 7.5.2 of the District's Basis of Review (BOR) states the following:

"Subsurface exfiltration will be reviewed only on the basis of representative or actual test data submitted by the applicant. Tests shall be consistent as to the elevation, location, soils, etc. with the system design to which the test data will be applied".

NUMBER: TM/ERP-961212.e
TITLE: Determination of Vertical/Horizontal Permeability...
PAGE: Attachment "B" (9 of 10)

When selecting the minimum number of borings, a minimum of one soil boring should be drilled to at least 10 feet below the proposed pond bottom elevation within the pond area. When more than one boring is required, the following approximate equation (empirical equation developed by Jammal & Associates, Inc.) can be applied to estimate the recommended number of soil borings required. The approximate equation takes into consideration the average area and configuration of the proposed pond:

$$B = 1 + \sqrt{2A} + \frac{L}{(2\pi W)} \qquad (3-1)$$

Where:

- B = number of recommended borings
- A = average pond area in acres
- L = length of pond, in feet
- W = width of pond, in feet
- ∏ = pi (3.14)

Recommended # of borings

In addition, an approximate equation to estimate the recommended number of hydraulic conductivity tests to be conducted was also developed by Jammal & Associates, Inc., and is presented below:

$$P = 1 + \frac{B}{4} \qquad (3-2)$$

Where:

- P = number of hydraulic conductivity tests required
- B = number of borings drilled

Recommended # of hydraulic conductivity tests

These equations are useful in determining the minimum number of tests that should be conducted. Additional tests may be required for systems located within a site which has complex hydrogeology and/or appreciable topographic relief.

Since we will be using a fictitious project for the following example problems, actual soil borings and Kv / Kh tests are not available. Therefore, we will use the NRCS soils information as representative test data.

Determination of Kv and Kh in Surfacewater Management System Soil

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT
RESOURCE REGULATION
TRAINING MEMORANDUM

DATE: December 04, 1996

This document is subject to change. If in doubt, verify current status with Technical Services staff or the author(s).

SUBJECT: TM/ERP - 961212.e
Determination of Vertical Permeability (K_V) and Horizontal Permeability (K_H) in Surfacewater Management System Soil

TO: Surface Water Managers and Staff

FROM: Charlie H. Miller, P.E., Chief Regulation Engineer, Technical Services

THE PURPOSE OF THIS DOCUMENT IS TO PROVIDE GENERAL GUIDANCE FOR REGULATION REVIEW BY DISTRICT STAFF. THE GUIDELINES SET FORTH HEREIN MAY BE MODIFIED IN APPROPRIATE CIRCUMSTANCES.

BACKGROUND: District staff may receive an ERP application that does not identify soil (K_V) and/or (K_H) in the proposed stormwater management system. Staff may then be faced with reviewing (or calculating) a groundwater analysis for any (or all) of the following items:

1) Required treatment volume recovery in "dry" retention/detention ponds;

2) Soil infiltration rates in a retention/detention pond that are exported as a rating curve to a computer software flood routing model;

3) Radius of influence calculations for elevated retention/detention ponds; or

4) Radius of influence calculations for drainage ditches, subsurface drains, or retention/detention ponds with outfall structures designed to lower on/off-site groundwater tables.

DESCRIPTION: The District's Governing Board has the authority to establish rules to limit impacts which would be significantly harmful to the water resources and/or ecology of the area. District rules provide conditions of issuance for permits which require an applicant to provide reasonable assurance that the proposed project will not cause adverse impacts to existing surface water storage, wetland functions, and groundwater levels. In addition, the project design must be based on generally accepted engineering principles which will allow for proper functioning of the system.

Procedure - The proper determination of vertical and horizontal permeability rates are critical in groundwater calculations for the four situations listed above. Alterations of K_V and/or K_H can significantly change radius of influence distances, altered groundwater elevations, and required treatment volume drawdown times.

Process - The following outline is provided to aid staff in the determination of K_V and/or K_H that is based on generally accepted engineering principles.

I. K_V and/or K_H rates for final design of a project should always be based on field and laboratory test methods. These methods are summarized in Chapter 3 of the Jammal & Associates report

entitled "Stormwater Retention Pond Infiltration Analysis in Unconfined Aquifers." An abbreviated portion of Chapter 3 can be found in Attachment "A" of this Training Memorandum. The reader of this Training Memorandum should obtain a complete copy of the Jammal Report for additional information on K_V and K_H. Table 3-3 in Chapter 3 goes into greater detail, especially on the methods for determining K_H.

II. A proposed stormwater management system should contain the appropriate number of soil and/or hydraulic permeability tests (a.k.a. hydraulic conductivity tests in the Jammal report). The recommended minimum number of tests is also summarized in Chapter 3 of the Jammal report (Attachment "B" of this Technical Memorandum).

III. In the event that the applicant does not provide K_V and/or K_H rates, staff can estimate these values from the appropriate USDA-NRCS Soil Survey of the area. However, these estimated K_V and/or K_H rates should only be used for initial review of the application for the purpose of preparing the "request for additional information" letter to the applicant. **Staff should use extreme caution in accepting these estimated K_V and/or K_H values as final design rates for the purpose of evaluating the permit application.**

Attachment "C" of this Technical Memorandum outlines a rational procedure that can be used for estimating the preliminary K_V and/or K_H rates.

REFERENCES:

1. Chapters 373.016(2)(b),(d),(e),and(f); 373.042(2); 373.113; 373.171(1)(c); 373.413(h); 373.414(1)(a)(1), (2), (5), and (7), Florida Statutes
2. Rule 40D-4.091(1), Section 7.5.2, Basis of Review; Rule 40D-4.101(1)(c) and (e); 40D-4.301(1)(c), (g), and (I), Florida Administrative Code
3. TM/ERP-961212.b, "Overdrainage and Water Conservation, Section 4.6, Basis of Review"
4. TM/ERP-961212.c, "Potential Impacts to On-Site and Off-Site Property From Stormwater Ponds Located Near Property Boundaries"
5. TM/ERP-961212.d, "Water Table Drawdown Effects Due to Ditching, Subsurface Drains, and/or Stormwater Retention/Detention Ponds"
6. Jammal & Associates, Inc. (Nicolas E. Andreyev, P.E.), 1989/91 Edition of "Stormwater Retention Pond Infiltration Analysis in Unconfined Aquifers", prepared for the Southwest Florida Water Management District.
7. David K. Todd, University of California, Berkeley, "Groundwater Hydrology ©", Second Edition, John Wiley & Sons, Inc.,1980
8. Modret© *, Version 5.0 computer model
9. Ponds©*, Version 2.24 computer model
10. USGS Modflow computer model (Public Domain model)

* The Modret© and Ponds© computer models are graphical pre- and post-processors that utilize the USGS Modflow computer model as their "software engine"

Determination of Kv and Kh in Surfacewater Management System Soil

STATUS: This Training Memorandum along with TM/ERP - 961212.d replaces IOP/SWP-030 and SWP-20.02 dated April 20, 1990, entitled "Water Table Drawdown Effects Due to Ditching and Sub-Surface Drains"

ATTACHMENTS:

A) A portion of Chapter 3 of the 1989/91 edition of "Stormwater Retention Pond Infiltration Analysis in Unconfined Aquifers" by Jammal & Associates, Inc., dealing with recommended testing methods and techniques for vertical and horizontal permeability.

B) A portion of Chapter 3 of the 1989/91 edition of "Stormwater Retention Pond Infiltration Analysis in Unconfined Aquifers" by Jammal & Associates, Inc., dealing with the recommended minimum number of soil borings in a proposed retention/detention pond.

C) A Rational Procedure for Estimating Preliminary Vertical and Horizontal Permeability.

DISTRIBUTION: Executive, General Counsel, Resource Regulation Directors, Technical Services, Records & Data, Administrative Secretaries, Permit Coordinators, Central Records

AUTHOR: **Hank Higginbotham, P.E., Professional Engineer, Technical Services**

This may be an electronically distributed copy of an original document that was signed and sealed on the date ascribed. The original document is on file in Technical Services, and a copy is also available in Central Records.

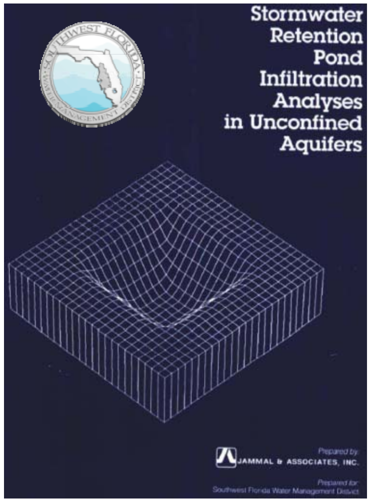
(seal)

(Original document was signed and sealed on12/04/96)

____
Henry H. Higginbotham, Jr., P.E.
Florida Registration No. 31977 Date:__________

Stormwater Retention Pond Infiltration Analyses in Unconfined Aquifers

March 1989
Revised February 1991



Prepared by:

Nicolas E. Andreyev, P.E.
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Jammal & Associates Division
1675 Lee Road
Winter Park, Florida 32789
Telephone (407) 645-5560

Prepared for:

Southwest Florida Water Management District
2379 Broad Street
Brooksville, Florida 34609-6899
Telephone (352) 796-7211

This publication is available from the Southwest Florida Water Management District Technical Services Department for $30.00, which covers the costs of printing, handling and shipping.

Determination of Kv and Kh in Surfacewater Management System Soil

Chapter 3
Review of Field and Laboratory Test Methods

Conclusions and Recommendations

There are many different field and laboratory test methods which can be used to explore and estimate hydrogeologic conditions and hydraulic parameters of an aquifer. In most instances, the limitations of the various methods are not clearly understood. To measure the horizontal hydraulic conductivity of the entire effective aquifer thickness, we recommend using short or long term pumping tests. This method, if used properly, provides the most reliable results. Slug tests are the next best means of measuring the hydraulic conductivity of the entire aquifer thickness, but the accuracy of this method is usually hindered by the need to install the piezometer in an undisturbed condition. For instance, if a clayey fine sand or clay is encountered in the profile in which the well is to be installed, unreliable results are usually obtained due to smearing of the soil surface during drilling and piezometer installation.

Laboratory permeability measurements on undisturbed samples generally yield accurate results, but the value of hydraulic conductivity is usually representative of a point of a soil stratum within the aquifer. Therefore, to characterize the entire aquifer system, permeability tubes would need to be collected in each soil strata comprising the aquifer system. This method is generally limited by the number of tests required and the fact that undisturbed samples must be collected.

Therefore, it is our opinion that the most effective method of hydraulic conductivity testing is a combination of laboratory and field tests that produce the most reliable results. These would include laboratory tests on undisturbed samples obtained from shallow depths, field auger/tube tests in sandy soils and above ground water table, piezometer slug tests with properly installed and developed wells in deeper sandy deposits and short term or long term pump tests for multi-layer aquifer systems. A summary of recommended methods for the various exploration and testing techniques is presented in **Table 3-4**.

It should be realized that the information contained in this chapter is intended for planning purposes. Good, sound engineering judgment is still needed to determine when and where a particular method is applicable, to assess the limitations of each method and the validity of its results.

Table 3-4.
Recommended Field and Laboratory Testing Methods for Stormwater Retention Pond Infiltration Analysis

CONDITIONS	TEST METHOD
Soil Exploration	
Type and condition of soil	
<10 feet	hand or power auger borings
>10 feet <60 feet	power auger borings
In-situ density needed (any depth)	Standard Penetration Test Boring
Accurate ground water level reading is critical	Hand or power auger boring and allow water level to stabilize for a minimum of 24 hours
Hydraulic Conductivity Measurement	
Shallow hydraulic conductivity measurement above ground water table (sandy soil)	
<4 feet	Excavate test pit with post-hole digger or shovel, hand drive shelby tube and perform laboratory permeameter tests
>4 feet <10 feet	Excavate test pit with backhoe or other equipment, collect shelby tubes by hand and perform laboratory permeameter tests.
>10 feet <50 feet	Drill power auger borings to depth of proposed test. Install casing to bottom of borehole and screen the desired test interval. Conduct field hydraulic test using well permeameter method (U.S.B.R. Designation E-19).
Hydraulic Conductivity Measurement below Ground Water Table (sandy soil) <30 feet	Install piezometer to desired depth, develop piezometers, stabilize for 24 hour minimum and conduct slug test or constant head test (Hvorslev, 1951, U.S. Navy, 1974 and Bouwer & Rice, 1971)
Accurate Determination of Hydraulic Conductivity is critical. Measurement below ground water table. Any depth.	Install two wells and conduct short-term pumping test (Lohman, 1972)

Determination of Kv and Kh in Surfacewater Management System Soil

NUMBER: TM/ERP-961212.e
TITLE: Determination of Vertical/Horizontal Permeability...
PAGE: Attachment "A" (7 of 10)

Table 3-4.
Recommended Field and Laboratory Testing Methods for Stormwater Retention Pond Infiltration Analysis

CONDITIONS	TEST METHOD
Hydraulic Conductivity Measurement	
Estimate K_v (unsaturated initial infiltration)	Conduct Double Ring Infiltrometer tests. Alternatives, obtain undisturbed tube sample in the vertical direction. Conduct laboratory permeameter test and then estimate K_v (unsaturated) by empirical methods
Deep hydraulic conductivity measurement below restrictive soils or confining unit (sandy soil). Ground water table below bottom of restrictive soil	Install piezometer(s) to desired depth and screen below confining unit. Grout from bottom of confining unit to land surface. Conduct slug test in piezometer(s) (Hvorslev, 1951; U.S. Navy, 1974)
Deep hydraulic conductivity measurement below restrictive soil or confining unit (sandy soil). Ground water table above confining unit. Leakance suspected to be high through confining unit.	Install two (2) piezometers to desired depth and screen below confining unit. Grout from bottom of confining unit to land surface. Conduct long-term pumping test (Lohman, 1972)
Shallow or deep hydraulic conductivity measurement of restrictive soils (clayey sand, clays and hardpan)	Collect shelby tube soil sample by hand or with drill rig and conduct laboratory permeameter test in triaxial machine.
Approximate estimate of hydraulic conductivity after drilling is completed	Remold sample collected during drilling program to the approximate *in-situ* unit weight and conduct laboratory test in triaxial machine.
Unsaturated Vertical Infiltration Estimate, Direct Method	Conduct double ring infiltrometer test at pond bottom level. Compact test surface to the approximate post-construction density. Use final (I_c) infiltration rate determined during test.

NUMBER: TM/ERP-961212.e
TITLE: Determination of Vertical/Horizontal Permeability...
PAGE: Attachment "B" (8 of 10)

Chapter 3
Review of Field and Laboratory Test Methods

General Considerations
One of the most important steps in the evaluation of a stormwater retention pond is determining which test methods and how many tests should be conducted per site or per system. Typically, a soil boring and some type of hydraulic conductivity measurement is conducted for each stormwater retention pond, as a minimum. The number of soil borings and hydraulic conductivity tests performed are usually based on site topography, subsurface hydrogeologic conditions, pond size and pond geometry. Judgement and experience are usually applied in the decision-making process. In this report, we have developed methods for estimating the required number of borings and hydraulic conductivity tests in order to characterize the shallow aquifer system for retention pond designs. These methods should only be used as a guide and more or less tests may become necessary based on local experience and knowledge of site hydrogeologic conditions.

Soil Borings
To explore the subsurface soil and ground water table conditions within an area proposed for a stormwater retention pond, Standard Penetration Test (SPT) borings (ASTM D-1586) or auger borings (ASTM D-1452) can be used. Standard Penetration Test borings provide a reasonable soil profile and an estimate of the relative density of the soils. However, measurement of the ground water table depth in SPT borings is usually less accurate than in auger borings due to the drilling fluid (bentonite-mud) used during the drilling process. Power auger borings generally provide more accurate soil profiles and a better estimate of depth to the ground water table. Therefore, a combination of SPT and auger borings in a retention pond would provide the best data to characterize the effective aquifer system.

In general, it is preferable to extend soil borings to the confining layers of the effective aquifer system. However, for small retention pond systems (<1,000 ft^2), such a requirement may not be practical or cost effective. A more appropriate method of estimating minimum soil boring depth would be to extend the boring to the confining layers or a minimum of 10 feet below proposed pond bottom. For modeling purposes, confining layers should be set at the encountered elevations of poorly permeable soil layers (confining layers) or at the bottom of the test borings, if confining layers are not encountered.

Determination of Kv and Kh in Surfacewater Management System Soil

NUMBER: TM/ERP-961212.e
TITLE: **Determination of Vertical/Horizontal Permeability...**
PAGE: **Attachment "B" (9 of 10)**

When selecting the minimum number of borings, a minimum of one soil boring should be drilled to at least 10 feet below the proposed pond bottom elevation within the pond area. When more than one boring is required, the following approximate equation (empirical equation developed by Jammal & Associates, Inc.) can be applied to estimate the recommended number of soil borings required. The approximate equation takes into consideration the average area and configuration of the proposed pond:

$$B = 1 + \sqrt{2A} + \frac{L}{(2\pi W)} \qquad (3\text{-}1)$$

Where:

- B = number of recommended borings
- A = average pond area in acres
- L = length of pond, in feet
- W = width of pond, in feet
- π = pi (3.14)

In addition, an approximate equation to estimate the recommended number of hydraulic conductivity tests to be conducted was also developed by Jammal & Associates, Inc., and is presented below:

$$P = 1 + \frac{B}{4} \qquad (3\text{-}2)$$

Where:

- P = number of hydraulic conductivity tests required
- B = number of borings drilled

These equations are useful in determining the minimum number of tests that should be conducted. Additional tests may be required for systems located within a site which has complex hydrogeology and/or appreciable topographic relief.

NUMBER: TM/ERP-961212.e
TITLE: **Determination of Vertical/Horizontal Permeability...**
PAGE: **Attachment "C" (10 of 10)**

A Rational Procedure for Estimating Preliminary K_V and K_H

The applicant did **not** provide any on-site soil borings or permeability tests. The local USDA-NRCS soils maps of the area show that the upland areas of the site in question are comprised entirely of Ona series soils (HSG of "B/D") with a Seasonal High Ground Water Table (SHGWT) from 0" to 12" below the ground surface, and the following **vertical** permeability rates

Depth From Surface	Vertical Permeability (K_V)
0" - 9"	6.0 - 20.0 in./hr
9" - 16"	0.6 - 2.0 in./hr
16" - 80"	6.0 - 20.0 in./hr

1. Determine a composite vertical permeability (K_V) for the soil in question using the following equation:

$$K_V = \frac{Z_1 + Z_2 + \cdots + Z_N}{\frac{Z_1}{K_{V1}} + \frac{Z_2}{K_{V2}} + \cdots + \frac{Z_N}{K_{VN}}}$$

Where: K_{V1}, K_{V2}, ... K_{VN} - Vertical hydraulic conductivities of soil layers

Z_1, Z_2, ... Z_N - Thickness of soil layers

From the local USDA-NRCS soils information, assume the **average** vertical permeability as follows:

Depth	Range of K_{Vi}	Average K_{Vi}
0" - 9"	6.0 - 20.0 in./hr	13.0 in./hr
9" - 16"	0.6 - 2.0 in./hr	1.3 in./hr
16" - 80"	6.0 - 20.0 in./hr	13.0 in./hr

Therefore: $Z_1 = 9"$, $Z_2 = 7"$, $Z_3 = 64"$

$K_{V1} = 13$ in./hr, $K_{V2} = 1.3$ in./hr, $K_{V3} = 13$ in./hr

and **$K_V = 7.27$ in./hr. (14.54 ft./day)**

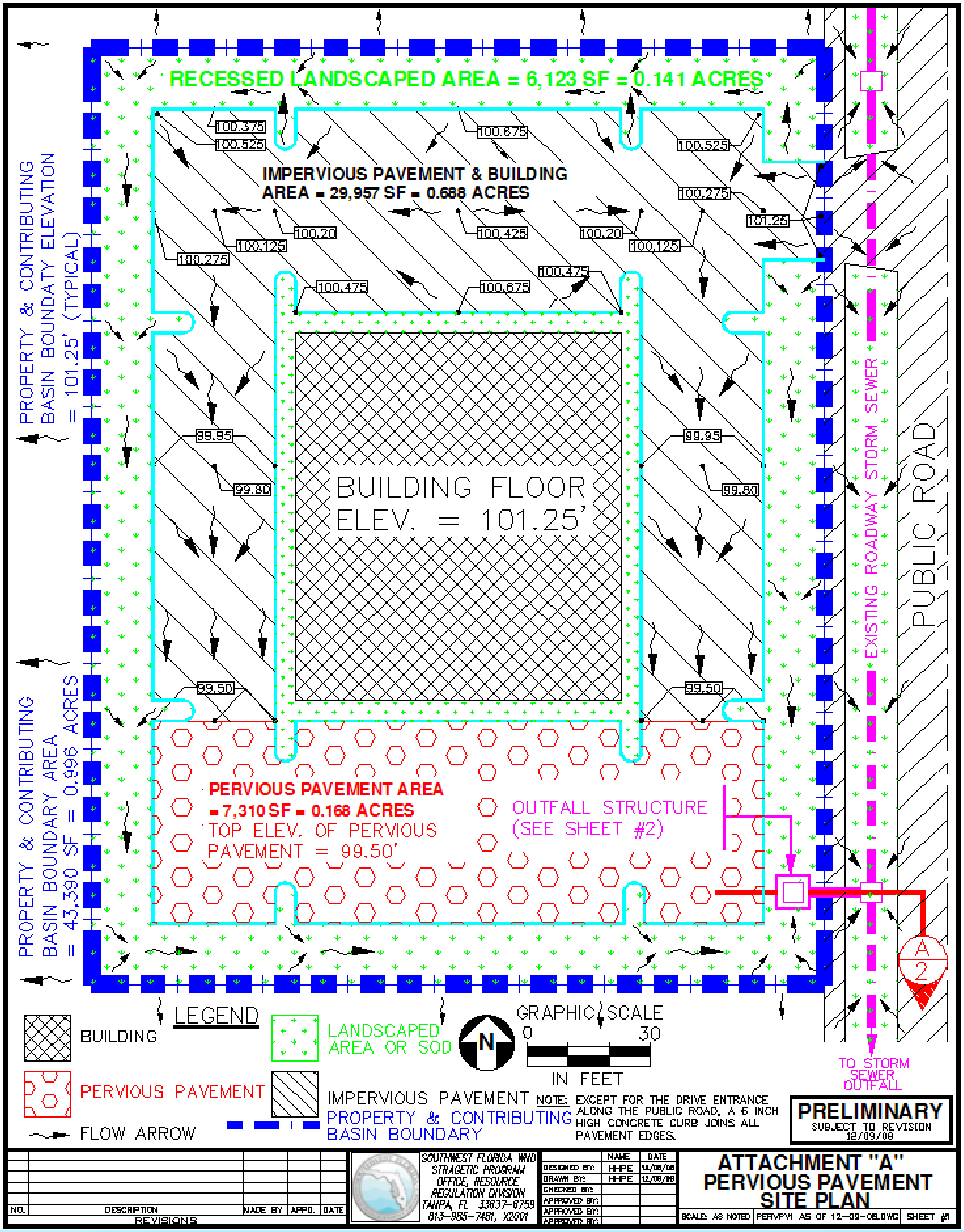
2. Determine a composite horizontal permeability (K_H) for the soil in question using the following equation:

$$K_H = \frac{K_{H1} \cdot Z_1 + K_{H2} \cdot Z_2 + \ldots + K_{HN} \cdot Z_N}{Z_1 + Z_2 + \ldots + Z_N}$$

Use a 1.5 multiplier as an approximate conversion factor between K_H and K_V.

Therefore: $Z_1 = 9"$, $Z_2 = 7"$, $Z_3 = 64"$
$K_{H1} = 19.5$ in./hr, $K_{H2} = 1.95$ in./hr, $K_{H3} = 19.5$ in./hr

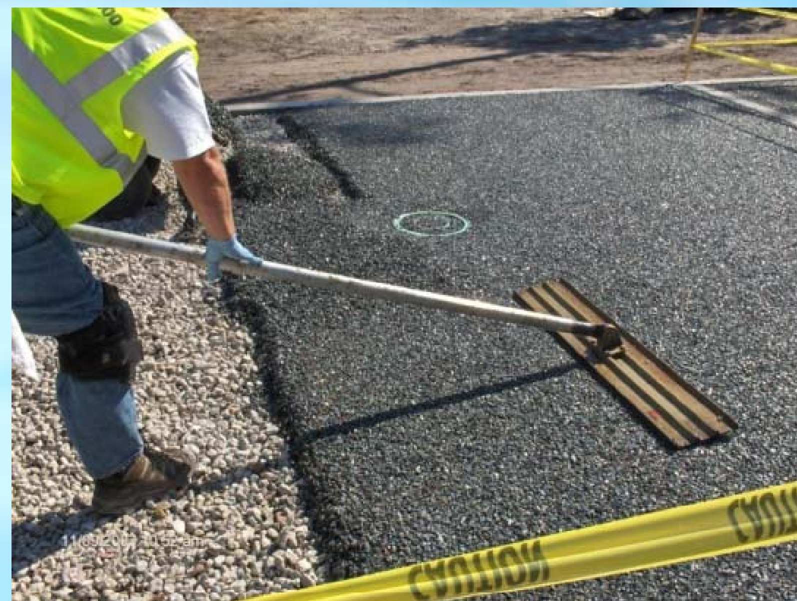
and **$K_H = 17.96$ in./hr (35.92 ft./day)**



Example Problem

Two (2) inches of Flexi™-Pave * placed over a eleven (11) inch #57 stone storage reservoir.

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



Landscaped (green impervious) areas = 6,123 SF = 0.141 Acres

Impervious Pavement & Building = 29,957 SF = 0.688 Acres

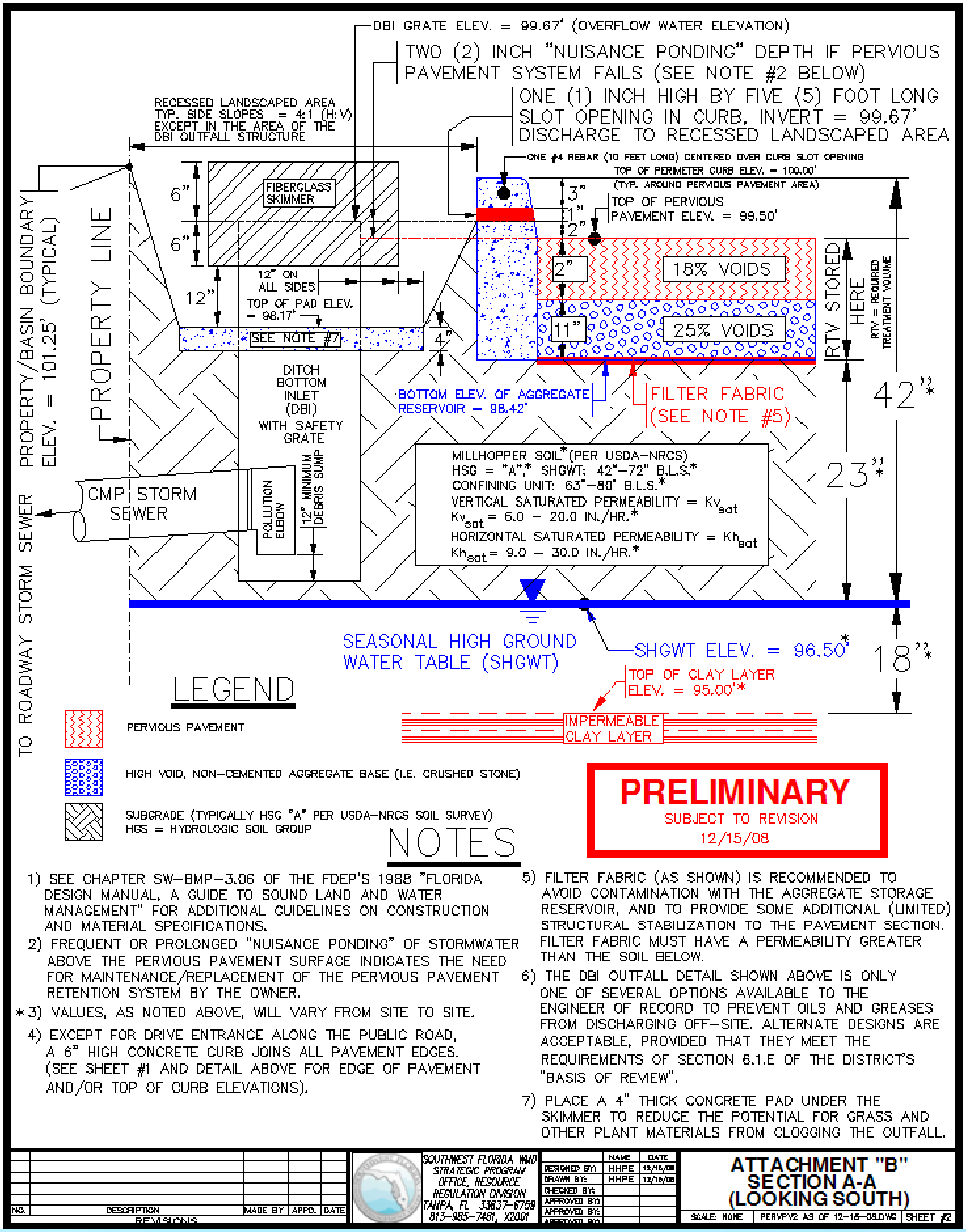
Pervious Pavement Area = 7,310 SF = 0.168 Acres

Total Property & Contributing Basin Boundary Area = 43,390 SF = 0.996 Acres

Example Problem

Two (2) inches of Flexi™-Pave * placed over an eleven (11) inch #57 stone storage reservoir.

Available Pervious Pavement Section Storage (S') = 3.11 Inches (see below)



Calculator for Pervious Pavement Section Storage (S')

Layer	Thickness (in)	SUSTAINABLE Void Space (%)	Storage (in)
Flexi Pave®	2	18	0.36
Other Perv. Pvmt. (see Note #1 above)	0	15	0
#57 rock	11	25	2.75
#89 pea rock	0	25	0
#4 rock	0	30	0
Recycled (crushed) concrete	0	25	0
Black and Gold™	0	9	0
Other Sub Base (see Note #1 above)	0	20	0
		S' =	3.11

Retention Volume Computations

Total Property & Contributing Basin Boundary Area = 43,390 SF = 0.996 Acres

Required Treatment Volume (RTV) = Contributing Basin x 0.5 Inches (refer to Section 5.2.c.1 of the District's *"Basis of Review"*) = 43,390 SF * (0.5 Inches / 12 Inches Per Foot)

= 1,808 CF = 0.042 Acre-Feet

From a previous slide, the Pervious Pavement Area = 7,310 SF = 0.168 Acres

Designed Pervious Pavement Storage Volume (within the sustainable void spaces in the design section) = Pavement Area x Available Storage = 7,310 SF * (3.11 Inches / 12 Inches Per Foot) **= 1,895 CF = 0.043 Acre-Feet**

Two (2) inches of Flexi™-Pave * placed over an eleven (11) inch #57 stone storage reservoir.

Calculator for Pervious Pavement Section Storage (S')

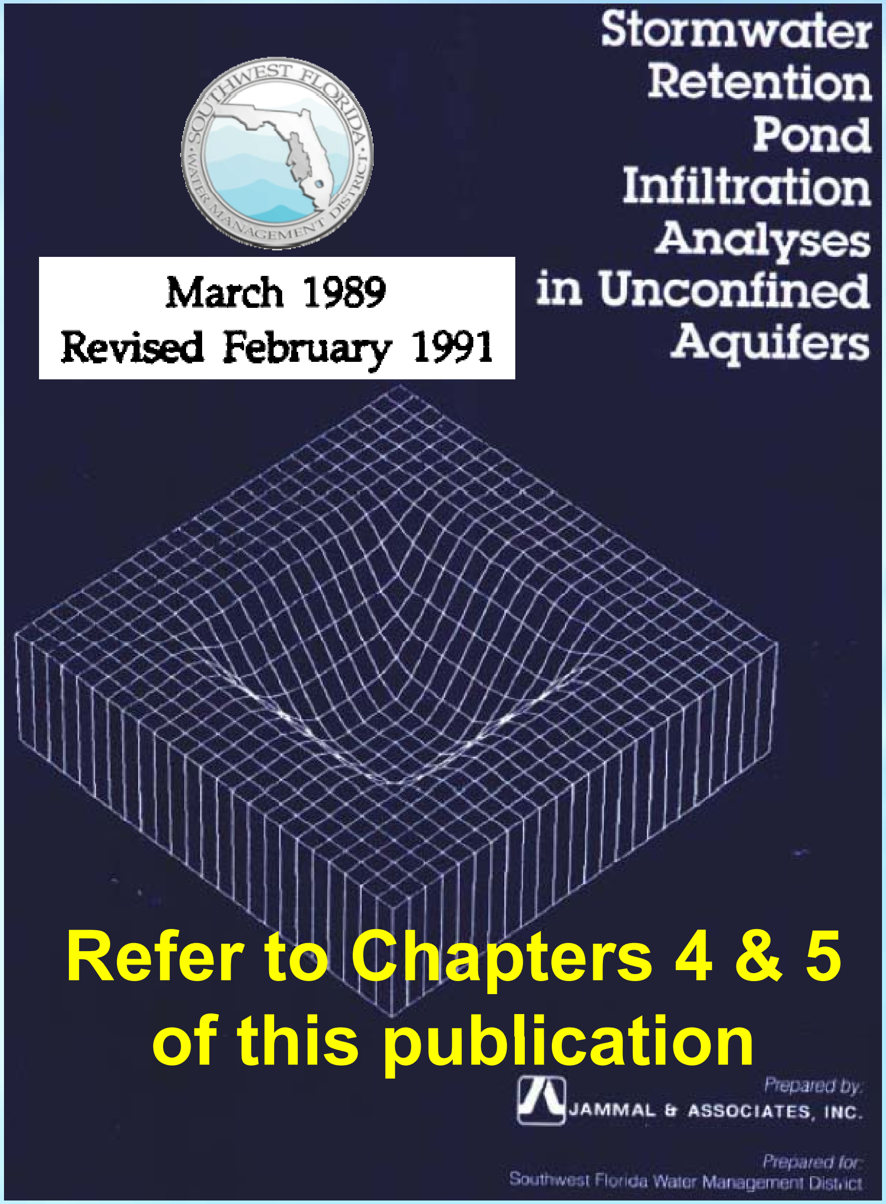
Layer	Thickness (in)	SUSTAINABLE Void Space (%)	Storage (in)
Flexi Pave®	2	18	0.36
Other Perv. Pvmt. (see Note #1 above)	0	15	0
#57 rock	11	25	2.75
#89 pea rock	0	25	0
#4 rock	0	30	0
Recycled (crushed) concrete	0	25	0
Black and Gold™	0	9	0
Other Sub Base (see Note #1 above)	0	20	0
		S' =	3.11

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

Since the Designed Pervious Pavement Storage Volume of = 1,895 CF is greater than the Required Treatment Volume (RTV) of 1,808 CF, **the retention portion of the analysis is okay.**

A mounding analysis is now required to demonstrate that the RTV will recover within 72 hours with a safety factor of two (2). Refer to the next several slides for the recovery analysis.

Mounding (recovery) analysis of the Required Treatment Volume (RTV)



Refer to Chapters 4 & 5 of this publication

A significant percentage of engineering consultants utilize the PONDS© *, Modret© *, or ICPR© * software packages to perform this analysis.

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

Mounding (recovery) analysis of the Required Treatment Volume (RTV) using Modret *

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

MODRET

MODRET Version 6.1 (Windows 95/98/NT)

SUMMARY OF UNSATURATED & SATURATED INPUT PARAMETERS

PROJECT NAME : Pervious Pavement
POLLUTION VOLUME RUNOFF DATA USED
UNSATURATED ANALYSIS INCLUDED

150' / 50'

Pond Bottom Area	7,310.00 ft²
Pond Volume between Bottom & DHWL	7,919.17 ft³
Pond Length to Width Ratio (L/W)	3.00
Elevation of Effective Aquifer Base	95.00 ft
Elevation of Seasonal High Groundwater Table	96.50 ft
Elevation of Starting Water Level	98.42 ft
Elevation of Pond Bottom	98.42 ft
Design High Water Level Elevation	99.50 ft
Avg. Effective Storage Coefficient of Soil for Unsaturated Analysis	0.10
Unsaturated Vertical Hydraulic Conductivity	8.00 ft/d
Factor of Safety	2.00
Saturated Horizontal Hydraulic Conductivity	18.00 ft/d
Avg. Effective Storage Coefficient of Soil for Saturated Analysis	0.11
Avg. Effective Storage Coefficient of Pond/Exfiltration Trench	0.24

Weighted average of the sustainable void spaces in the pervious pavement section (see the next slide).

0.67 * Kv (per the Modret User's manual).

Hydraulic Control Features:

	Top	Bottom	Left	Right
Groundwater Control Features - Y/N	N	N	N	N
Distance to Edge of Pond	0.00	0.00	0.00	0.00
Elevation of Water Level	0.00	0.00	0.00	0.00
Impervious Barrier - Y/N	N	N	N	N
Elevation of Barrier Bottom	0.00	0.00	0.00	0.00

MODRET

MODRET Version 6.1 (Windows 95/98/NT)

TIME - RUNOFF INPUT DATA

PROJECT NAME: PERVIOUS PAVEMENT

STRESS PERIOD NUMBER	INCREMENT OF TIME (hrs)	VOLUME OF RUNOFF (ft³)
Unsat	1.15	1,403.52
1	1.00	404.48
2	8.73	0.00
3	8.73	0.00
4	8.73	0.00
5	8.73	0.00
6	8.73	0.00
7	8.73	0.00
8	8.73	0.00
9	8.73	0.00

"Slug" loading Hydrograph (above) from the 1,808 CF Required Treatment Volume input (below).

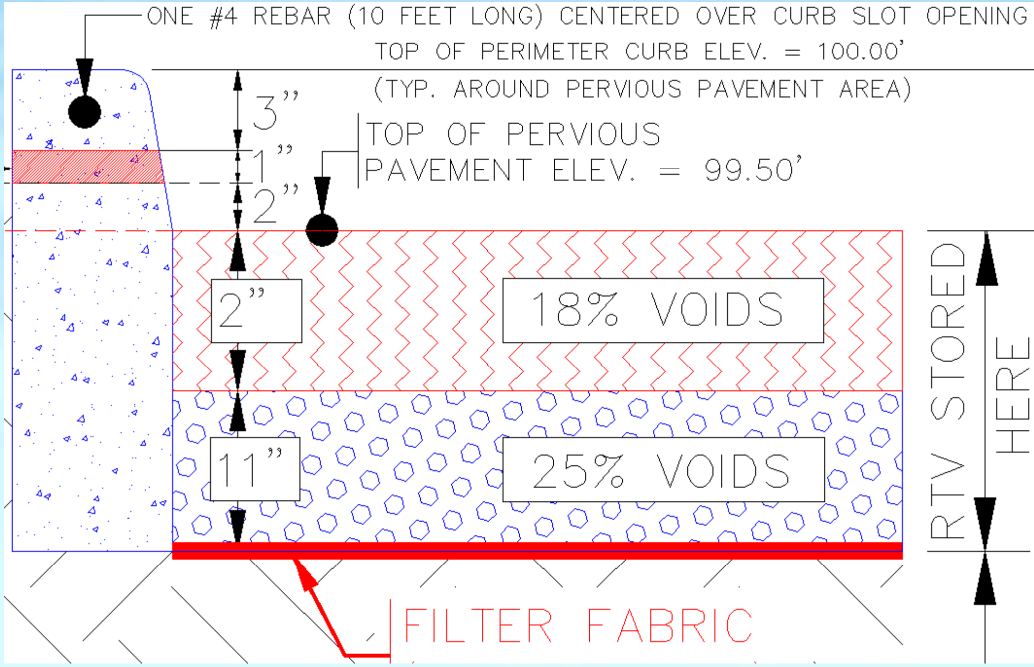
Runoff Data: Pollution Volume

Total Pollution Abatement Volume (ft3):	1808.00
Time of Recovery (hrs):	72.00

OK Cancel

Mounding (recovery) analysis of the Required Treatment Volume (RTV) using Modret *

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



Weighted average of the sustainable void spaces

(refer to the data in the pervious pavement calculator below)

2" x 0.18 = 0.36

11" x 0.25 = 2.75

13" 3.11

3.11 / 13" = 0.24

Two (2) inches of Flexi™-Pave * placed over an eleven (11) inch #57 stone storage reservoir.

Calculator for Pervious Pavement Section Storage (S')			
Layer	Thickness (in)	SUSTAINABLE Void Space (%)	Storage (in)
Flexi Pave®	2	18	0.36
Other Perv. Pvmt. (see Note #1 above)	0	15	0
#57 rock	11	25	2.75
#89 pea rock	0	25	0
#4 rock	0	30	0
Recycled (crushed) concrete	0	25	0
Black and Gold™	0	9	0
Other Sub Base (see Note #1 above)	0	20	0
		S' =	3.11

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

Weighted average of the sustainable void spaces in the "composite" pervious pavement section.

Mounding (recovery) analysis of the Required Treatment Volume (RTV) using Modret *

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

MODRET

MODRET Version 6.1 (Windows 95/98/NT)

SUMMARY OF RESULTS

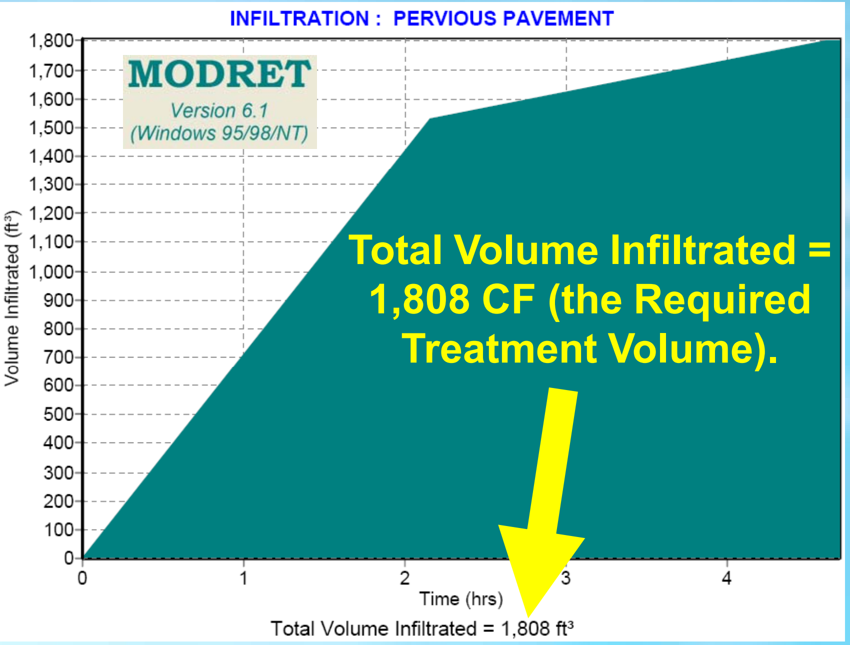
PROJECT NAME : Pervious Pavement

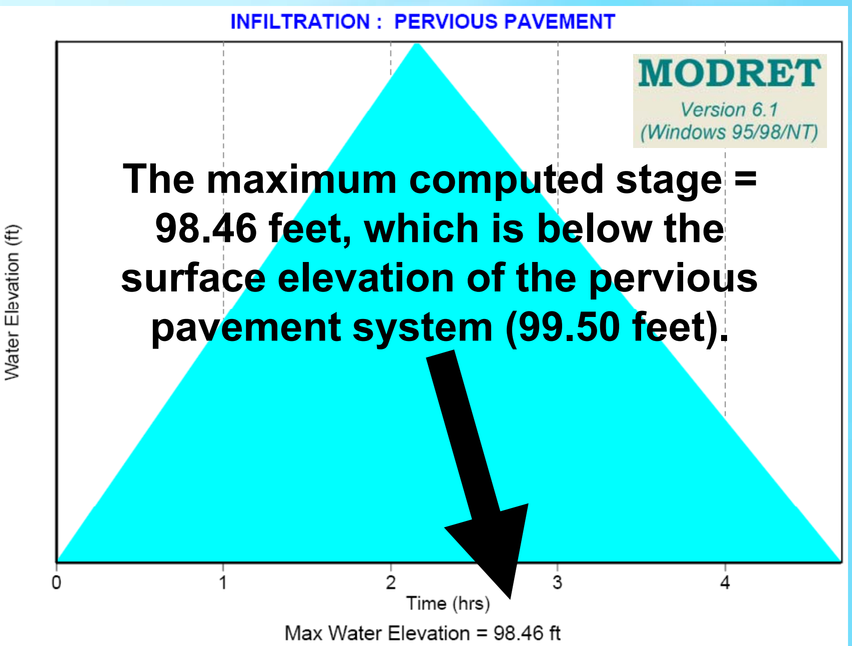
CUMULATIVE TIME (hrs)	WATER ELEVATION (feet)	INSTANTANEOUS INFILTRATION RATE (cfs)	AVERAGE INFILTRATION RATE (cfs)	CUMULATIVE OVERFLOW (ft³)
00.00 - 0.00	96.500	0.000 *		
			0.00000	
0.00	96.500	0.22992		
			0.19705	
2.15	98.458	0.16417		0.00
			0.03079	
4.69	98.420	0.02812		0.00
			0.02545	
19.61	98.217	0.02301		0.00
			0.02057	
28.34	98.129	0.01866		0.00
			0.01675	
37.08	98.057	0.01535		0.00
			0.01395	
45.81	97.998	0.01292		0.00
			0.01190	
54.54	97.947	0.01114		0.00
			0.01037	
63.27	97.902	0.00979		0.00
72.00	97.863			0.00

As the Required Treatment Volume (RTV) of 1,808 CF recovers to the bottom of the pervious pavement system elevation of 98.42 feet in 4.69 hours (< 72 hours with a safety factor of two), it meets the criteria specified in Section 5.2.c.2 of the District's *"Basis of Review"*.

Maximum Water Elevation: 98.458 feet @ 2.15 hours   Recovery @ 4.691 hours
* Time increment when there is no runoff
Maximum Infiltration Rate: 0.557 ft/day

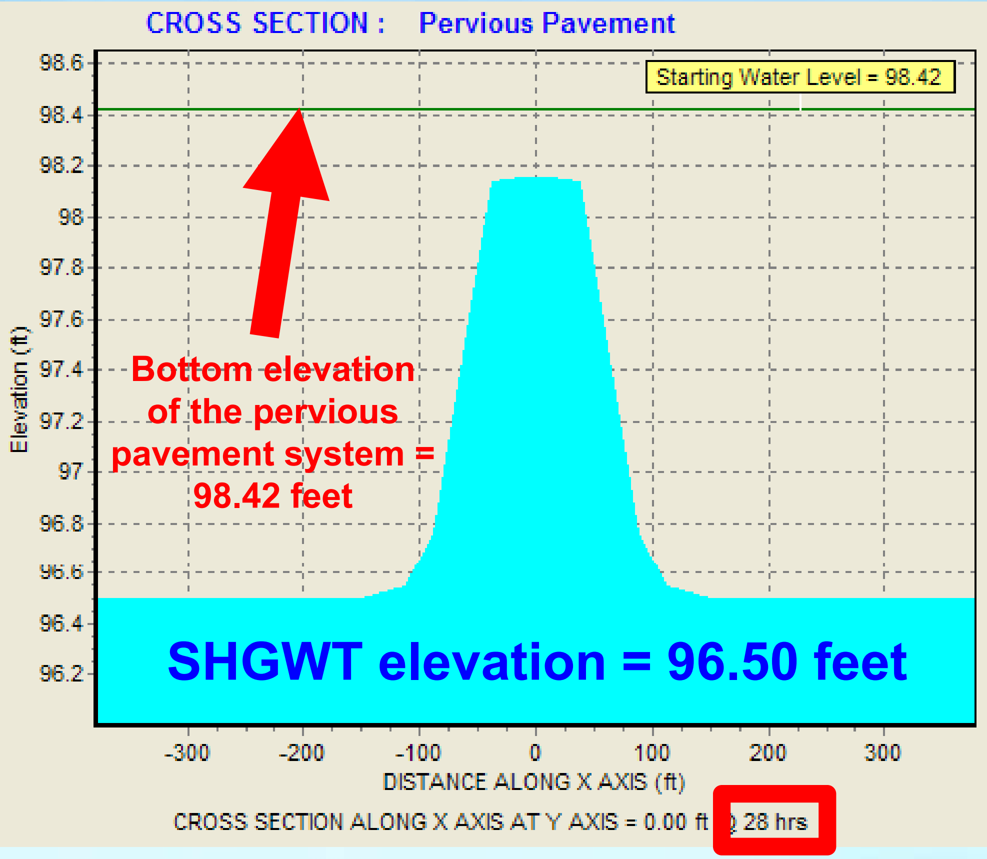
The SHGWT = 96.50 feet



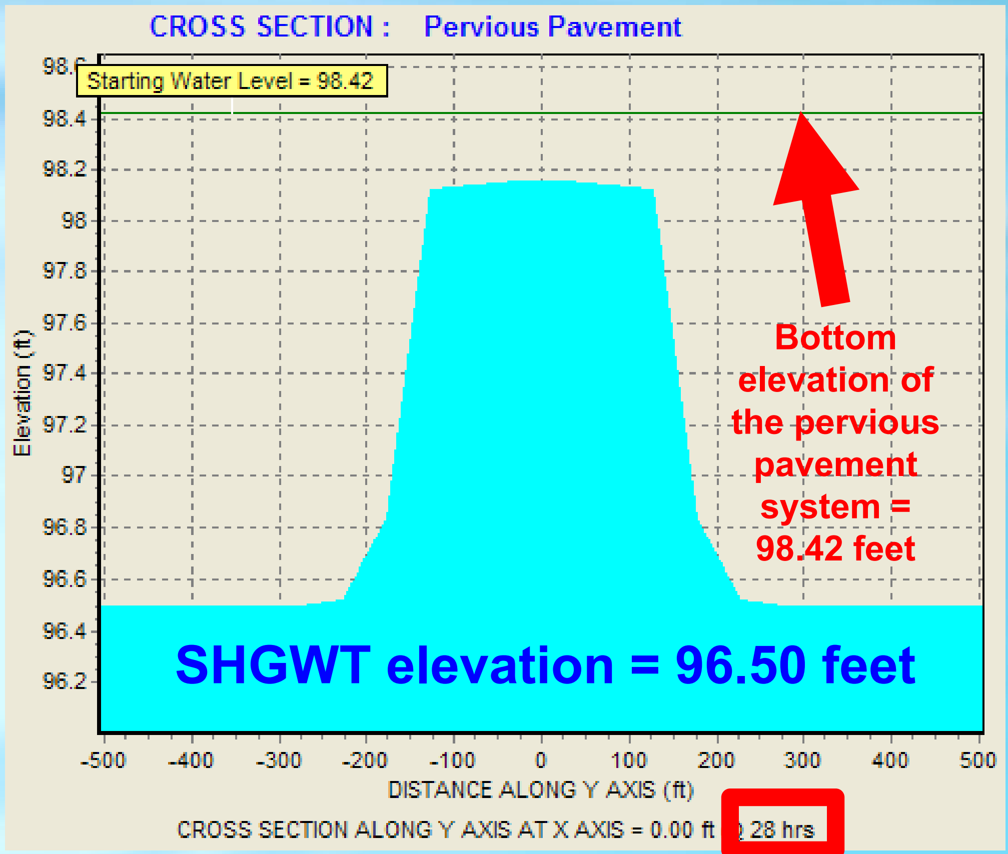


Mounding (recovery) analysis of the Required Treatment Volume (RTV) using Modret *

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



Looking **north / south** through the pervious pavement section

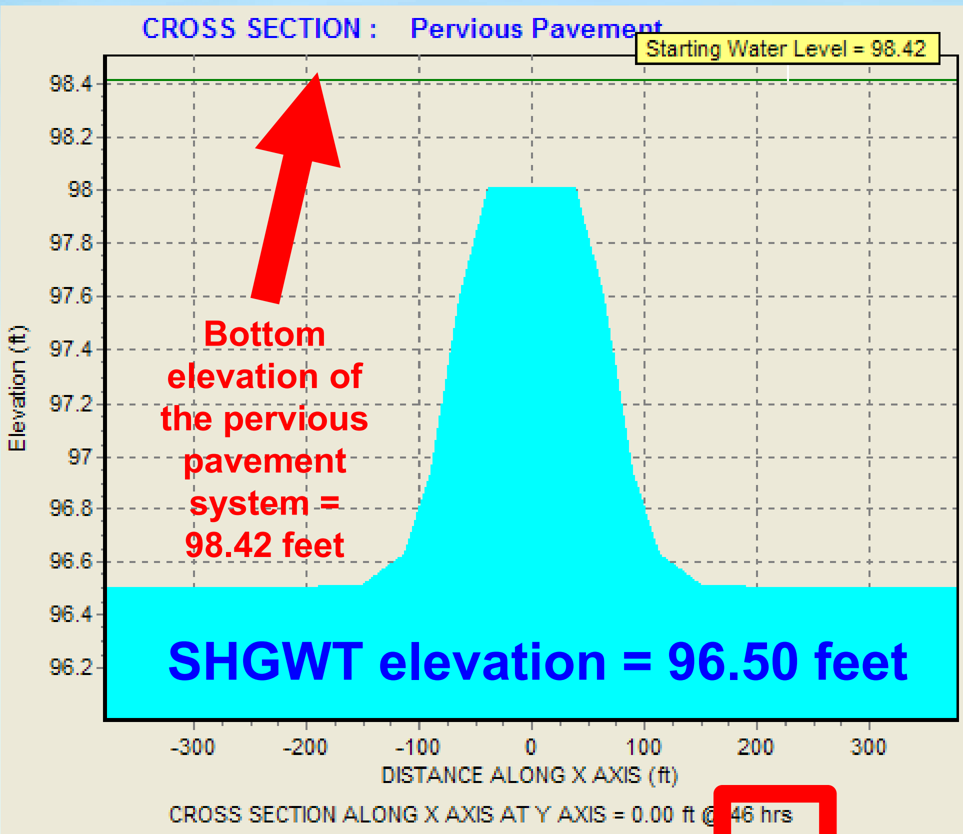


Looking **east / west** through the pervious pavement section

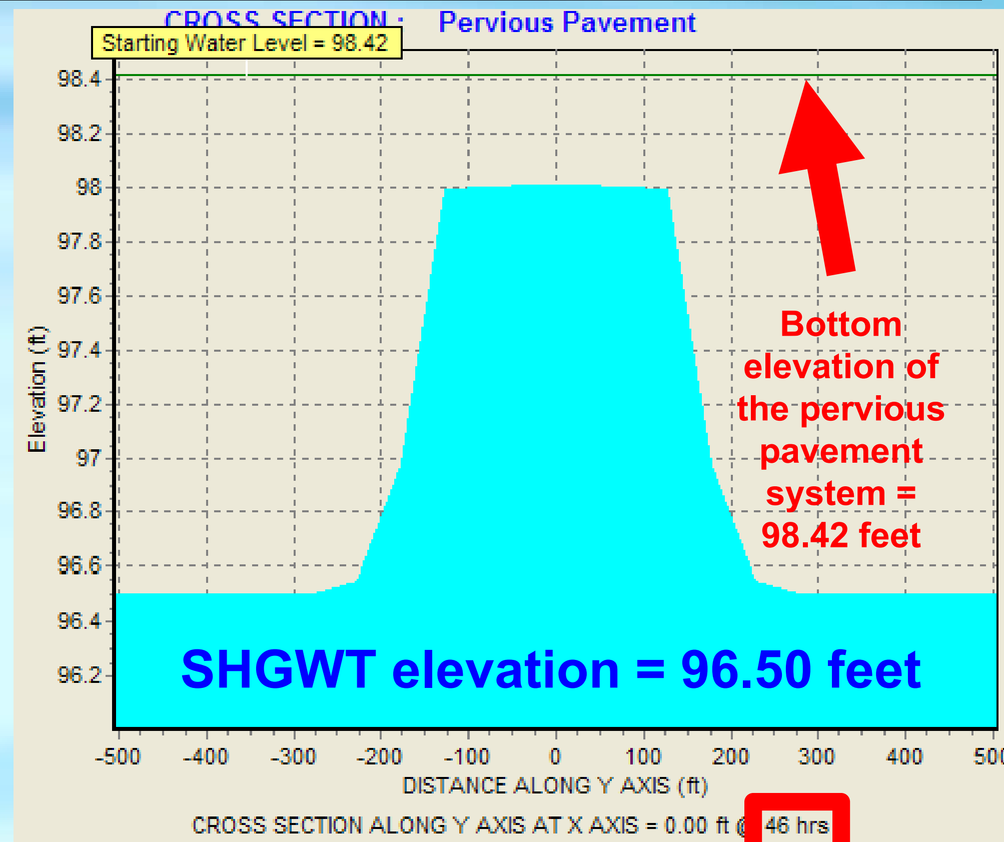
Groundwater mound after 28 hours

Mounding (recovery) analysis of the Required Treatment Volume (RTV) using Modret *

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



Looking **north / south** through the pervious pavement section

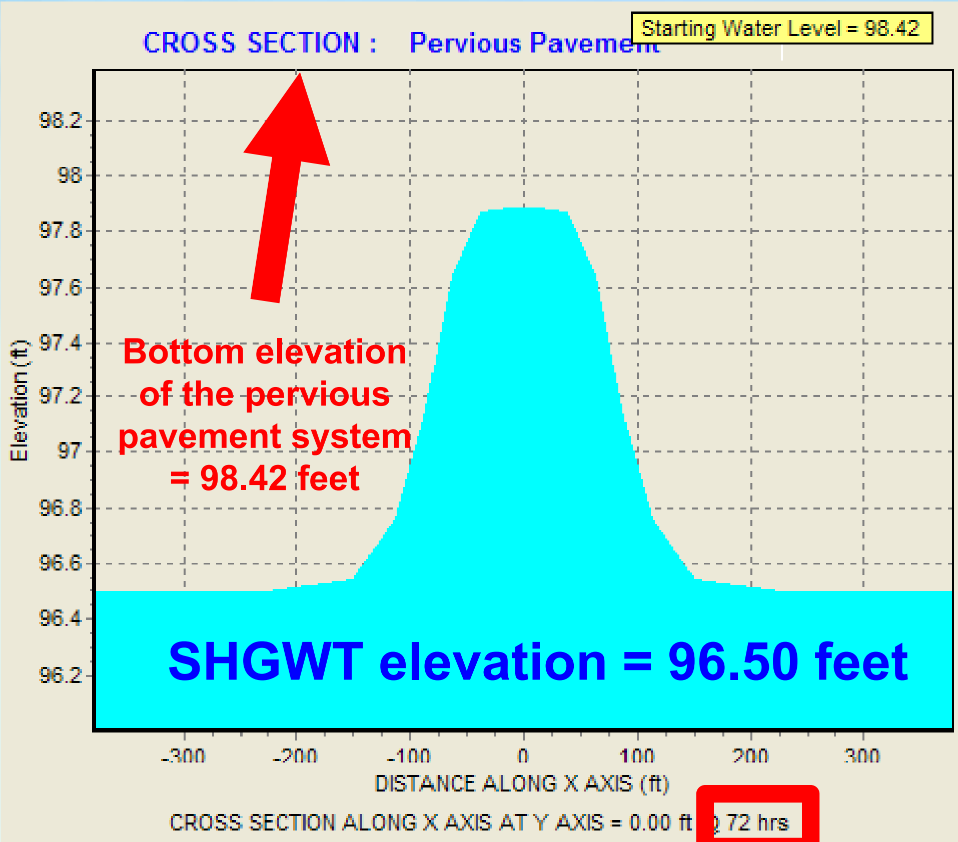


Looking **east / west** through the pervious pavement section

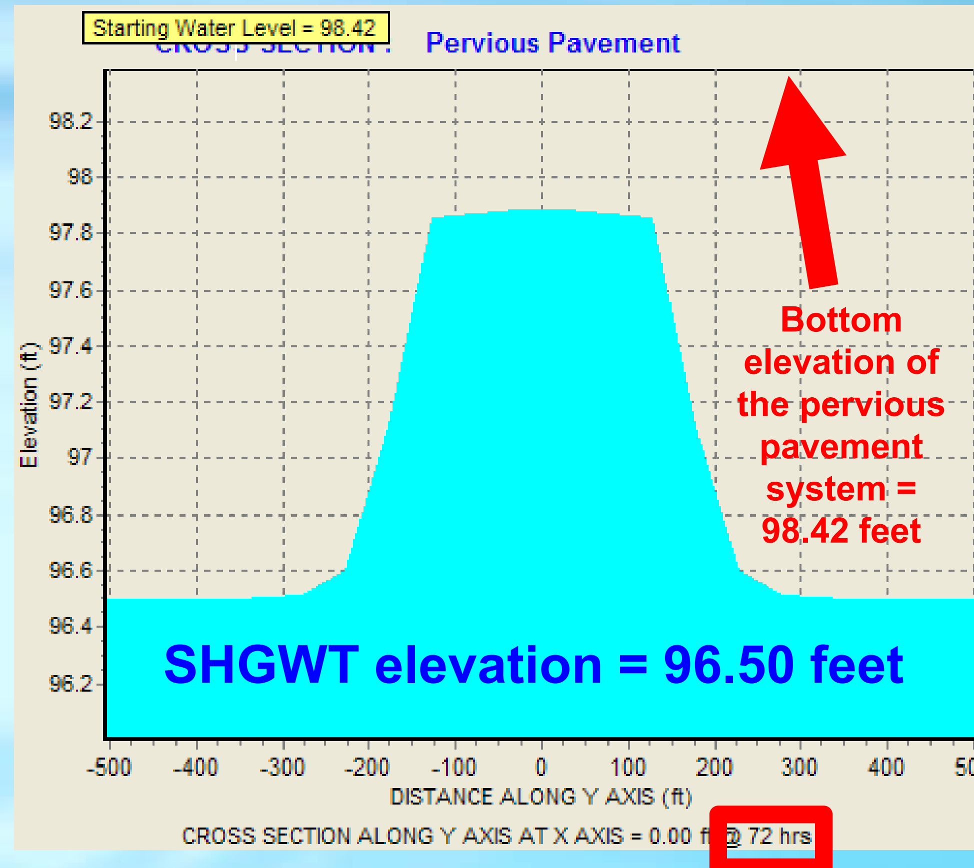
Groundwater mound after 46 hours

Mounding (recovery) analysis of the Required Treatment Volume (RTV) using Modret *

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



Looking **north / south** through the pervious pavement section



Looking **east / west** through the pervious pavement section

Groundwater mound after 72 hours

Mounding (recovery) analysis of the Required Treatment Volume (RTV) using PONDS *

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

The PONDS * software package models an open pond or trench with a porosity of 1.0. It does NOT directly model an exfiltration trench (or pervious pavement) that has a porosity less than 1.0.

Therefore, Devo Seereeram, P.E., Ph.D. (the author of the PONDS * software package), published a procedure for gravel filled ponds and trenches - refer to his Technical Memo dated 09/25/06, available at:

http://devoeng.com/technical_memo.html

This memo is shown on the next two (2) slides.

DEVO Engineering
CONSULTING GEOTECHNICAL ENGINEERS

PONDS* 3.2 TECHNICAL MEMO

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

Date: September 25, 2006
Re: **Adjusting Geometry Parameters (etc) for an Exfiltration Trench**

The following memo outlines some details that may need to be considered when modeling an exfiltration trench (i.e., French drain, etc.) using the PONDS 3.2 Refined Method. These considerations affect the following:

- Stage vs Area Data
- Maximum Area for Unsaturated Infiltration

Consider the example of a gravel filled trench as depicted in Exhibit 1 below.

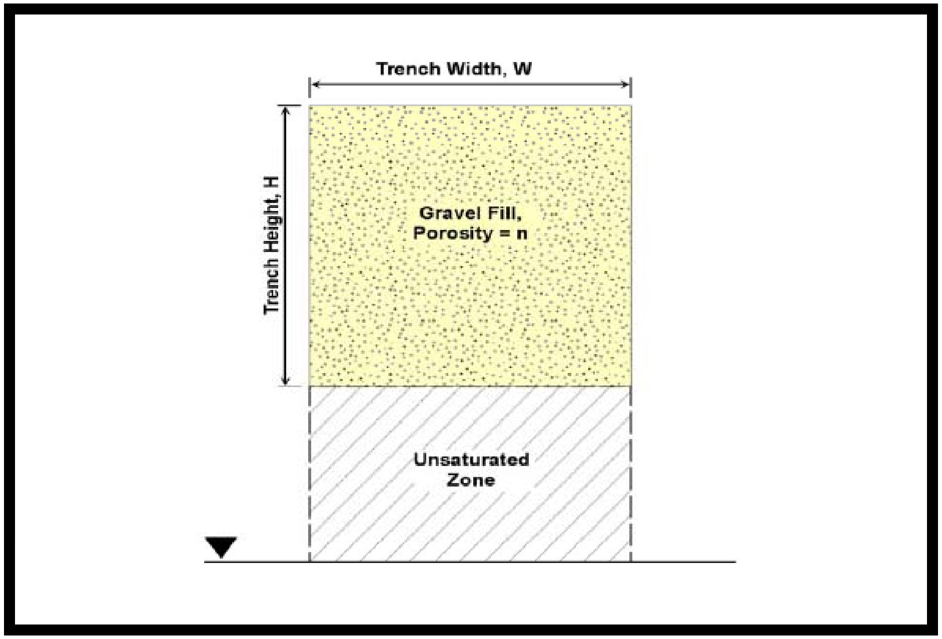


Exhibit 1. Gravel filled exfiltration trench

- The width of the trench excavation is W. The bottom area of the excavation is W x L
- The porosity of the gravel fill is n, which for gravel fill is typically on the order of n = 0.4, or 40%.
- If vertical unsaturated infiltration is considered, then the soil voids in the soil beneath the trench bottom are available for filling.

Problem...

PONDS 3.2 models an open pond/trench, i.e., porosity within the pond equals 1.0. It does not directly model a pond/trench with a porosity less than 1.0.

In PONDS 3.2, the stage vs area data are used to define the storage volume relationship of the pond, i.e., the stage vs area data are integrated in order to calculate the storage volume. When analyzing a gravel filled exfiltration trench (or other trench configuration in which the internal porosity of the trench is less than 1.0) the stage vs area data needs to be adjusted so that the resulting storage calculation remains correct.

In order to do this, the areas in the stage vs area are adusted as follows:

$$Area_{adjusted} = Area_{actual} \times n = W \times L \times n$$

where

n is the porosity of the gravel fill
W is the width of the trench excavation
L is the length of the trench excavation

Adjusting the stage vs area data in this fashion, is equivalent to modeling an open trench (porosity = 1.0) as depicted in Exhibit 2 below.

" .... When .... the internal porosity is less than 1.0, the stage area data needs to be adjusted so that the resulting storage calculation remains correct."

http://devoeng.com/technical_memo.html

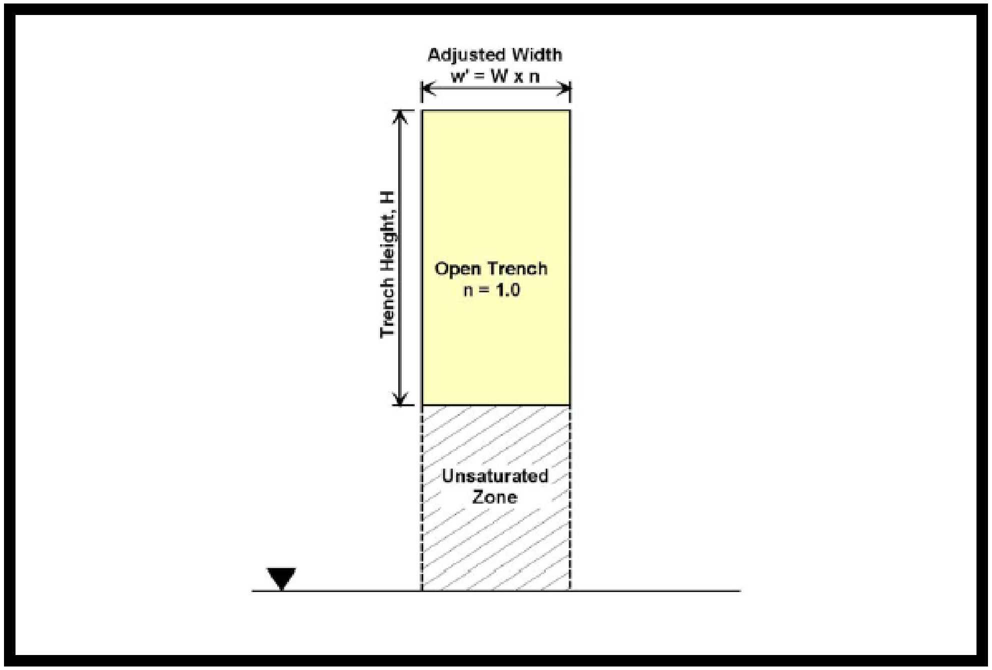


Exhibit 2. Equivalent open trench

Problem...

In PONDS 3.2 the volume of soil voids which is available for filling during vertical unsaturated infiltration is determined by specifying a **Maximum Area for Unsaturated Infiltration**. PONDS calculates the volume in the soil voids beneath the specified area, and unsaturated infiltration occurs until the soil void volume is filled. However, the Maximum Area for Unsaturated Infiltration cannot be greater than the largest area in the stage vs area data, and for an exfiltration trench (assuming vertical walls) the Maximum Area for Unsaturated Infiltration is generally equal to the area of the trench bottom.

The representation shown in Exhibit 2 above implies a Maximum Area for Unsaturated Infiltration equal to **W x L x n** which is less than the actual bottom width of the trench, W x L. Therefore, using this model configuration provides less available soil void volume for vertical unsaturated infiltration, which may or may not be acceptable depending on the application.

In order to ensure that all of the soil void volume beneath the trench is available for vertical unsaturated infiltration, the trench configuration shown in Exhibit 3 can alternately be utilized.

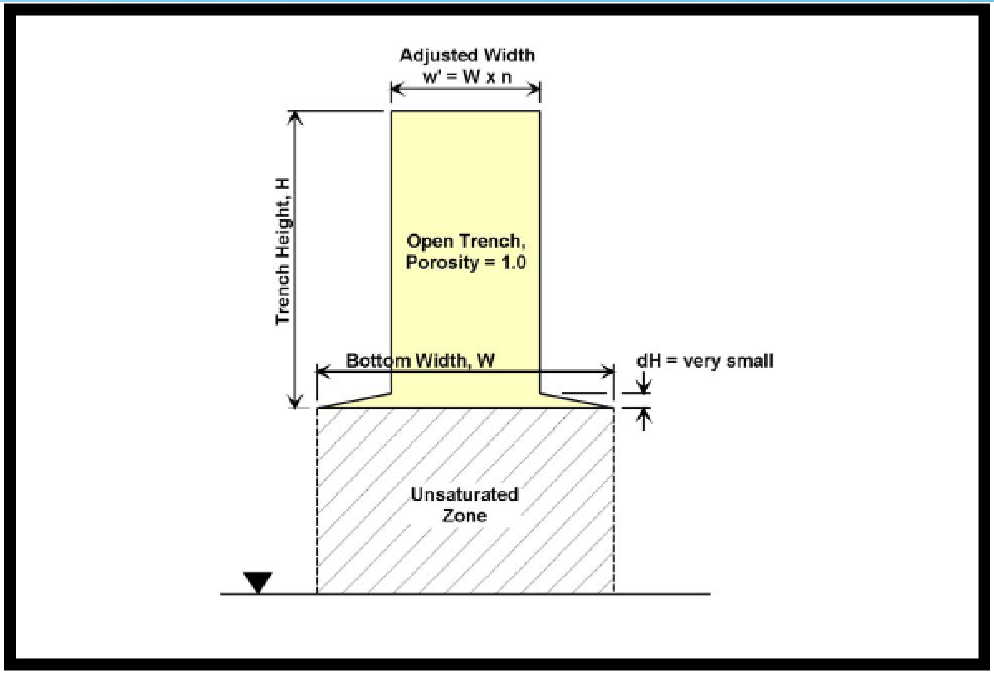
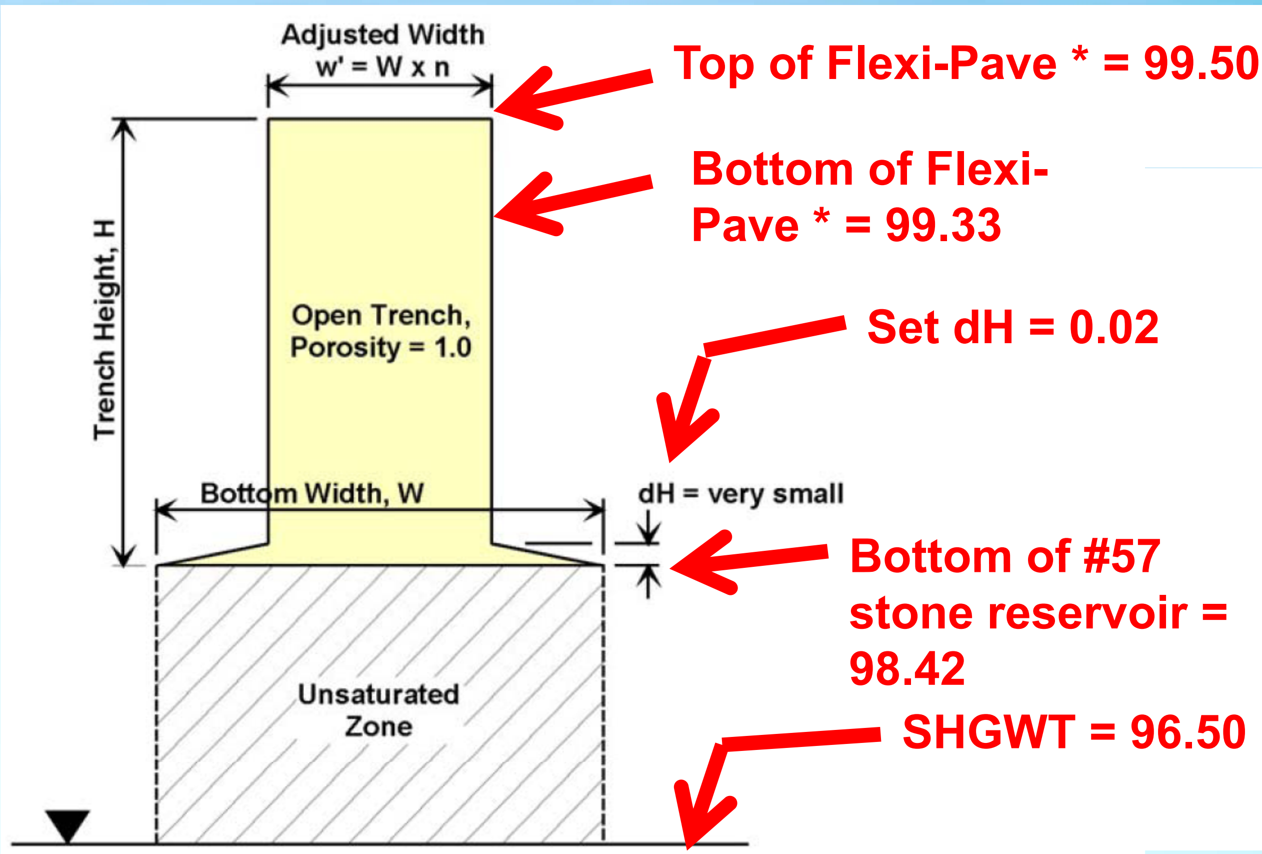


Exhibit 3. Alternate equivalent open trench in PONDS 3.2

In Exhibit 3 above, the area of the trench transitions from the actual trench bottom area (W x L) to the equivalent porosity-adjusted area (W x L x n) over a small vertical increment (dH). This preserves the soil void volume available for unsaturated infiltration, because it allows the Maximum Area for Vertical Infiltration to be set to the actual trench bottom area. However, the vertical increment (dH) needs to be set very small to avoid introducing a significant error in the resulting storage volume calculation within the trench. (Setting the value of dH ***too small*** may result in convergence problems, so this value may need to be determined iteratively.)

Note: This example can be adapted for other types of trench configurations, such as a drain pipe in a gravel envelope or a manufactured infiltration chamber system.

http://devoeng.com/technical_memo.html



Adjusted stage / area data for a pervious pavement section using the PONDS * Technical Memo for this example problem.

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

Stage	Pervious Pavement Area	x	Porosity (N)	=	Adjusted Area (A')
98.40	= Max. Area for Unsaturated Infiltration = 7,310 SF (see plan sketch)				
98.42	7,310 SF	x	0.24 **	=	1,754 SF
99.50	7,310 SF	x	0.24 **	=	1,754 SF

** Weighted void space of the pervious pavement section (see a previous slide for this value).

Mounding (recovery) analysis of the Required Treatment Volume (RTV) using PONDS *

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

PONDS Version 3.3.0229
Retention Pond Recovery - Refined Method
Copyright 2008
Devo Seereeram, Ph.D., P.E.

DEVO Engineering
Consulting Geotechnical Engineers

Project Data

Project Name:	Pervious Pavement Recovery Analysis
Simulation Description:	Design Section consistrs of 2 inches of Flexi-Pave over an 11 inch #57 stone reservoir,
Project Number:	not applicable
Engineer :	Hank Higginbotham, P.E.
Supervising Engineer:	NONE
Date:	12-17-2008

Safety Factor of Two (2) applied here.

Aquifer Data

Base Of Aquifer Elevation, [B] (ft datum):	95.00
Water Table Elevation, [WT] (ft datum):	96.50
Horizontal Saturated Hydraulic Conductivity, [Kh] (ft/day):	9.00
Fillable Porosity, [n] (%):	10.00
Unsaturated Vertical Infiltration Rate, [Iv] (ft/day):	4.0
Maximum Area For Unsaturated Infiltration, [Av] (ft²):	7310.0

Geometry Data

Equivalent Pond Length, [L] (ft):	150.0
Equivalent Pond Width, [W] (ft):	50.0

Ground water mound is expected to intersect the pond bottom

Stage vs Area Data

Stage (ft datum)	Area (ft²)
98.40	7310.0
98.42	1754.0
99.50	1754.0

Adjusted stage / area data from the previous three (3) slides.

Discharge Structures

Discharge Structure #1 is inactive

Discharge Structure #2 is inactive

Discharge Structure #3 is inactive

Scenario Input Data

Scenario 1 :: 1808 ft³ slug load

Hydrograph Type:	Slug Load
Modflow Routing:	Routed with infiltration

Treatment Volume (ft³) 1808

Initial ground water level (ft datum) default, 96.50

Time After Storm Event (days)	Time After Storm Event (days)
0.100	2.000
0.250	2.500
0.500	3.000
1.000	3.500
1.500	4.000

Except as noted, the input data into the PONDS * model was the same as the previous Modret * example.

Mounding (recovery) analysis of the Required Treatment Volume (RTV) using PONDS *

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

PONDS Version 3.3.0229
Retention Pond Recovery - Refined Method
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Devo Seereeram, Ph.D., P.E.

Consulting Geotechnical Engineers

Summary of Results :: *Scenario 1 :: 1808 ft³ slug load*

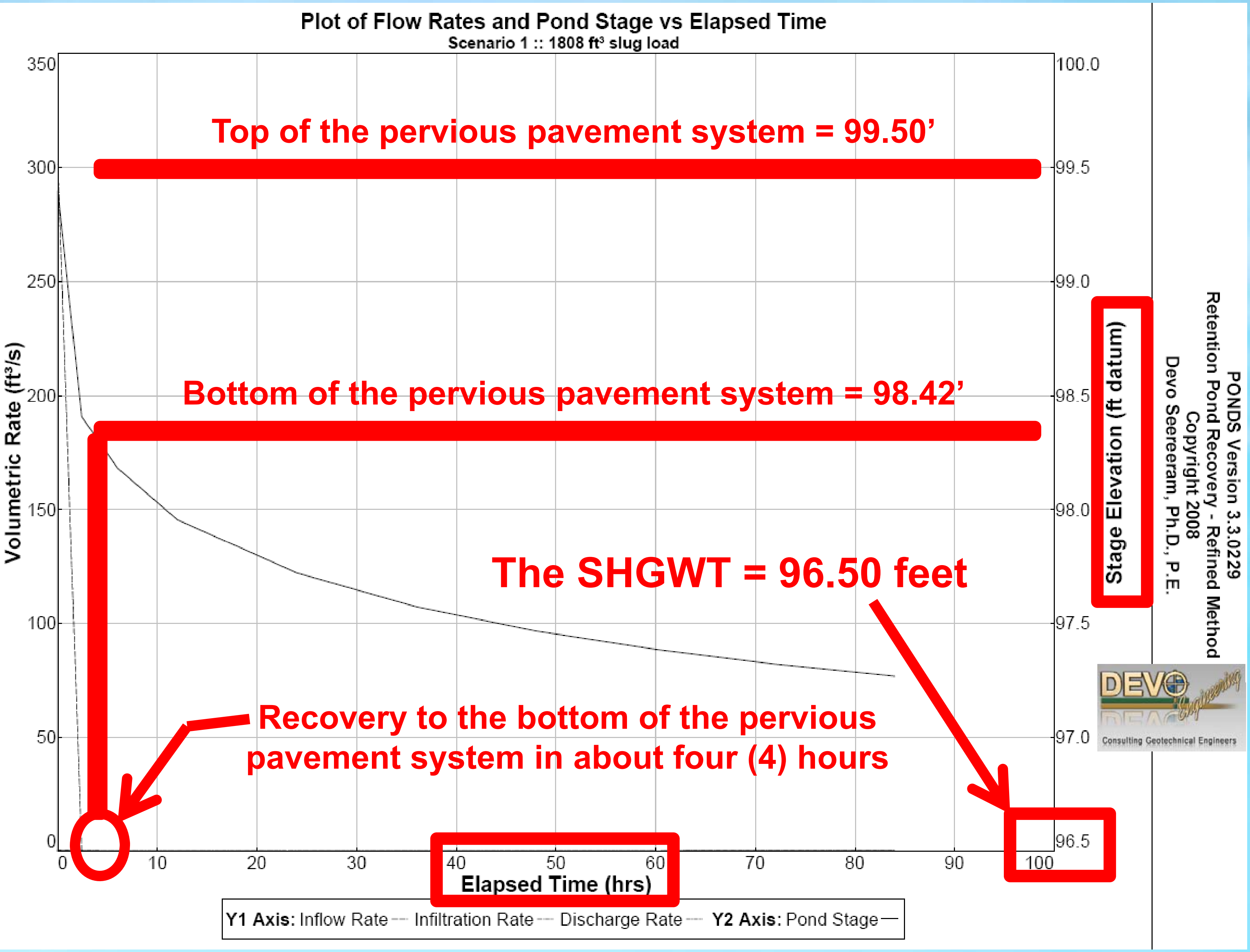
	Time (hours)	Stage (ft datum)	Rate (ft³/s)	Volume (ft³)
Stage				
Minimum	0.000	96.50		
Maximum	0.002	99.40		
Inflow				
Rate - Maximum - Positive	0.002		301.3333	
Rate - Maximum - Negative	None		None	
Cumulative Volume - Maximum Positive	0.002			1808.0
Cumulative Volume - Maximum Negative	None			None
Cumulative Volume - End of Simulation	96.000			1808.0
Infiltration				
Rate - Maximum - Positive	0.002		0.3383	
Rate - Maximum - Negative	None		None	
Cumulative Volume - Maximum Positive	6.000			1808.0
Cumulative Volume - Maximum Negative	None			None
Cumulative Volume - End of Simulation	96.000			1808.0
Combined Discharge				
Rate - Maximum - Positive	None		None	
Rate - Maximum - Negative	None		None	
Cumulative Volume - Maximum Positive	None			None
Cumulative Volume - Maximum Negative	None			None
Cumulative Volume - End of Simulation	96.000			0.0
Discharge Structure 1 - inactive				
Rate - Maximum - Positive	disabled		disabled	
Rate - Maximum - Negative	disabled		disabled	
Cumulative Volume - Maximum Positive	disabled			disabled
Cumulative Volume - Maximum Negative	disabled			disabled
Cumulative Volume - End of Simulation	disabled			disabled
Discharge Structure 2 - inactive				
Rate - Maximum - Positive	disabled		disabled	
Rate - Maximum - Negative	disabled		disabled	
Cumulative Volume - Maximum Positive	disabled			disabled
Cumulative Volume - Maximum Negative	disabled			disabled
Cumulative Volume - End of Simulation	disabled			disabled
Discharge Structure 3 - inactive				
Rate - Maximum - Positive	disabled		disabled	
Rate - Maximum - Negative	disabled		disabled	
Cumulative Volume - Maximum Positive	disabled			disabled
Cumulative Volume - Maximum Negative	disabled			disabled
Cumulative Volume - End of Simulation	disabled			disabled
Pollution Abatement:				
36 Hour Stage and Infiltration Volume	36.000	97.57		1808.0
72 Hour Stage and Infiltration Volume	72.000	97.32		1808.0

Pervious Pavement Recovery Analysis 12-17-2008 11:37:31

As the Required Treatment Volume (RTV) of 1,808 CF recovers below the bottom of the pervious pavement system elevation of 98.42 feet in less than 72 hours (with a safety factor of two), it meets the criteria specified in Section 5.2.c.2 of the District's *"Basis of Review"*.

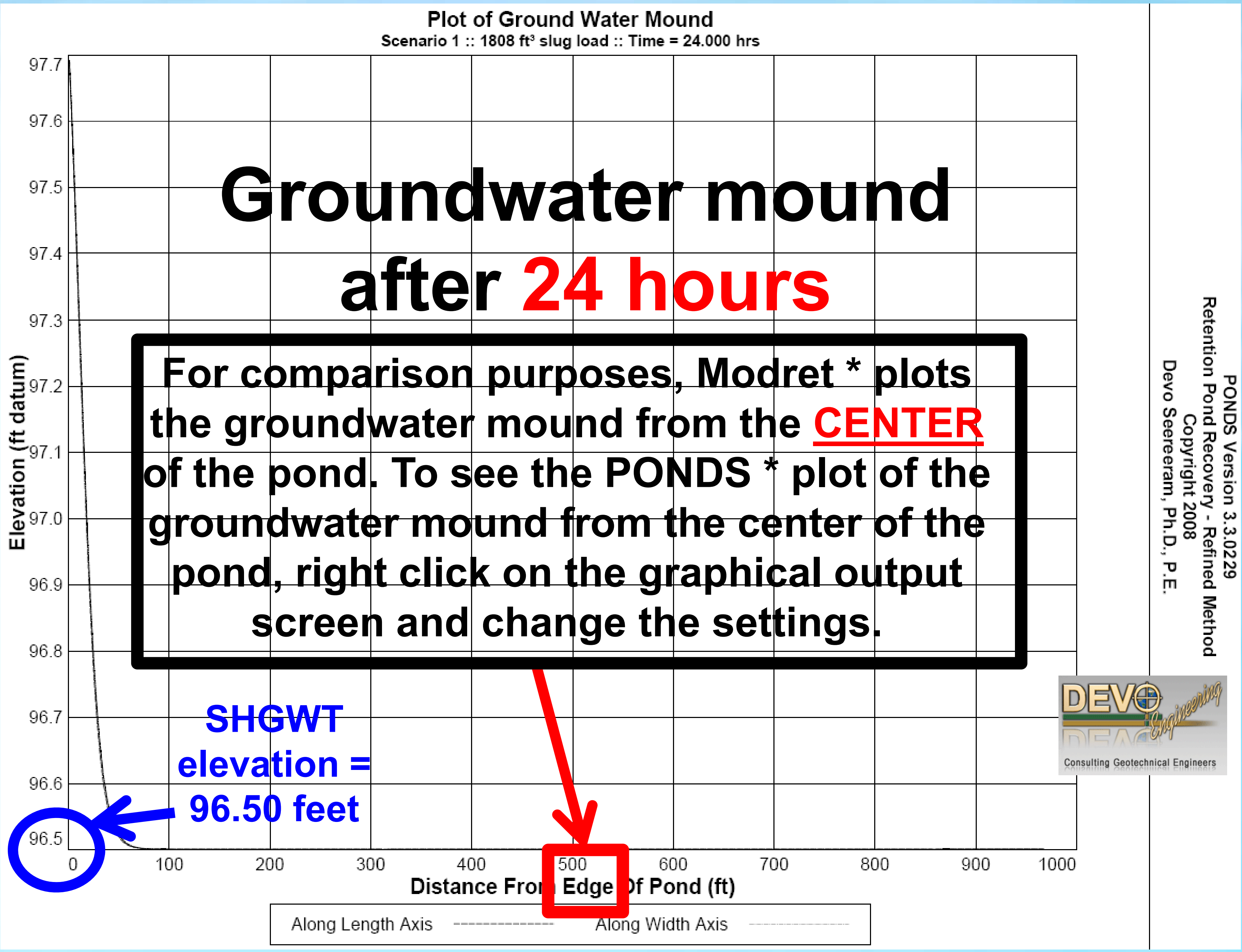
Mounding (recovery) analysis of the Required Treatment Volume (RTV) using PONDS *

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



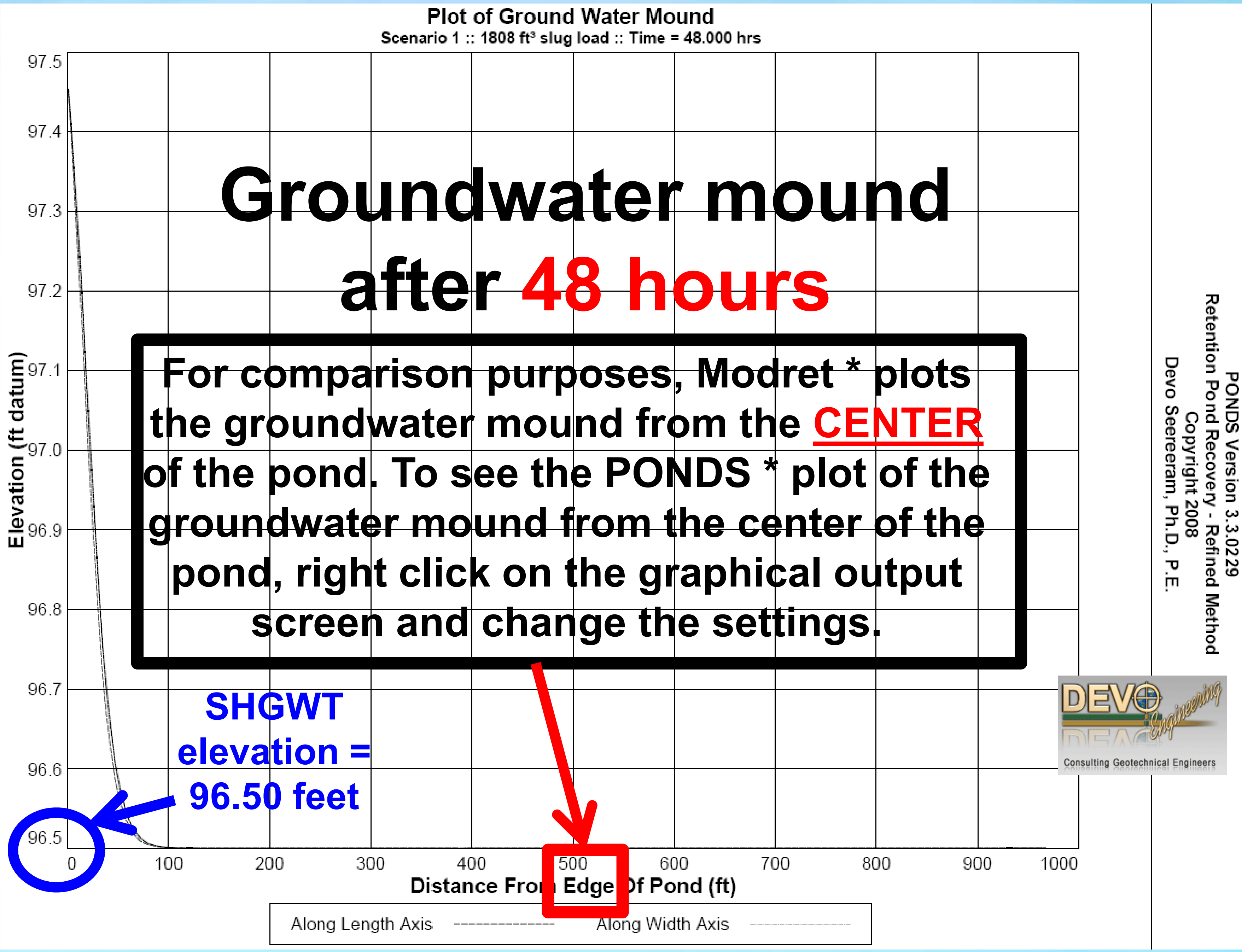
Mounding (recovery) analysis of the Required Treatment Volume (RTV) using PONDS *

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



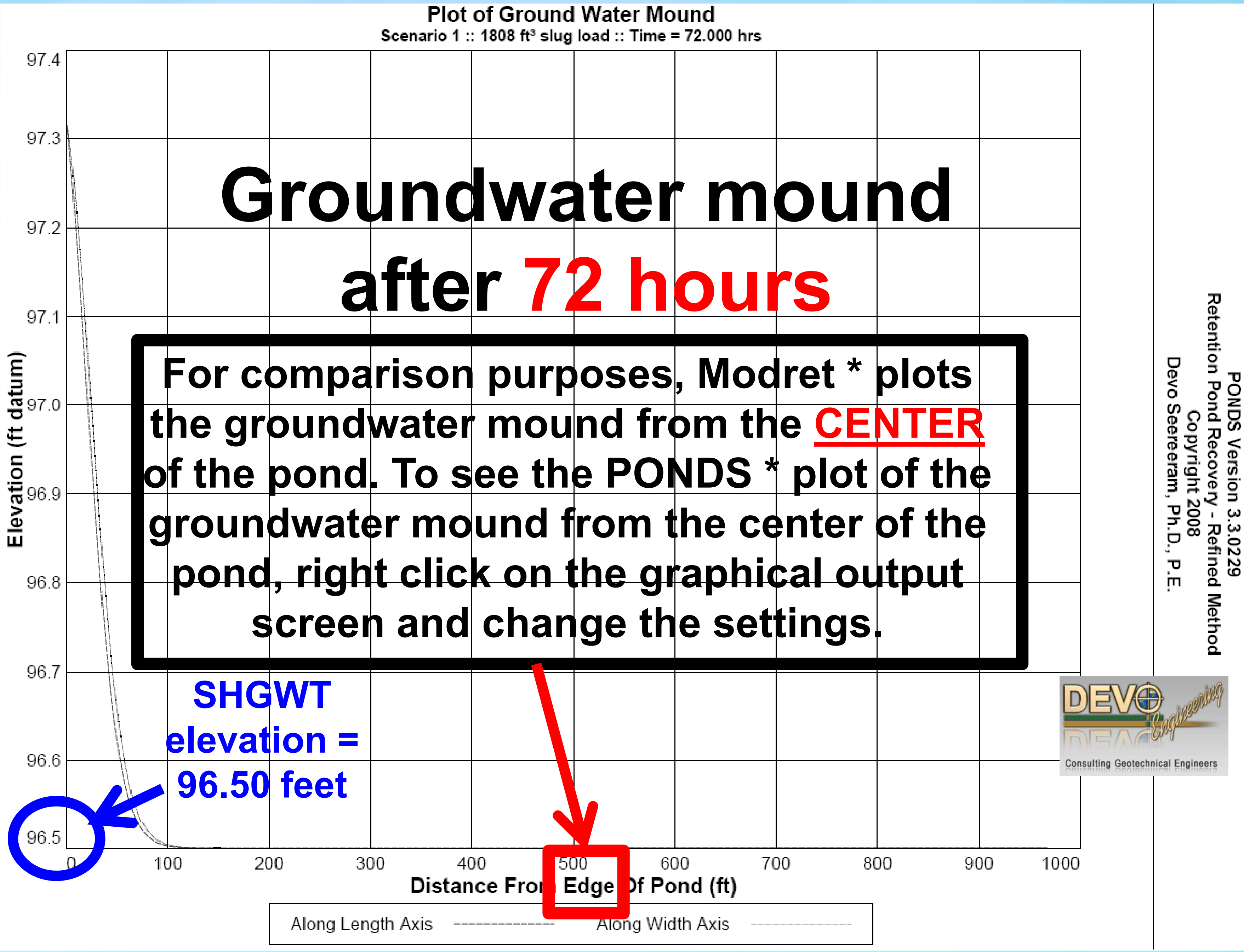
Mounding (recovery) analysis of the Required Treatment Volume (RTV) using PONDS *

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



Mounding (recovery) analysis of the Required Treatment Volume (RTV) using PONDS *

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



Excel© BMP *"Review Aid"*

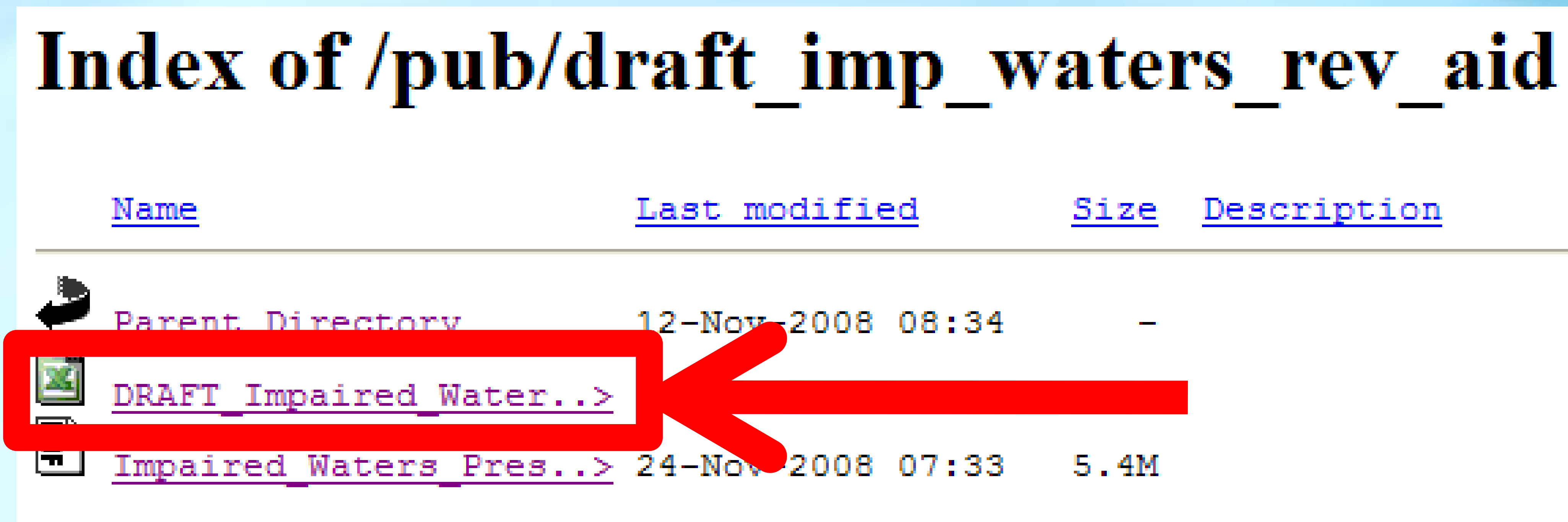
Using Beta Version 1.03 (dated 12/05/08)

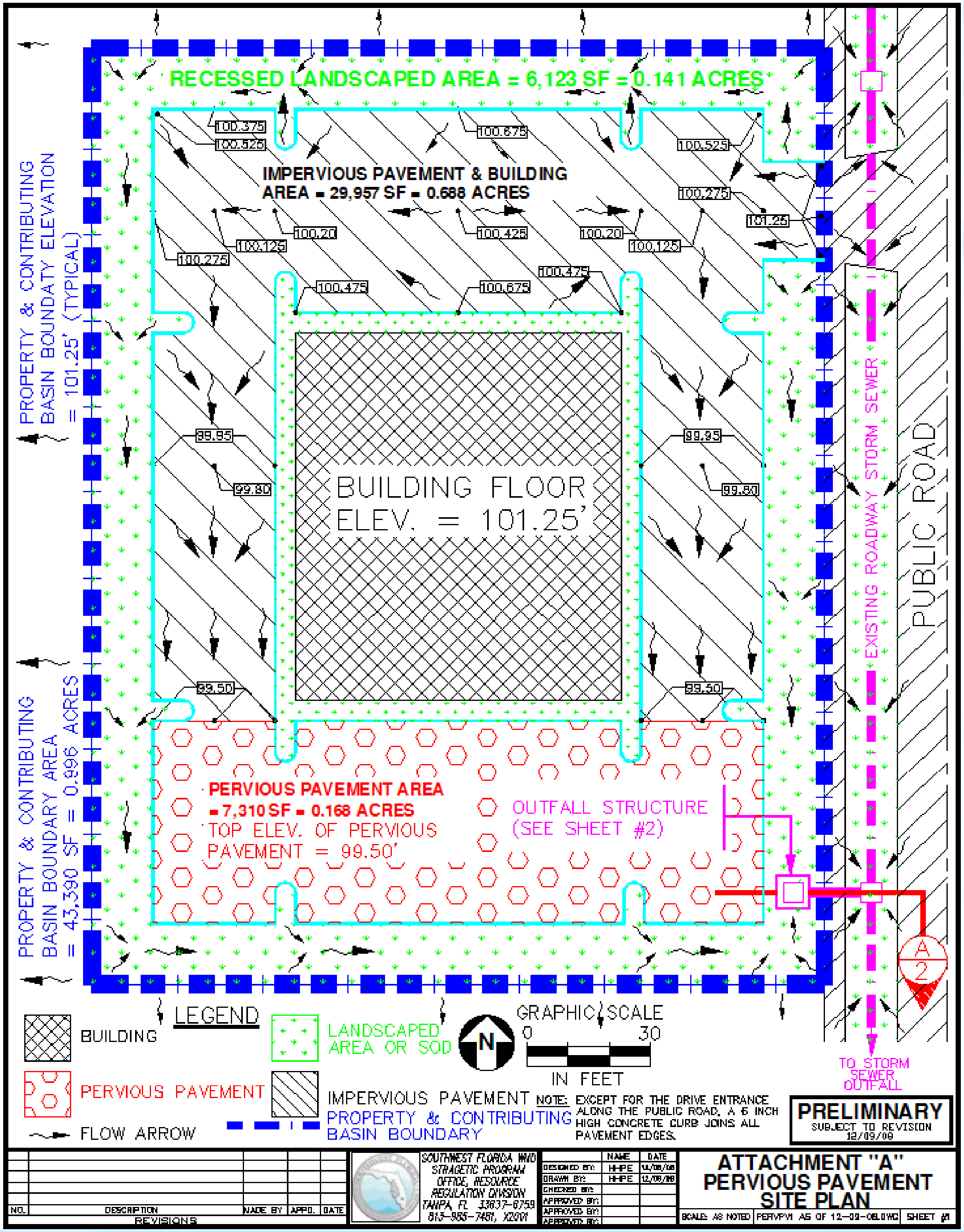
Fictitious Example for a Small Pervious Pavement Project that Discharges Into Waters not Meeting Water Quality Standards (net improvement needed)

Note: **As this is a fictitious project for storm water quality review, no attempt was made to ensure that the example problems meet the other local codes of Sarasota County (i.e. flood control, land use intensity computations, landscaping requirements, minimum # of parking spaces, etc.).**

The Excel© BMP *“Review Aid”* is available from the following FTP site:

http://ftp.swfwmd.state.fl.us/pub/draft_imp_waters_rev_aid/





Example Problem

Two (2) inches of Flexi™-Pave * placed over a twenty-four (24) inch #57 stone storage reservoir.

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

Landscaped (green impervious) areas = 6,123 SF = 0.141 Acres

Impervious Pavement & Building = 29,957 SF = 0.688 Acres

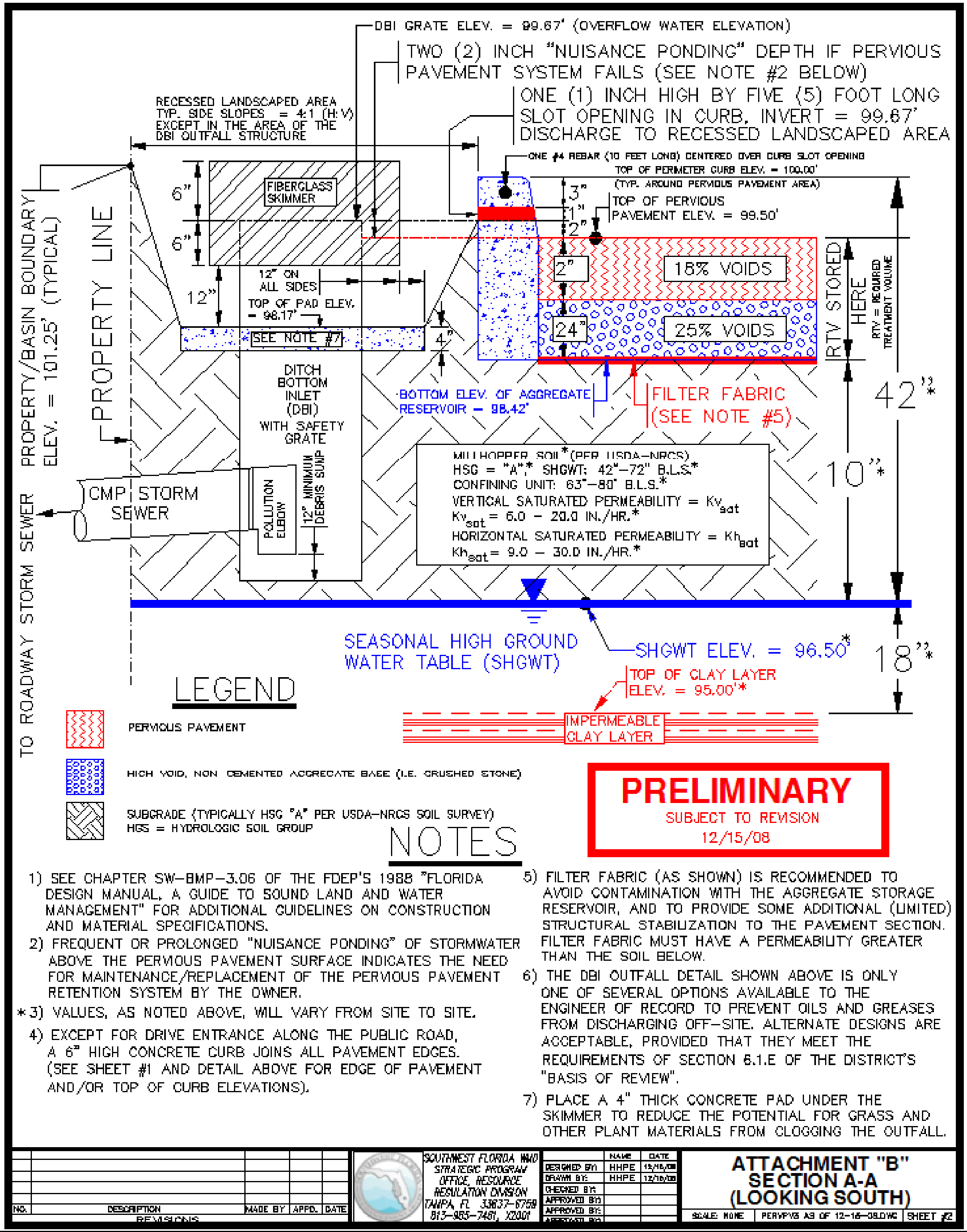
Pervious Pavement Area = 7,310 SF = 0.168 Acres

Total Property & Contributing Basin Boundary Area = 43,390 SF = 0.996 Acres

Example Problem

Two (2) inches of Flexi™-Pave * placed over a twenty-four (24) inch #57 stone storage reservoir.

Available Pervious Pavement Section Storage (S') = 6.36 Inches (see below)



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

Calculator for Pervious Pavement Section Storage (S')

Layer	Thickness (in)	SUSTAINABLE Void Space (%)	Storage (in)
Flexi Pave®	2	18	0.36
Other Perv. Pvmt. (see Note #1 above)	0	15	0
#57 rock	24	25	6
#89 pea rock	0	25	0
#4 rock	0	30	0
Recycled (crushed) concrete	0	25	0
Black and Gold™	0	9	0
Other Sub Base (see Note #1 above)	0	20	0

S' = 6.36

DRAFT BEST MANAGEMENT PRACTICE REVIEW A… | **CLICK HERE TO START** | TH… IS A DRAFT DOCUMENT SUBJECT TO REVISION

Evaluation of Current Stormwater Design Criteria within the State of Florida

Final Report

Prepared for:

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

FDEP Contract No. SO108

June 2007

Prepared By:

Harvey H. Harper, Ph.D., P.E.
David M. Baker, P.E.

Environmental Research & Design, Inc.
3419 Trentwood Blvd., Suite 102
Orlando, FL 32812

INTRODUCTION HOME PAGE

University of Central Florida Stormwater Management Academy "Managed Stormwater is Good Water"

Southwest Florida Water Management District

IMPORTANT NOTES!!!

1) DO NOT navigate through this spreadsheet by using the RED tabs on the bottom of the Excel window. You will get lost! To get to the appropriate tabs USE the buttons that look just like…

THIS ONE!!!

2) This spreadsheet is best viewed at 1280 BY 1080 PIXELS screen resolution. If the maximum resolution of your computer screen is lower than 1280 BY 1080 PIXELS you can adjust the view in the Excel VIEW menu by zooming out to value smaller than 100 PERCENT.

3) This spreadsheet has incorporated ERROR MESSAGE WINDOWS. Your analysis is not valid unless ALL ERROR MESSAGE WINDOWS are clear.

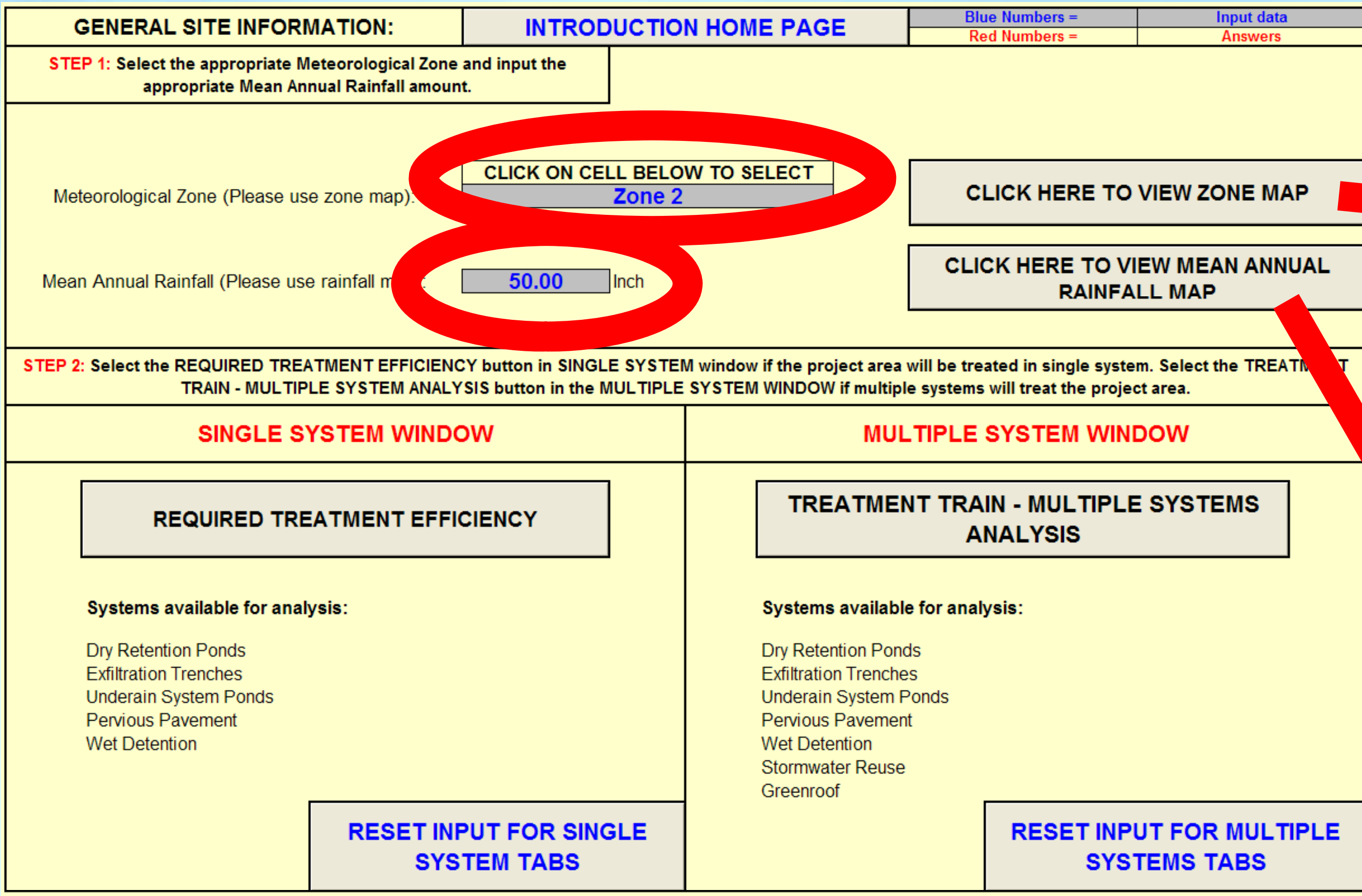
4) PRINTING INSTRUCTIONS: The print settings in this spreadsheet are adjusted so only the necessary information is printed. For the best printing results, print the page to MICROSOFT OFFICE DOCUMENT IMAGE WRITER (typically the default) or ADOBE PDF, save the page as an image document, then print the document you saved.

5) Click on the button located on the top of this window titled CLICK HERE TO START to begin the analysis.

Disclaimer: These workbooks were created to assist in the review of commonplace calculations. These are not District approved or required. All users are responsible for validating the accuracy of the internal calculations. If errors or omissions are noted within this workbook, please e-mail Christopher Kuzlo, E.I. at christopher.kuzlo@watermatters.org, Hank Higginbotham, P.E. at hank.higginbotham@watermatters.org or Richard Alt, P.E. at richard.alt@watermatters.org with specific information so that revisions can be made. **Public telephone support or training will not be available.**

BETA Version 1.00	10/31/2008	Initial release to District staff and the public.
BETA Version 1.01	11/21/2008	Updated the natural land use characteristics, and corresponding Event Mean Concentrations, from Dr. Harper's TAC presentation on October 01, 2008.
		Added multiple land use capability for pre and post-developed contributing basins (up to 3 land uses per contributing watershed).
		Added the ability to specify other Event Mean Concentrations by the user (the user must document and justify these inputs as a part of his/her ERP application).
		Simplified input on the Required Treatment Efficiency tab.
		Added an exfiltration trench storage calculator as a new Best Management Practice option.
		Added additional error and omission traps to assist the user.
BETA …	…/2008	Corrected an input error for Curve Number values between 95 and 98 (problem from BETA Version 1.01).
		Added a Conventional Roof land use option, with a corresponding Event Mean Concedntration (from Dr. Wanielista's technical memorandum dated October 30, 2008).
BETA Version 1.03	12/5/2008	Added greenroof systems to the Treatment Train tab.
		Added a latteral spacing calcualtor to the Underdrain System BMP.

This Example is located in Winter Haven (Zone 2), with an annual rainfall of 50”


GENERAL SITE INFORMATION:

INTRODUCTION HOME PAGE

Blue Numbers =	Input data
Red Numbers =	Answers

STEP 1: Select the appropriate Meteorological Zone and input the appropriate Mean Annual Rainfall amount.

Meteorological Zone (Please use zone map): CLICK ON CELL BELOW TO SELECT — Zone 2

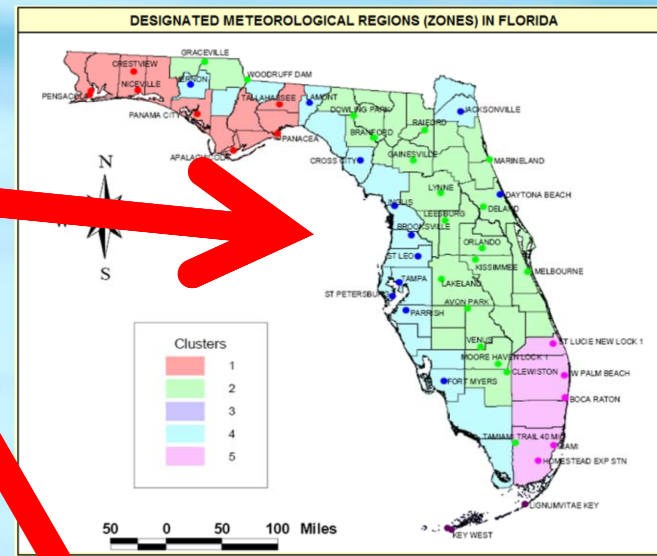
Mean Annual Rainfall (Please use rainfall m... 50.00 Inch

CLICK HERE TO VIEW ZONE MAP

CLICK HERE TO VIEW MEAN ANNUAL RAINFALL MAP

STEP 2: Select the REQUIRED TREATMENT EFFICIENCY button in SINGLE SYSTEM window if the project area will be treated in single system. Select the TREATM...T TRAIN - MULTIPLE SYSTEM ANALYSIS button in the MULTIPLE SYSTEM WINDOW if multiple systems will treat the project area.

SINGLE SYSTEM WINDOW	MULTIPLE SYSTEM WINDOW
REQUIRED TREATMENT EFFICIENCY	TREATMENT TRAIN - MULTIPLE SYSTEMS ANALYSIS
Systems available for analysis:	Systems available for analysis:
Dry Retention Ponds Exfiltration Trenches Underain System Ponds Pervious Pavement Wet Detention	Dry Retention Ponds Exfiltration Trenches Underain System Ponds Pervious Pavement Wet Detention Stormwater Reuse Greenroof
RESET INPUT FOR SINGLE SYSTEM TABS	RESET INPUT FOR MULTIPLE SYSTEMS TABS



This Example is a single system analysis

GENERAL SITE INFORMATION:	INTRODUCTION HOME PAGE	Blue Numbers =	Input data
		Red Numbers =	Answers

STEP 1: **Select the appropriate Meteorological Zone and input the appropriate Mean Annual Rainfall amount.**

CLICK ON CELL BELOW TO SELECT

Meteorological Zone (Please use zone map): Zone 2

CLICK HERE TO VIEW ZONE MAP

Mean Annual Rainfall (Please use rainfall map): 50.00 Inch

CLICK HERE TO VIEW MEAN ANNUAL RAINFALL MAP

STEP 2: **Select the REQUIRED TREATMENT EFFICIENCY button in SINGLE SYSTEM window if the project area will be treated in single system. Select the TREATMENT TRAIN - MUL [illegible] ANALYSIS button in the MULTIPLE SYSTEM WINDOW if multiple systems will treat the project area.**

SINGLE SYSTEM WINDOW

REQUIRED TREATMENT EFFICIENCY

Systems available for analysis:

Dry Retention Ponds
Exfiltration Trenches
Underain System Ponds
Pervious Pavement
Wet Detention

Click here to continue

RESET INPUT FOR SINGLE SYSTEM TABS

MULTIPLE SYSTEM WINDOW

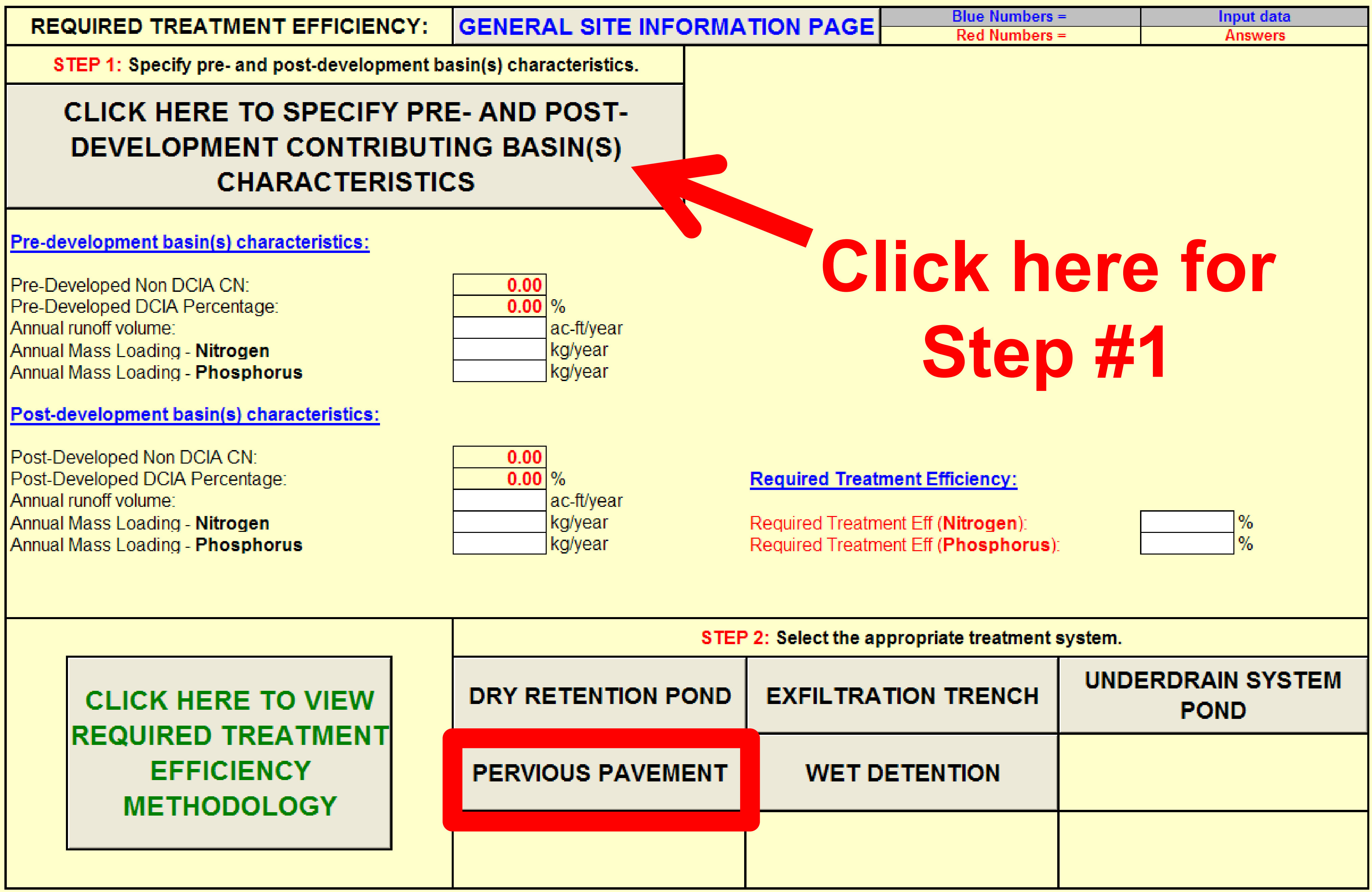
TREATMENT TRAIN - MULTIPLE SYSTEMS ANALYSIS

Systems available for analysis:

Dry Retention Ponds
Exfiltration Trenches
Underain System Ponds
Pervious Pavement
Wet Detention
Stormwater Reuse
Greenroof

RESET INPUT FOR MULTIPLE SYSTEMS TABS

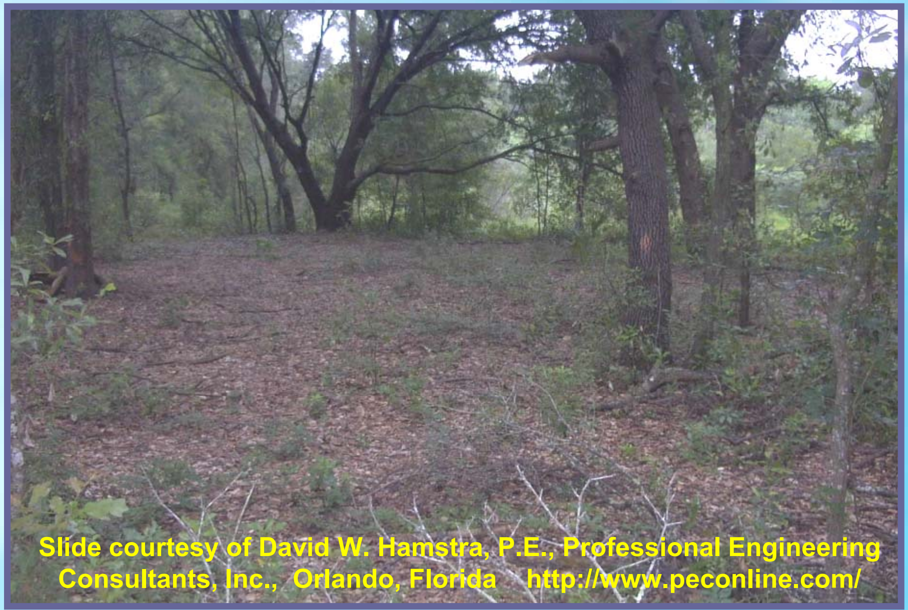
Enter the contributing watershed data



Example #1 – Retention System Design

Existing Conditions:

- **Contributing watershed size & location** – 0.996 Acres near Winter Haven that discharge into an impaired water body.
- **Annual Rainfall depth** – 50 inches
- **Land Use** – Mixed hardwood forest
- **Ground Cover** – Poor Condition, HSG = “A” with a composite non-DCIA curve number (CN) = 45 (refer to Table 2-2c from TR-55)
- **DCIA percentage** – Zero percent (0.0%)

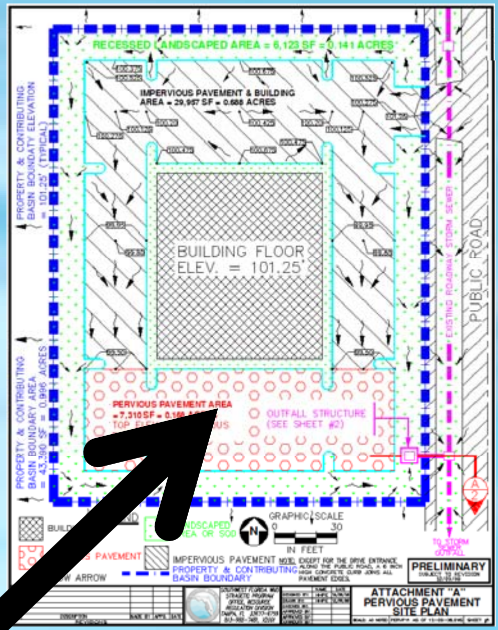


TR-55 documentation (from the NRCS) is available at the following web address:
http://www.wsi.nrcs.usda.gov/products/W2Q/H&H/Tools_Models/other/TR55.html

Determine the pre-developed nitrogen & phosphorous loadings.

Enter the contributing watershed data

After data entry, click here to go back to Step #2



BASIN(S) TO SINGLE SYSTEM

REQUIRED TREATMENT EFFICIENCY

Bl Numbers =	Input data
d Numbers =	Answers

BASIN NO.1 CHARACTERISTICS:

	CLICK ON CELL BELOW TO SELECT
Pre Developed Land Use:	Undeveloped - Mixed Hardwood
	CLICK ON CELL BELOW TO SELECT
Post Developed Land Use:	High-Intensity Commercial

Total pre-developed basin area:	1.00	AC
Post-developed area (contributing basin to the pond, excluding pond):	0.69	AC
Pre-Developed Non DCIA CN:	45.00	
Pre-Developed DCIA Percentage:	0.00	%
Post-Developed Non DCIA CN:	89.00	
Post-Developed DCIA Percentage:	85.00	%

OVERWRITE DEFAULT CONCENTRATIONS:

	PRE:		POST:	
EMC(N):	0.000	mg/L	0.000	mg/L
EMC(P):	0.000	mg/L	0.000	mg/L

CLICK ON CELL BELOW TO SELECT:

USE DEFAULT CONCENTRATIONS

Pre-development Annual Mass Loading - **Nitrogen:**	0.015	kg/year
Pre-development Annual Mass Loading - **Phosphorus:**	0.026	kg/year
Post-development Annual Mass Loading - **Nitrogen:**	6.140	kg/year
Post-development Annual Mass Loading - **Phosphorus:**	0.883	kg/year

From Table 2-2a of TR-55 (for a commercial site placed over HSG = "A" soils), the CN = 89, with an estimated DCIA of 85%

Recessed Landscaped (green impervious) area = 6,123 SF = 0.141 Acres
Impervious Pavement & Building = 29,957 SF = 0.688 Acres
Pervious Pavement Area = 7,310 SF = 0.168 Acres
Total Property & Contributing Basin Boundary Area = 43,390 SF = 0.996 Acres

Go to Step #2 to view the results

Analysis Results

SINGLE PERVIOUS PAVEMENT SYSTEM:

Blue Numbers =	Input data
Red Numbers =	Answers

CONTRIBUTING BASIN AND PERVIOUS PAVEMENT CHARACTERISTICS:

Pervious Pavement Section Storage Calculator (S')

Layer	Thickness [illegible]	Void Space (%):	Storage (in):
Flexi Pave®	2.00	[illegible]	0.36
Other Per[illegible] Pvmt. (see not[illegible]			
#57 rock	24.00	[illegible]	6.00
		25	0.00
#4 rock	0.00	30	0.00
Recycled (crushed) concrete	0.00	25	0.00
Black and Gold™	0.00	9	0.00
Other Sub Base (see note # 1 below)	0.00	0	0.00

Entire contributing basin area:	0.69	ac
Required treatment efficiency:	99.76	%
Storage provided in specified pervious pavement system **ONLY**:	6.36	in
Required water quality retention (for the total contributing basin):	10,019	cf
if pervious pavement is the only desired design option:	0.230	ac-ft
Required area for pervious pavement system based on storage provided	0.43	ac

CLICK HERE TO GO TO REQ[illegible]IRED TREATMENT EFFICIEN[illegible] TAB

CLICK HERE TO VIE[illegible] METHODOLOGY FOR PERVIOUS [illegible]AVEMENT SYSTEMS

[illegible]RVE NUMBER CALCULATOR FOR PERVIOUS PAVEMENT SYSTEM

CLICK HERE TO VIEW TYPICAL PERVIOUS PAVEMENT SYSTEM SCHEMATIC

ERROR MESSAGE WINDOW FOR SINGLE PERVIOUS PAVEMENT:

WARNING: THE REQUIRED TREATMENT EFFICIENCY EXCEEDS THE HIGHEST TREATMENT EFFICIENCY ASSOCIATED WITH MAXIMUM RETENTION OF 4.00 INCHES (SEE APPENDIX D OF THE HARPER REPORT DATED JUNE 2007). THE SPREADSHEET WILL UTILIZE 4.00 INCHES FOR VOLUME COMPUTATION.

ERROR MESSAGE WINDOW FOR SINGLE PERVIOUS PAVEMENT:

The provided pervious pavement area = 0.168 Acres, which is less than the required 0.43 acres. Therefore, the design is inadequate.

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

Revise the design (using trial & error) until the pervious pavement system can retain more storm water.

This data will change with a revised design.

Entire contributing basin area:	0.69	ac
Required treatment efficiency:	99.76	%
Storage provided in specified pervious pavement system **ONLY**:	6.36	in
Required retention over the total contributing basin for required efficiency:	4.00	in
Required water quality retention (for the total contributing basin):	10,019	cf
if pervious pavement is the only desired design option:	0.230	ac-ft
Required area for pervious pavement system based on storage provided in designed section (see button above):	0.43	ac

Potential Design Revisions & Required Analysis:

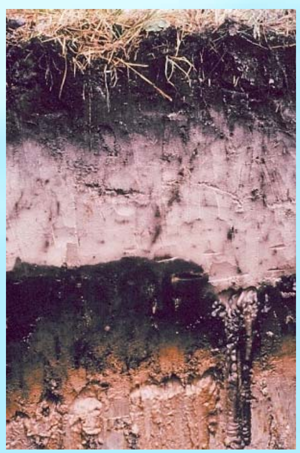
1. **Increase the area** of the pervious pavement parking lot.
2. **Increase the thickness** of the pervious pavement system.
3. **Import clean sands** to increase the vertical separation between the bottom of the pervious pavement system and the Seasonal High Ground Water Table (SHGWT) & confining unit (i.e. clay / hardpan layer). **See the next slide for additional information.**
4. **Check the RTV recovery** time using the required mounding analysis.

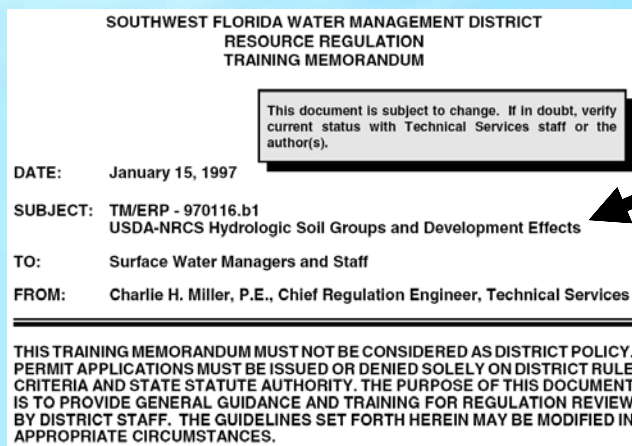
District Training Memorandum on B/D soils

Importing HGS “A” soils over HSG “B/D” soils

to provide additional clearance from the proposed finished grades to the historical SHGWT elevations.

B/D soils





SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT
RESOURCE REGULATION
TRAINING MEMORANDUM

This document is subject to change. If in doubt, verify current status with Technical Services staff or the author(s).

DATE: January 15, 1997

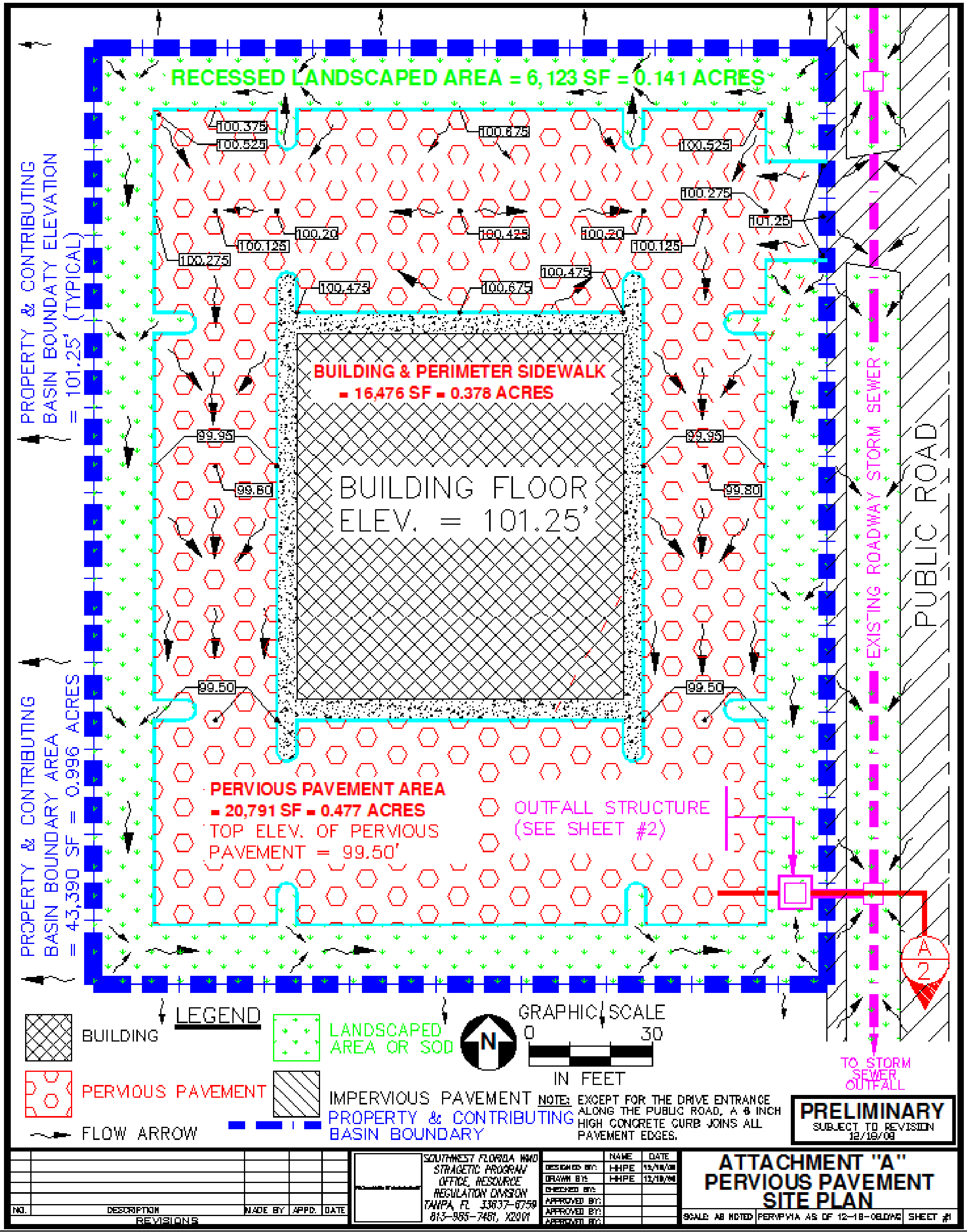
SUBJECT: TM/ERP - 970116.b1
USDA-NRCS Hydrologic Soil Groups and Development Effects

TO: Surface Water Managers and Staff

FROM: Charlie H. Miller, P.E., Chief Regulation Engineer, Technical Services

THIS TRAINING MEMORANDUM MUST NOT BE CONSIDERED AS DISTRICT POLICY. PERMIT APPLICATIONS MUST BE ISSUED OR DENIED SOLELY ON DISTRICT RULE CRITERIA AND STATE STATUTE AUTHORITY. THE PURPOSE OF THIS DOCUMENT IS TO PROVIDE GENERAL GUIDANCE AND TRAINING FOR REGULATION REVIEW BY DISTRICT STAFF. THE GUIDELINES SET FORTH HEREIN MAY BE MODIFIED IN APPROPRIATE CIRCUMSTANCES.

District Training Memorandum



Example Problem

Two (2) inches of Flexi™-Pave * placed over a fifteen (15) inch #57 stone storage reservoir.

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

Landscaped (green impervious) areas = 6,123 SF = 0.141 Acres

Decreased Impervious Area (Building & Perimeter Sidewalk remain) = 16,476 SF = 0.378 Acres

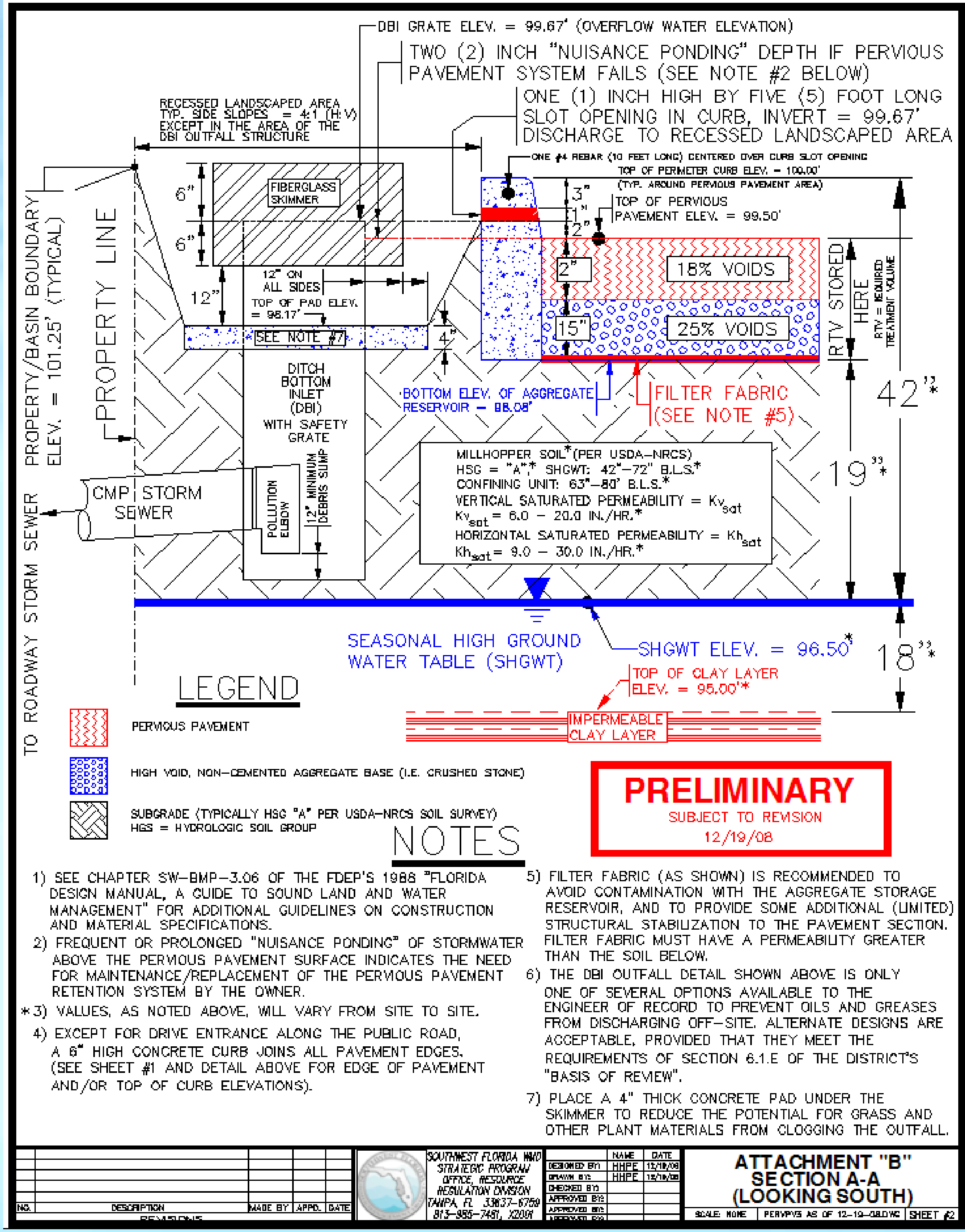
Increased Pervious Pavement Area = 20,791 SF = 0.477 Acres

Total Property & Contributing Basin Boundary Area = 43,390 SF = 0.996 Acres

Example Problem

Two (2) inches of Flexi™-Pave * placed over an fifteen (15) inch #57 stone storage reservoir.

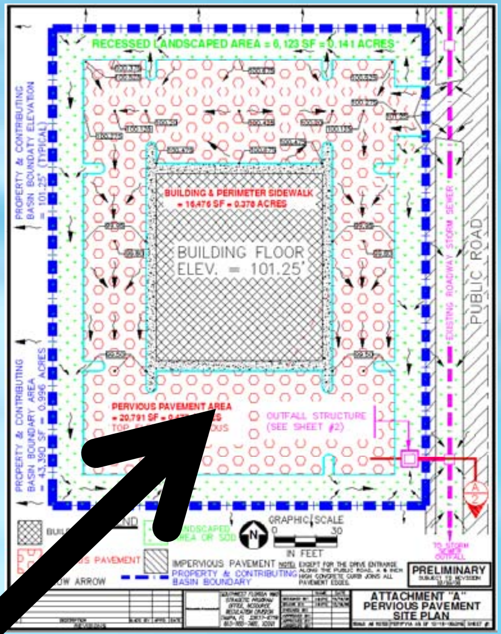
<u>Increased</u> Pervious Pavement Section Storage (S') = 4.11 Inches (see below)



Calculator for Pervious Pavement Section Storage (S')			
Layer	Thickness (in)	SUSTAINABLE Void Space (%)	Storage (in)
Flexi Pave®	2	18	0.36
Other Perv. Pvmt. (see Note #1 above)	0	15	0
#57 rock	15	25	3.75
#89 pea rock	0	25	0
#4 rock	0	30	0
Recycled (crushed) concrete	0	25	0
Black and Gold™	0	9	0
Other Sub Base (see Note #1 above)	0	20	0
		S' =	4.11

Enter the contributing watershed data

After data entry, click here to go back to Step #2



BASIN(S) TO SINGLE SYSTEM

REQUIRED TREATMENT EFFICIENCY

Input data

Answers

CLICK ON CELL BELOW TO SELECT

Pre Developed Land Use: Undeveloped - Mixed Hardwood

Post Developed Land Use: High-Intensity Commercial

Total pre-developed basin area:	1.00	AC
Post-developed area (contributing basin to the pond, excluding pond):	0.38	AC
Pre-Developed Non DCIA CN:	45.00	
Pre-Developed DCIA Percentage:	0.00	%
Post-Developed Non DCIA CN:	89.00	
Post-Developed DCIA Percentage:	85.00	%

OVERWRITE DEFAULT CONCENTRATIONS:

	PRE:		POST:	
EMC(N):	0.000	mg/L	0.000	mg/L
EMC(P):	0.000	mg/L	0.000	mg/L

CLICK ON CELL BELOW TO SELECT:

USE DEFAULT CONCENTRATIONS

Pre-development Annual Mass Loading - **Nitrogen:**	0.015	kg/year
Pre-development Annual Mass Loading - **Phosphorus:**	0.026	kg/year
Post-development Annual Mass Loading - **Nitrogen:**	3.382	kg/year
Post-development Annual Mass Loading - **Phosphorus:**	0.486	kg/year

From Table 2-2a of TR-55 (for a commercial site placed over HSG = "A" soils), the CN = 89, with an estimated DCIA of 85%

Landscaped (green impervious) areas = 6,123 SF = 0.141 Acres
Decreased Impervious Area (Building & Perimeter Sidewalk remain) = 16,476 SF = 0.378 Acres
Increased Pervious Pavement Area = 20,791 SF = 0.477 Acres
Total Property & Contributing Basin Boundary Area = 43,390 SF = 0.996 Acres

Go to Step #2 to view the results

REQUIRED TREATMENT EFFICIENCY:	GENERAL SITE INFORMATION PAGE	Blue Numbers =	Input data
		Red Numbers =	Answers

STEP 1: Specify pre- and post-development basin(s) characteristics.

CLICK HERE TO SPECIFY PRE- AND POST-DEVELOPMENT CONTRIBUTING BASIN(S) CHARACTERISTICS

Pre-development basin(s) characteristics:

Pre-Developed Non DCIA CN:	45.00	
Pre-Developed DCIA Percentage:	0.00	%
Annual runoff volume:	0.042	ac-ft/year
Annual Mass Loading - **Nitrogen**	0.015	kg/year
Annual Mass Loading - **Phosphorus**	0.026	kg/year

Post-development basin(s) characteristics:

Post-Developed Non DCIA CN:	89.00	
Post-Developed DCIA Percentage:	85.00	%
Annual runoff volume:	1.143	ac-ft/year
Annual Mass Loading - **Nitrogen**	3.382	kg/year
Annual Mass Loading - **Phosphorus**	0.486	kg/year

Click here for Step #2

Required Treatment Efficiency:

Required Treatment Eff (**Nitrogen**):	99.56	%
Required Treatment Eff (**Phosphorus**):	94.70	%

CLICK HERE TO VIEW REQUIRED TREATMENT EFFICIENCY METHODOLOGY

STEP 2: Select the appropriate treatment system.

DRY RETENTION POND	EXFILTRATION TRENCH	UNDERDRAIN SYSTEM POND
PERVIOUS PAVEMENT	WET DETENTION	

Analysis Results

SINGLE PERVIOUS PAVEMENT SYSTEM:	Blue Numbers =	Input data
	Red Numbers =	Answers

CONTRIBUTING BASIN AND PERVIOUS PAVEMENT CHARACTERISTICS:

Pervious Pavement Section Storage Calculator (S')

Layer	Thickness (in):	Void Space (%):	Storage (in):
Flexi Pave®	2.00		0.36
Other Perv... Pvmt. (see no...			
#57 rock	15.00		3.75
		25	0.00
#4 rock	0.00	30	0.00
Recycled (crushed) concrete	0.00	25	0.00
Black and Gold™	0.00	9	0.00
Other Sub Base (see note # 1 below)	0.00	0	0.00

Entire contributing basin area:	0.38	ac
Required treatment efficiency:	99.56	%
Storage provided in specified pervious pavement system **ONLY**:	4.11	in
Required water quality retention (for the total contributing basin):	5,518	cf
if pervious pavement is the only desired design option:	0.127	ac-...
Required area for pervious pavement system based on storage provided	0.37	ac

ERROR MESSAGE WINDOW FOR SINGLE PERVIOUS PAVEMENT:

WARNING: THE REQUIRED TREATMENT EFFICIENCY EXCEEDS THE HIGHEST TREATMENT EFFICIENCY ASSOCIATED WITH MAXIMUM RETENTION OF 4.00 INCHES (SEE APPENDIX D OF THE HARPER REPORT DATED JUNE 2007). THE SPREADSHEET WILL UTILIZE 4.00 INCHES FOR VOLUME COMPUTATION.

ERROR MESSAGE WINDOW FOR SINGLE PERVIOUS PAVEMENT:

The provided pervious pavement area = 0.477 Acres, which is greater than the required 0.37 acres. Therefore, the design is okay so far, pending the results of the required mounding analysis.

CLICK HERE TO GO TO REQ...RED TREATMENT EFFICIENC... TAB

CLICK HERE TO VIEW ...ETHODOLOGY FOR PERVIOUS ...AVEMENT SYSTEMS

C...RVE NUMBER CALCULATOR FOR PERVIOUS PAVEMENT SYSTEM

CLICK HERE TO VIEW TYPICAL PERVIOUS PAVEMENT SYSTEM SCHEMATIC

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

Revised Mounding Analysis

Total Property & Contributing Basin Boundary Area = 43,390 SF = 0.996 Acres

From a previous slide, the Pervious Pavement Area = 20,791 SF = 0.477 Acres

Revised Pervious Pavement Storage Volume (within the sustainable void spaces in the design section) = Pavement Area x Available Storage = 20,791 SF * (4.11 Inches / 12 Inches Per Foot) = 7,121 CF = 0.163 Acre-Feet

From the previous slide, the retention portion of the analysis is okay, and the new RTV = 5,518 CF

Two (2) inches of Flexi™-Pave * placed over a fifteen (15) inch #57 stone storage reservoir.

Calculator for Pervious Pavement Section Storage (S')

Layer	Thickness (in)	SUSTAINABLE Void Space (%)	Storage (in)
Flexi Pave®	2	18	0.36
Other Perv. Pvmt. (see Note #1 above)	0	15	0
#57 rock	15	25	3.75
#89 pea rock	0	25	0
#4 rock	0	30	0
Recycled (crushed) concrete	0	25	0
Black and Gold™	0	9	0
Other Sub Base (see Note #1 above)	0	20	0
		S' =	4.11

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

Required water quality retention (for the total contributing basin):	5,518	cf
if pervious pavement is the only desired design option:	0.127	ac-ft
Required area for pervious pavement system based on storage provided in designed section (see button above):	0.37	ac

A mounding analysis is now required to demonstrate that the increased (required) retention storage of 5,518 CF will recover within 72 hours with a safety factor of two (2). Refer to the next several slides for the recovery analysis.

Mounding (recovery) analysis of the Required Treatment Volume (RTV) using Modret *

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

MODRET

MODRET Version 6.1 (Windows 95/98/NT)

SUMMARY OF UNSATURATED & SATURATED INPUT PARAMETERS

PROJECT NAME : Pervious Pavement - REVISED for increase
POLLUTION VOLUME RUNOFF DATA USED
UNSATURATED ANALYSIS INCLUDED

200' / 150'

Pond Bottom Area	20,791.00 ft²
Pond Volume between Bottom & DHWL	29,454.00 ft³
Pond Length to Width Ratio (L/W)	1.33
Elevation of Effective Aquifer Base	95.00 ft
Elevation of Seasonal High Groundwater Table	96.50 ft
Elevation of Starting Water Level	98.08 ft
Elevation of Pond Bottom	98.08 ft
Design High Water Level Elevation	99.50 ft
Avg. Effective Storage Coefficient of Soil for Unsaturated Analysis	0.10
Unsaturated Vertical Hydraulic Conductivity	8.00 ft/d
Factor of Safety	2.00
Saturated Horizontal Hydraulic Conductivity	18.00 ft/d
Avg. Effective Storage Coefficient of Soil for Saturated Analysis	0.11
Avg. Effective Storage Coefficient of Pond/Exfiltration Trench	0.24

Weighted average of the sustainable void spaces in the pervious pavement section (see the next slide).

0.67 * Kv (per the Modret User's manual).

Hydraulic Control Features:

	Top	Bottom	Left	Right
Groundwater Control Features - Y/N	N	N	N	N
Distance to Edge of Pond	0.00	0.00	0.00	0.00
Elevation of Water Level	0.00	0.00	0.00	0.00
Impervious Barrier - Y/N	N	N	N	N
Elevation of Barrier Bottom	0.00	0.00	0.00	0.00

MODRET

MODRET Version 6.1 (Windows 95/98/NT)

TIME - RUNOFF INPUT DATA

PROJECT NAME: PERVIOUS PAVEMENT - REVISED FOR INCREASE

STRESS PERIOD NUMBER	INCREMENT OF TIME (hrs)	VOLUME OF RUNOFF (ft³)
Unsat	0.95	3,284.98
1	1.00	2,233.02
2	8.76	0.00
3	8.76	0.00
4	8.76	0.00
5	8.76	0.00
6	8.76	0.00
7	8.76	0.00
8	8.76	0.00
9	8.76	0.00

"Slug" loading Hydrograph (above) from the 5,518 CF Required Treatment Volume input (below).

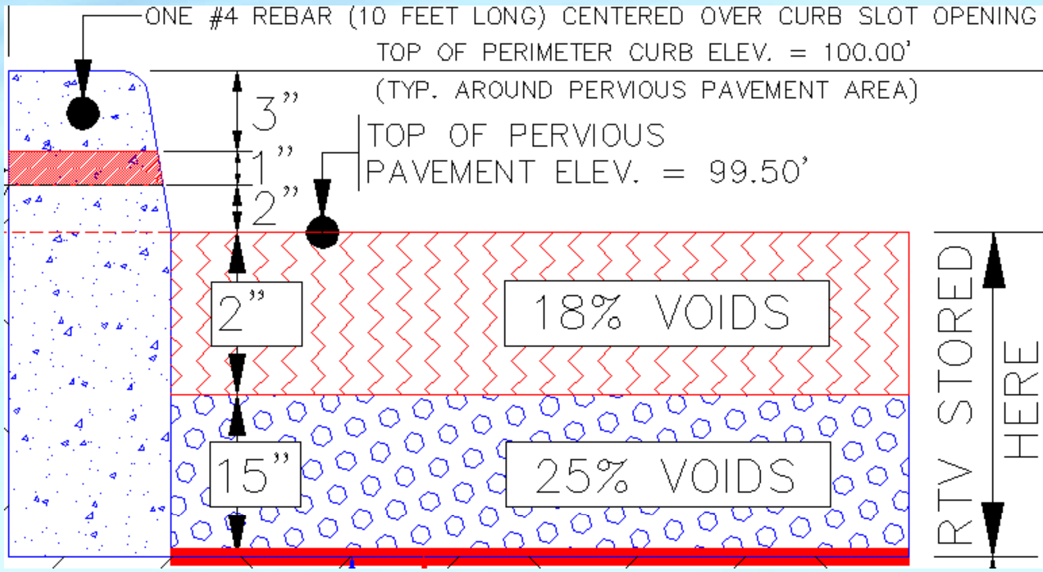
Runoff Data: Pollution Volume

Total Pollution Abatement Volume (ft3):	5518.00
Time of Recovery (hrs):	72.00

OK   Cancel

Mounding (recovery) analysis of the Required Treatment Volume (RTV) using Modret *

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



Weighted average of the sustainable void spaces

(refer to the data in the pervious pavement calculator below)

2" x 0.18 = 0.36

15" x 0.25 = 3.75

17" 4.11

4.11 / 17" = 0.24

Two (2) inches of Flexi™-Pave * placed over a fifteen (15) inch #57 stone storage reservoir.

Calculator for Pervious Pavement Section Storage (S')

Layer	Thickness (in)	SUSTAINABLE Void Space (%)	Storage (in)
Flexi Pave®	2	18	0.36
Other Perv. Pvmt. (see Note #1 above)	0	15	0
#57 rock	15	25	3.75
#89 pea rock	0	25	0
#4 rock	0	30	0
Recycled (crushed) concrete	0	25	0
Black and Gold™	0	9	0
Other Sub Base (see Note #1 above)	0	20	0
		S' =	4.11

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

Weighted average of the sustainable void spaces in the "composite" pervious pavement section.

Mounding (recovery) analysis of the Required Treatment Volume (RTV) using Modret *

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

MODRET

MODRET Version 6.1 (Windows 95/98/NT)

SUMMARY OF RESULTS

PROJECT NAME : Pervious Pavement - REVISED for increase

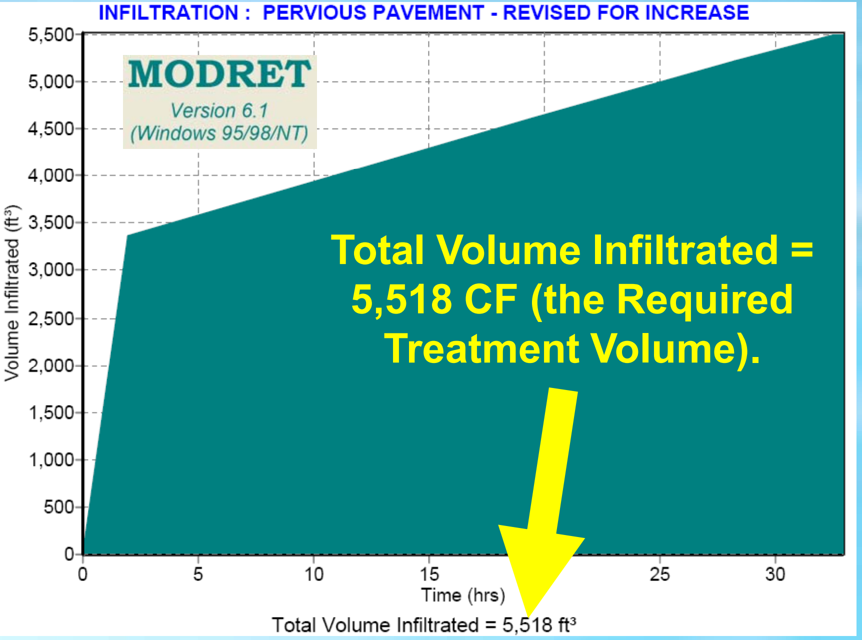
CUMULATIVE TIME (hrs)	WATER ELEVATION (feet)	INSTANTANEOUS INFILTRATION RATE (cfs)	AVERAGE INFILTRATION RATE (cfs)	CUMULATIVE OVERFLOW (ft³)
00.00 - 0.00	96.500	0.000 *		
			0.00000	
0.00	96.500	0.56238		
			0.47888	
1.95	98.184	0.39539		0.00
			0.02009	
10.70	98.154	0.01984		0.00
			0.01960	
19.46	98.124	0.01930		0.00
			0.01900	
28.22	98.095	0.01869		0.00
			0.01838	
32.90	98.080	0.01803		0.00
			0.01767	
45.73	98.040	0.01732		0.00
			0.01697	
54.49	98.014	0.01660		0.00
			0.01623	
63.24	97.990	0.01585		0.00
72.00	97.966			0.00

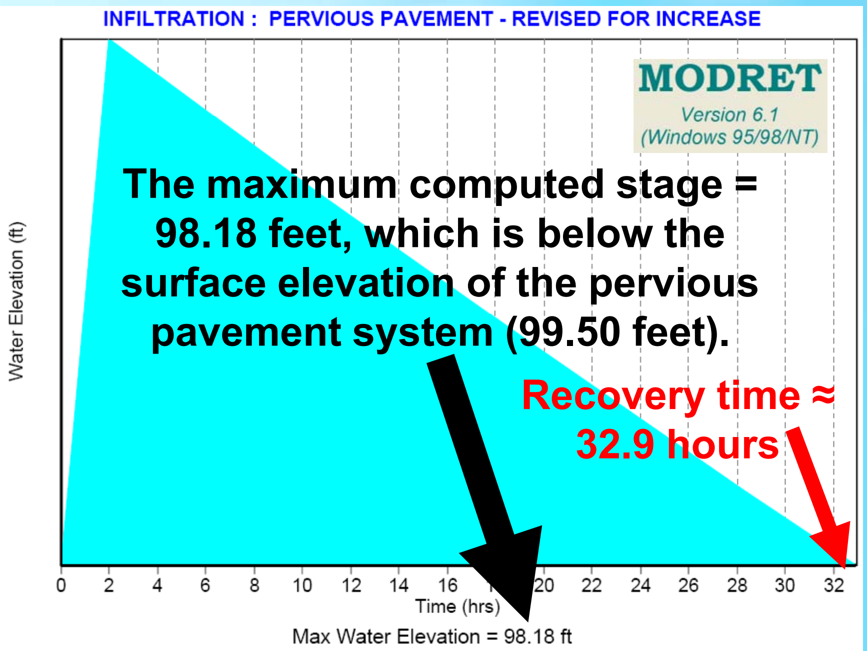
The SHGWT = 96.50 feet

As the Required Treatment Volume (RTV) of 5,518 CF recovers to the bottom of the pervious pavement system elevation of 98.08 feet in 32.9 hours (< 72 hours with a safety factor of two), it meets the criteria specified in Section 5.2.c.2 of the District's *"Basis of Review"*.

Maximum Water Elevation: 98.184 feet @ 1.95 hours
* Time increment when there is no runoff
Maximum Infiltration Rate: 0.479 ft/day

Recovery @ 32.897 hours





Optional Re-Design & Analysis

If desired by the ERP applicant / Engineer of record, additional (trial & error) analysis can be performed to optimize the final design to minimize pervious pavement costs ($$$).

This concludes our presentation

– thanks for your attention

Good engineering protects the environment!

Final Questions?

University of Central Florida
Stormwater Management Academy
"Managed Stormwater is Good Water"

Southwest Florida Water Management District