Water Resources: Technical Update

Pervious Pavements for DOT and Municipal Use

Virginia Concrete Conference

CONCRETE: THE DURABLE AND COMPETITIVE INVESTMENT

The Westin Richmond, Richmond, VA

March 5-6, 2015

Presented By:

Scott Blossom, P.E., CFM, LEED A.P.

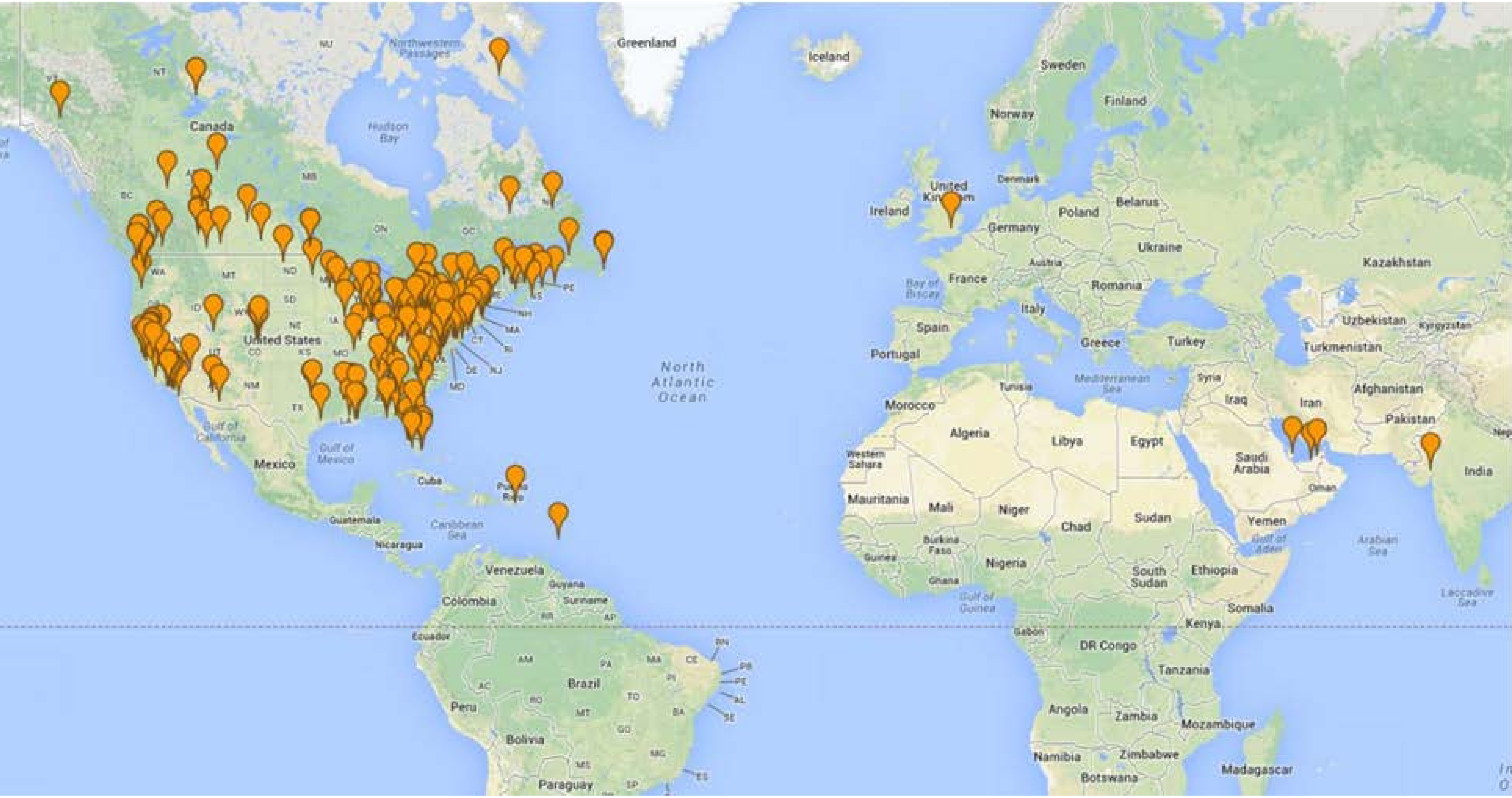
Date:

March 6, 2015

Stantec


A Safety
Moment

200+ Locations



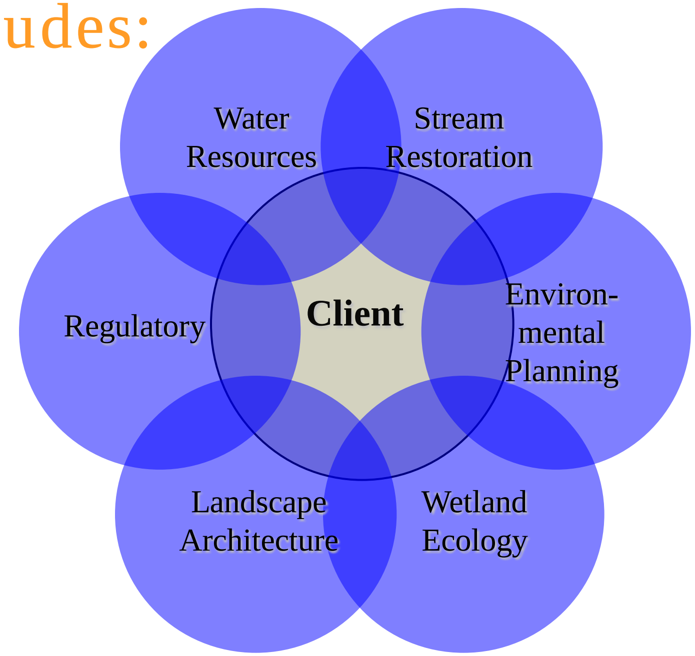
15,000 Professionals

Stantec

Multi Disciplinary Approach

Our Local Environmental Staff includes:

- Water Resources Engineers
- Environmental Planners
- Regulatory Specialists
- Wetland Ecologists
- LEED Accredited
- Landscape Architects
- Environmental Technicians
- CAD/GIS Specialists



...responsive services and high-quality deliverables on-time and within budget

Stantec

Stormwater Stakeholders

Stantec (formerly WEG) supports a variety of public- and private-sector clientele, including:

- Local, State, and Federal Government/Municipalities
- Commercial and Residential Developers
- Engineers/Surveyors/Planners
- Institutions
- Colleges and Universities
- K-12 Schools
- Home Owners Associations
- Utilities
- Non-profit Organizations
- Golf Courses, Parks, and Recreational Facilities

…timely, cost-effective solutions to today's complex environmental issues without "headaches" for our clients

Stantec

1 Water Resources: General

2 Regulatory Drivers

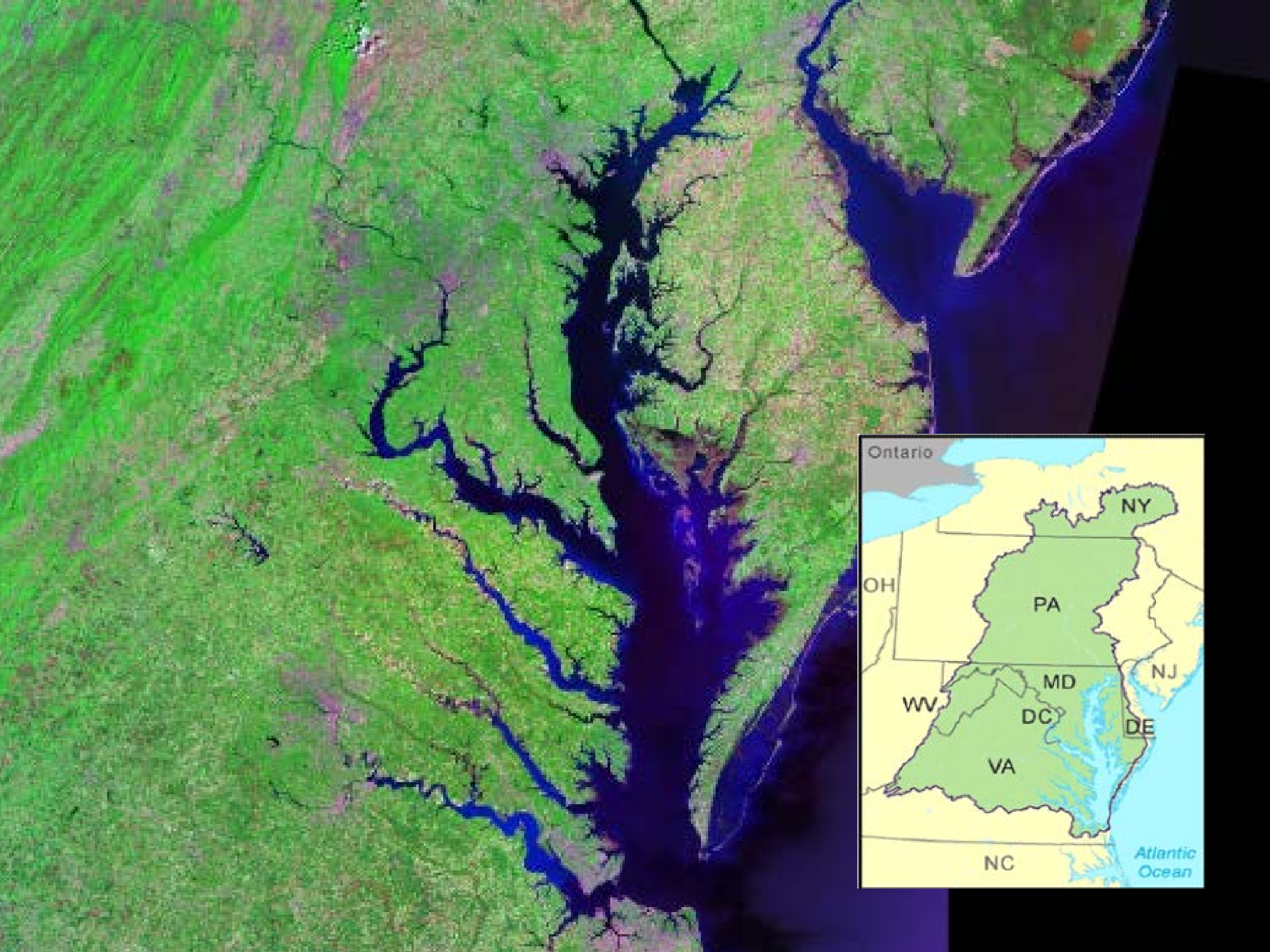
3 Technical Review

4 Best Management Practices

5 Case Studies

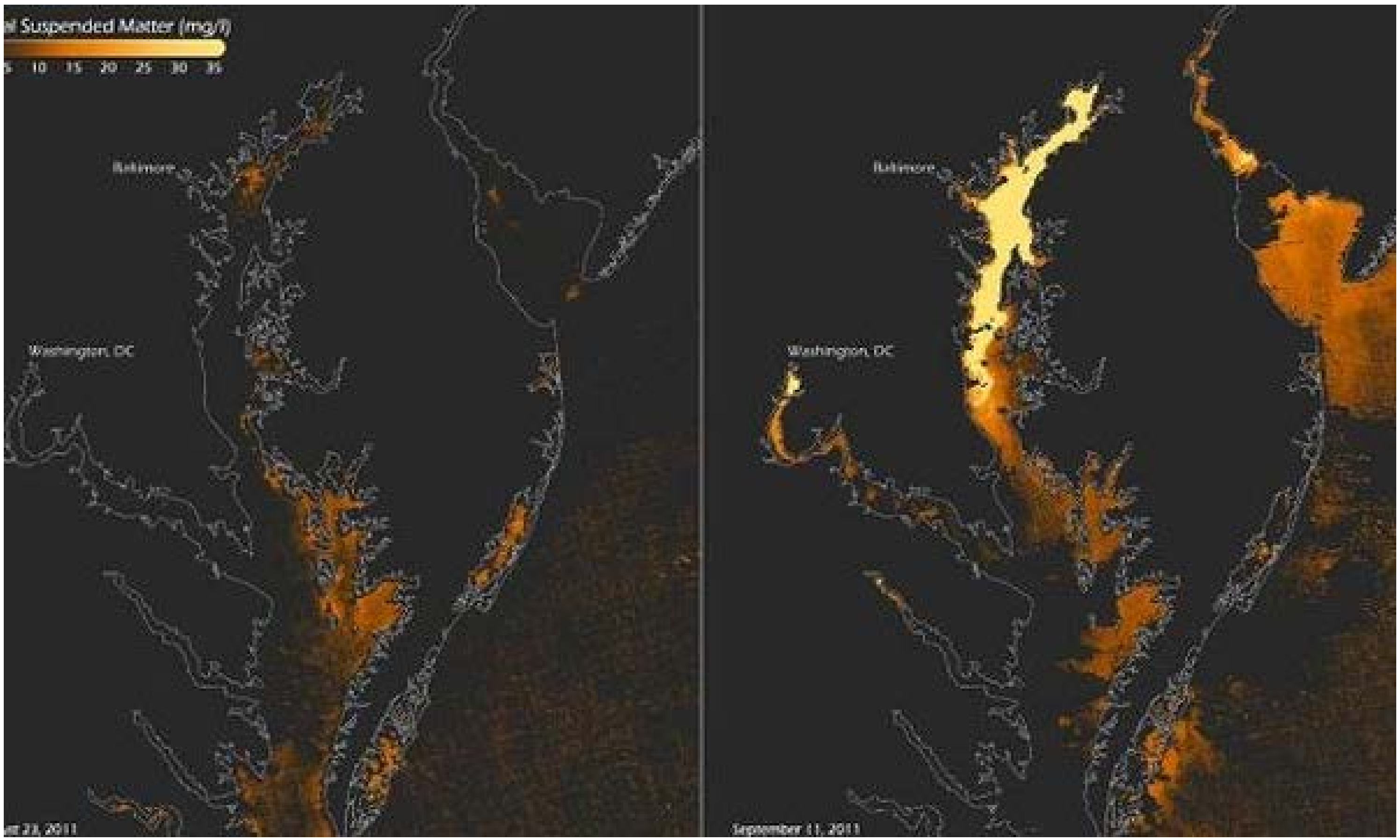
...team of exceptional professionals with extensive experience supporting federal clients in their efforts to achieve objectives

1 Water Resources: General


Ontario
NY
OH
PA
NJ
MD
WV
DC
DE
VA
Atlantic Ocean
NC


September 8-11 2011
Tropical Storm Lee
Susquehanna River at Harrisburg, Pennsylvania
Over 100,000 people evacuated from New York and Pennsylvania

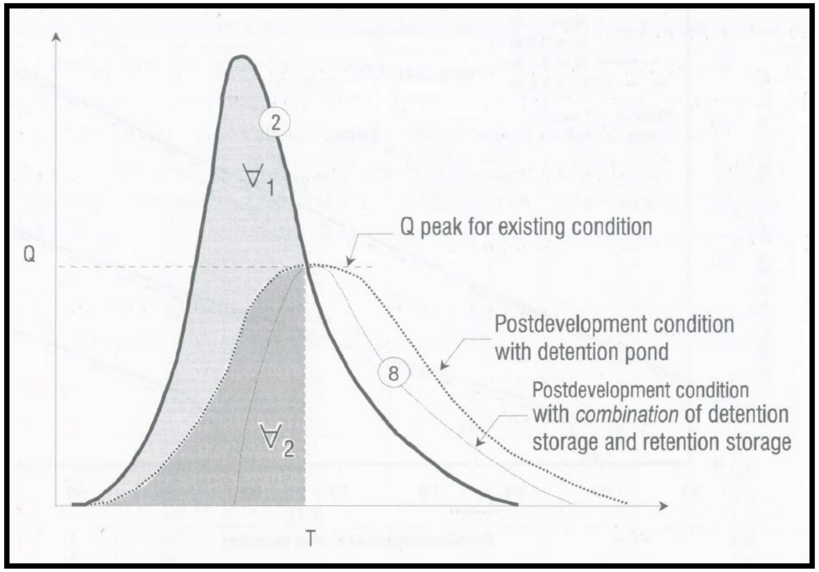
Regional Priorities



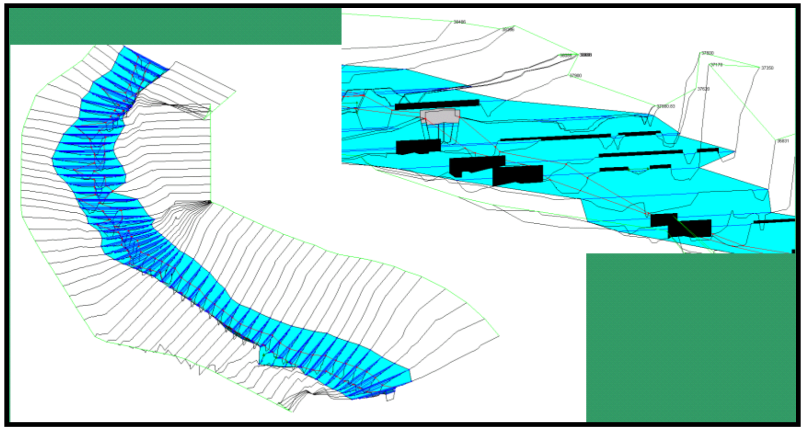
Stantec

Hydrologic & Hydraulic Analysis

- Replicate Predevelopment Hydrograph
- Increase Initial Abstraction



Source: LID Hydrologic Analysis
Prince George County 2000



- Watershed Connection to River & Stream Hydraulics
- Responsible Floodplain Management
- Stream Stability & Restoration

Stantec

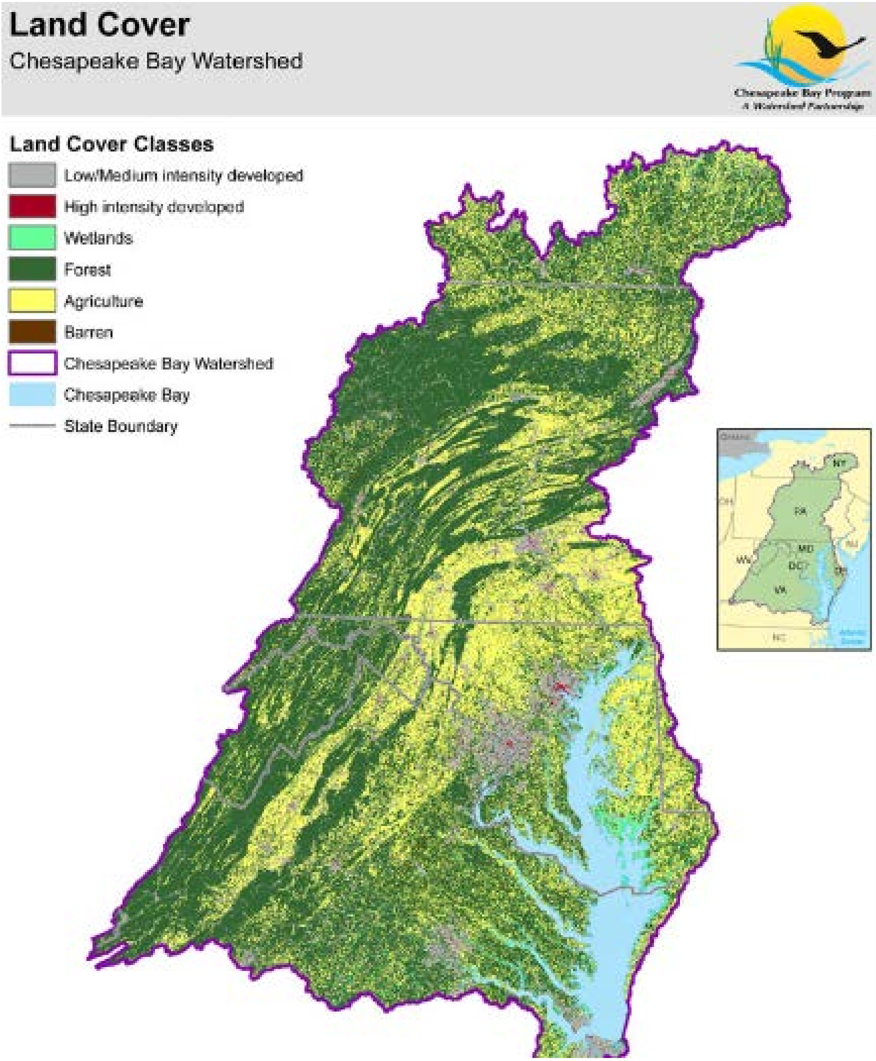
2 Regulatory Drivers

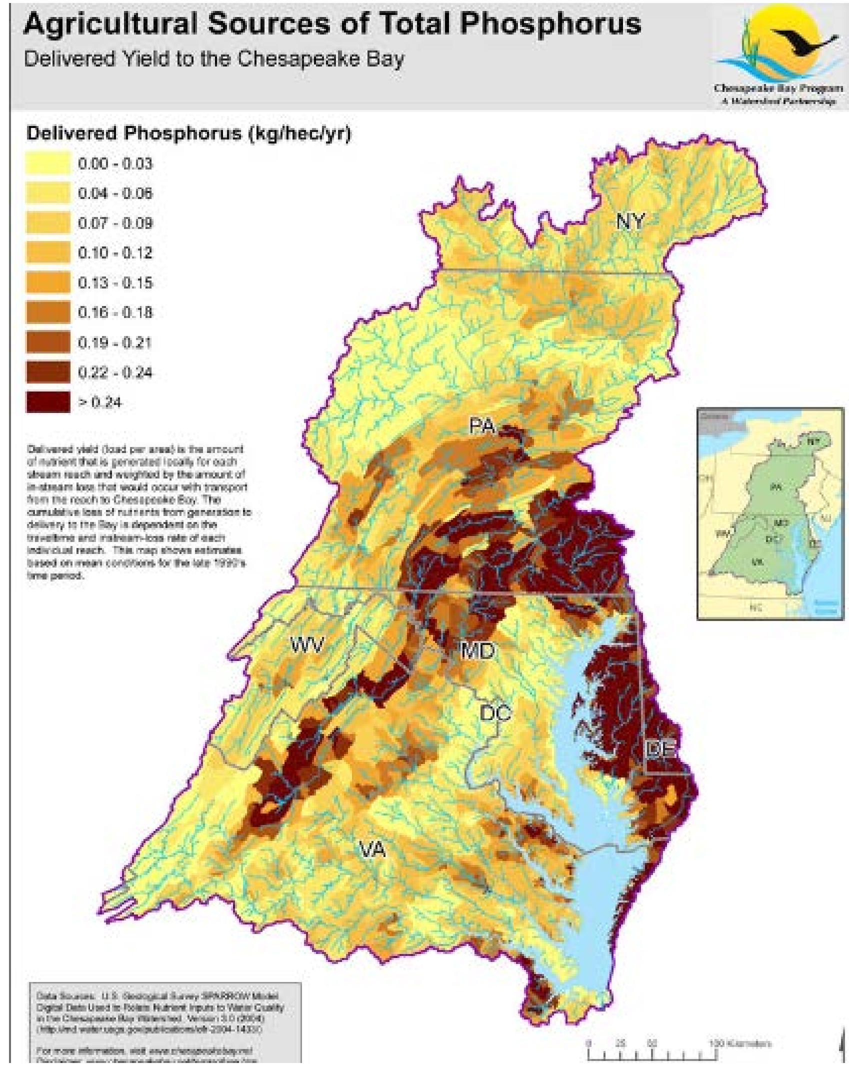
Stantec

Chesapeake Bay TMDL – A Commitment to Clean Water

- The Bay TMDL is a key part of an accountability Framework to ensure that all pollution control measures needed to fully restore the Bay and its tidal rivers are in place by 2025, with practices in place by 2017 to meet 60 percent of the necessary pollution reductions.

Crosses State lines


Land Cover
Chesapeake Bay Watershed
Chesapeake Bay Program
A Watershed Partnership
Land Cover Classes
Low/Medium intensity developed
High intensity developed
Wetlands
Forest
Agriculture
Barren
Chesapeake Bay Watershed
Chesapeake Bay
State Boundary


Agricultural Sources of Total Phosphorus
Delivered Yield to the Chesapeake Bay
Chesapeake Bay Program
A Watershed Partnership
Delivered Phosphorus (kg/hec/yr)
0.00 - 0.03
0.04 - 0.06
0.07 - 0.09
0.10 - 0.12
0.13 - 0.15
0.16 - 0.18
0.19 - 0.21
0.22 - 0.24
> 0.24
NY
PA
WV
MD
DC
DE
VA

Stantec

3 Technical Review

VA Stormwater Regulations

Stormwater Regulations:
Runoff Reduction Method

- **Total Phosphorus (TP)** is used as the target pollutant for compliance with proposed **Water Quality** criteria (4 VAC50-60-63 through 65). Total Nitrogen (TN) is also calculated and BMP designs address TN removal, as well as the removal of other stormwater pollutants.
- Each site also has a **Treatment Volume (Tv)**.
- Stormwater BMPs are assigned **Runoff Reduction (RR)** and **Pollutant Removal (PR)** rates. These rates vary based on the "level of design" used.

Stormwater Regulations:
Energy Balance Method

- Maximum Peak Flow Rate
- Allowable QDeveloped <
- I.F. x QPre-Developed x RVPre-Developed/ RVDeveloped


Mixed Use Development:
Runoff Reduction Example

Land Cover Summary	
Forest/Open Space Cover (acres)	0.00
Weighted Rv(forest)	0.00
% Forest	0%
Managed Turf Cover (acres)	1.00
Weighted Rv(turf)	0.22
% Managed Turf	26%
Impervious Cover (acres)	2.81
Rv(impervious)	0.95
% Impervious	74%
Total Site Area (acres)	3.81
Site Rv	0.76
Post-Development Treatment Volume (acre-ft)	0.24
Post-Development Treatment Volume (cubic feet)	10,489
Post_Development Load (TP) (lb/yr)	6.59
Total Load (TP) Reduction Required (lb/yr)	5.03

Site Results	
Phosphorous	
TOTAL TREATMENT VOLUME (cf)	10,489
TOTAL PHOSPHOROUS LOAD REDUCTION REQUIRED (LB/YEAR)	5.03
RUNOFF REDUCTION (cf)	0
PHOSPHOROUS LOAD REDUCTION ACHIEVED (LB/YR)	4.94
ADJUSTED POST-DEVELOPMENT PHOSPHOROUS LOAD (TP) (lb/yr)	1.65
REMAINING PHOSPHOROUS LOAD REDUCTION (LB/YR) NEEDED	0.09

Drainage Area and BMP Specific

Stantec

4 Best Management Practices

TABLE 1. Summary of Pervious Concrete Benefits and Limitations (Tennis et al. 2004; ACI 2010)

Benefits/Advantages	Limitations/Disadvantages
• Effective management of stormwater runoff, which may reduce the need for curbs and the number and sizes of storm sewers. • Reduced contamination in waterways. • Recharging of groundwater supplies. • More efficient land use by eliminating need for retention ponds and swales. • Reduced heat island effect (due to evaporative cooling effect of water and convective airflow). • Elimination of surface ponding of water and hydroplaning potential. • Reduced noise emissions caused by tire–pavement interaction. • Earned LEED® credits.	• Limited use in heavy vehicle traffic areas. • Specialized construction practices. • Extended curing time. • Sensitivity to water content and control in fresh concrete. • Lack of standardized test methods. • Special attention and care in design of some soil types such as expansive soils and frost-susceptible ones. • Special attention possibly required with high groundwater.

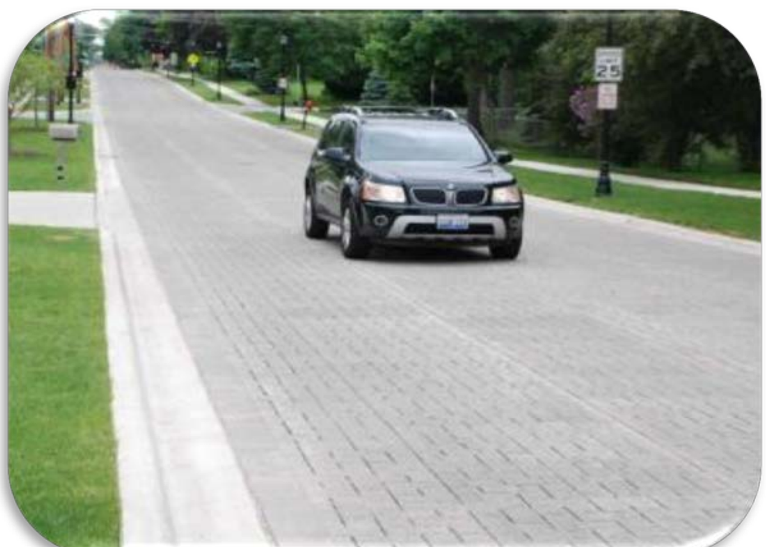
Stantec

Permeable Pavement

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 7

Permeable Pavement

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 7



Summary of Stormwater Functions [1]

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR)	45%	75%
Total Phosphorus (TP) EMC Reduction[1] by BMP Treatment Process	25%	25%
Total Phosphorus (TP) Mass Load Removal	59%	81%
Total Nitrogen (TN) EMC Reduction[1]	25%	25%
Total Nitrogen (TN) Mass Load Removal	59%	81%
Channel Protection	• Use VRRM Compliance spreadsheet to calculate a Curve Number (CN) adjustment[2]; ***OR*** • Design extra storage in the stone underdrain layer and peak rate control structure (optional, as needed) to accommodate detention of larger storm volumes.	
Flood Mitigation	Partial. May be able to design additional storage into the reservoir layer by adding perforated storage pipe or chambers.	

[1] Change in event mean concentration (EMC) through the practice. Actual nutrient mass load removed is the product of the removal rate and the runoff reduction rate (see Table 1 in the *Introduction to the New Virginia Stormwater Design Specifications*).

[2] NRCS TR-55 Runoff Equations 2-1 thru 2-5 and Figure 2-1 can be used to compute a curve number adjustment for larger storm events based on the retention storage provided by the practice(s).

Sources: CWP and CSN (2008) and CWP (2007)

Permeable Pavement

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 7

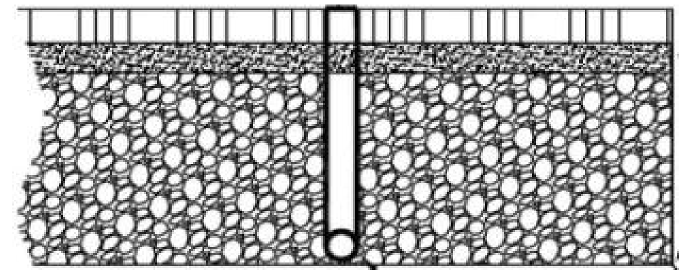
Permeable Pavement Design Criteria

Level 1 Design	Level 2 Design
Tv_{BMP} = (1)(Rv)(A) / 12 + any remaining volume from an upstream BMP(s) [1]	Tv_{BMP} = (1.1)(Rv)(A) / 12
Soil infiltration is less than 0.5 in./hr.	Soil infiltration rate exceeds 0.5 in./hr to remove underdrain requirement, or a drawdown design in accordance with **Section 6**.
Underdrain required	1. No underdrain; ***OR*** 2. If an underdrain is used, a 12-inch (minimum) stone reservoir infiltration sump below the underdrain invert that meets the drawdown requirements of Section 6 must be provided; ***OR*** 3. The Tv stone reservoir volume has at least a 48-hour drain time, as regulated by a control structure.
CDA[1] = The permeable pavement area plus upgradient parking, as long as the ratio of external contributing area to permeable pavement does not exceed 2:1.	CDA = The permeable pavement area;
[1] The contributing drainage area to the permeable pavements should be limited to paved surfaces in order to avoid sediment wash-on, and. When pervious areas are conveyed to permeable pavement, sediment source controls and/or pre-treatment must be provided. The pre-treatment may qualify for a runoff reduction credit if designed accordingly.	

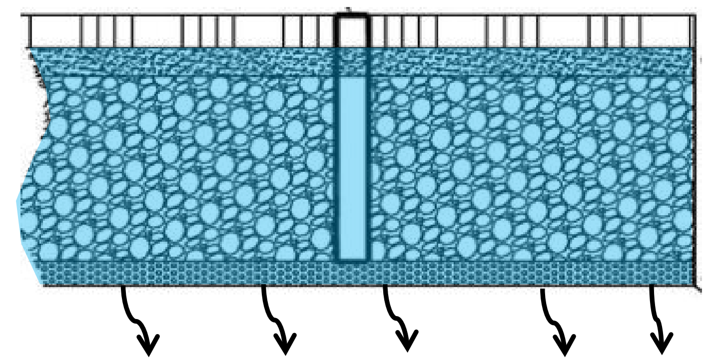
Permeable Pavement

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 7

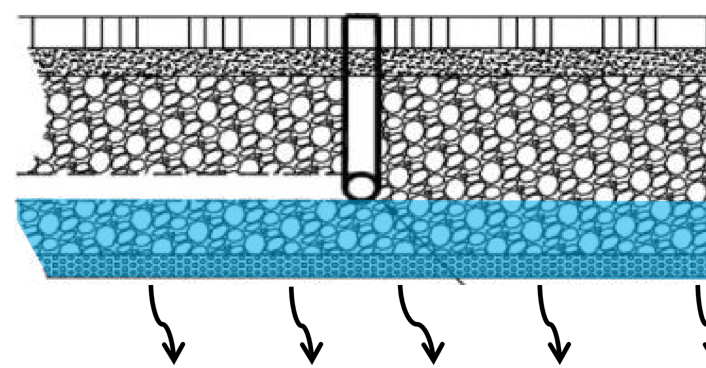
Level 1



Level 2 (infiltration)



Level 2 (infiltration sump)



Permeable Pavement

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 7

Type of pavement materials

Concrete Grid Pavers

Pervious Concrete

Porous Asphalt

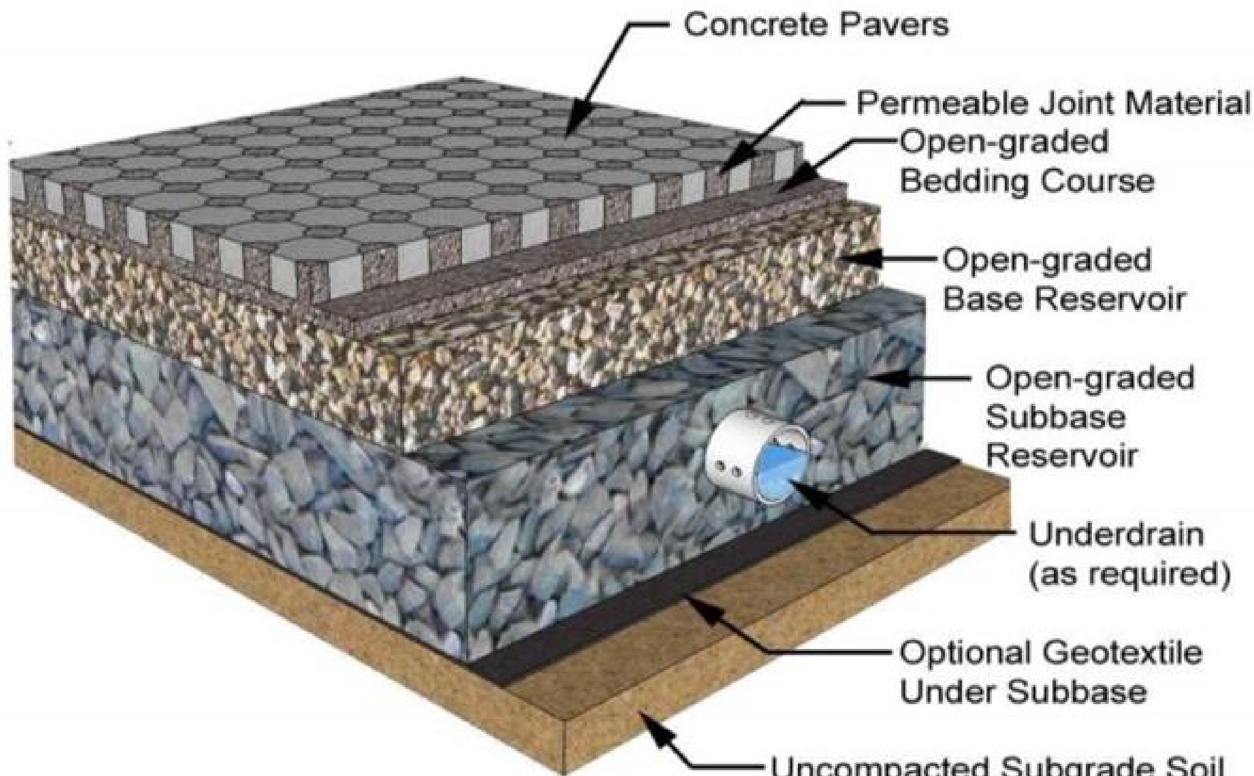
Permeable Interlocking Concrete Pavers

Pervious Composites

Permeable Rubber Overlays

Permeable Pavement

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 7



Permeable Pavement

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 7

- **Key Design Consideration:** stone reservoir depth, d_p

$$d_p = \frac{\{(d_c \times R) + P - (i/2 \times t_f)\}}{V_r}$$

Where:

d_p = Depth of the stone reservoir layer (ft.)

d_c = The depth of runoff from the contributing drainage area (not including the permeable paving surface) for the Treatment Volume (Tv/A_c), or other design storm (ft.)

R = A_c/A_p = The ratio of the contributing drainage area (A_c, not including the permeable paving surface) to the permeable pavement surface area (A_p)

P = The rainfall depth (in feet) for the Treatment Volume (Level 1 = 1 inch (0.08 ft); Level 2 = 1.1 inch (0.09 ft)) or other design storm

i = The field-verified infiltration rate for native soils (ft./day)

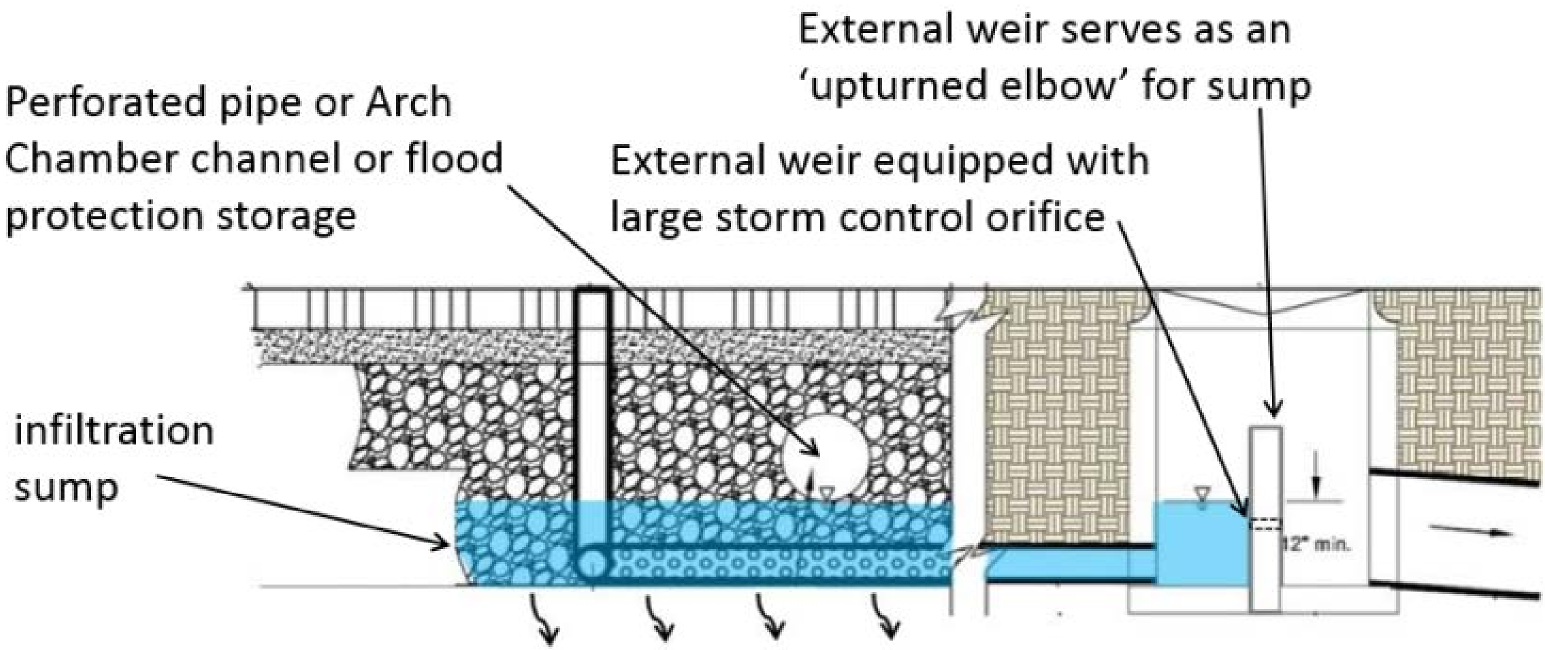
t_f = The time to fill the reservoir layer (day) – typically 2 hours or 0.083 day

V_r or η_r = Porosity (or void ratio) of reservoir layer (0.4)

Permeable Pavement

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 7

Key Design Consideration: ‘Upturned Elbow’



Permeable Pavement

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 7

Key Design Consideration: External Drainage Areas

- **The maximum external drainage area is limited to ratio with area of permeable pavement: 2:1**

- In all cases, external drainage areas should be limited to impervious surfaces to reduce potential sediment loading

Permeable Pavement

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 7

Key Design Consideration: Pavement Structural Design

Thickness of permeable pavement and reservoir layer must be sized to support structural loads

Four primary design elements:

- Anticipated traffic loads
- Underlying soil properties
- Environmental/climate factors
- Surface, bedding, and reservoir strength coefficients and layer thicknesses (strength coefficients vary for materials used)

Permeable Pavement

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 7

Key Design Consideration: Maintenance Agreements

Permeable Pavement (like all BMPs) must have a maintenance agreement, and should include provisions for owner awareness of routine (frequent) and infrequent maintenance requirements.

Virginia Department of Transportation
Special Provision for
PERMEABLE PAVEMENT

July 1, 2014

I. DESCRIPTION

This work shall consist of construction, testing, and a first year warranty, inspection, and maintenance period for permeable pavement with the requirements herein and in conformity with the lines, grades, dimensions, and thickness as shown on the plans and/or as directed by VDOT. The construction of permeable pavement shall encompass all activities and materials discussed and specified for explicit proper function of the facilities. All referenced sections herein are to the current VDOT Road and Bridge Standards and Specifications, unless otherwise noted.

j) General Construction Sequence -- The following is a typical construction sequence to properly install permeable pavement. The following shall be applied unless otherwise specified.

1. Construction of the permeable pavement shall only begin after the entire contributing drainage area has been stabilized. The proposed site should be checked for existing utilities prior to any excavation. Do not install the system in rain or snow, and do not install frozen aggregate materials.

2. As noted above, temporary erosion and sediment (E&S) controls are needed during installation to divert stormwater away from the permeable pavement area until it is completed. Special protection measures such as erosion control fabrics may be needed to protect vulnerable side slopes from erosion during the excavation process. The proposed permeable pavement area must be kept free from sediment during the entire construction process. Construction materials that are contaminated by sediments must be removed and replaced with clean materials.

Virginia Department of Transportation
Special Provision for
PERMEABLE PAVEMENT

VI. FIRST YEAR WARRANTY, INSPECTION, AND MAINTENANCE PERIOD

Contractor or Inspectors should look for bare or eroding areas in the contributing drainage area around the porous pavement area, and assure they are immediately stabilized with grass cover or other appropriate lining (riprap, blanketing/matting, etc.). Fertilizers may be needed to stabilize for initial planting in accordance with the approved nutrient management plan program adopted by VDOT.

Virginia Department of Transportation
Special Provision for
PERMEABLE PAVEMENT

VI. FIRST YEAR WARRANTY, INSPECTION, AND MAINTENANCE PERIOD

Underdrain repairs may be needed if water remains on the surface. The surface of the porous pavement should also be checked for accumulated sediment or a fine crust that builds up after the first several storm events. Tested infiltration rate of porous pavement shall be verified to VDOT to be a minimum of 2 inches per hour after the 1-yr care and maintenance period, and prior to acceptance.

If there is standing water, open the underdrain observation well or cleanout and pour in water to verify that the underdrains are functioning and not clogged or otherwise in need of repair. If there is standing water on top, but not in the underdrain, then there is a clogged layer. If the underdrain and stand pipe indicates standing water, then the underdrain is likely clogged and will need to be rehabilitated. Vacuuming the pavement with a standard street sweeper 2-4 times per year will discourage clogging.

End-of-First Year Facility Acceptance -- At the end of the year following construction completion, the Contractor shall conduct a joint inspection with VDOT Inspectors and, upon proper function and VDOT approval, transfer the facility to the appropriate authorities. The Contractor will also provide an itemized list of maintenance activities conducted, referenced warranty survey and installation documentation.

Integrated Management Practice:
Permeable Pavement for Highway Shoulders

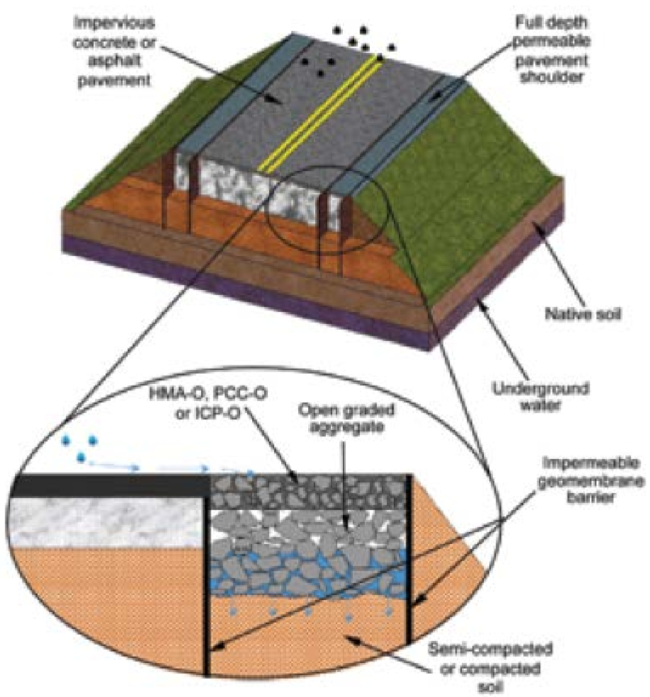
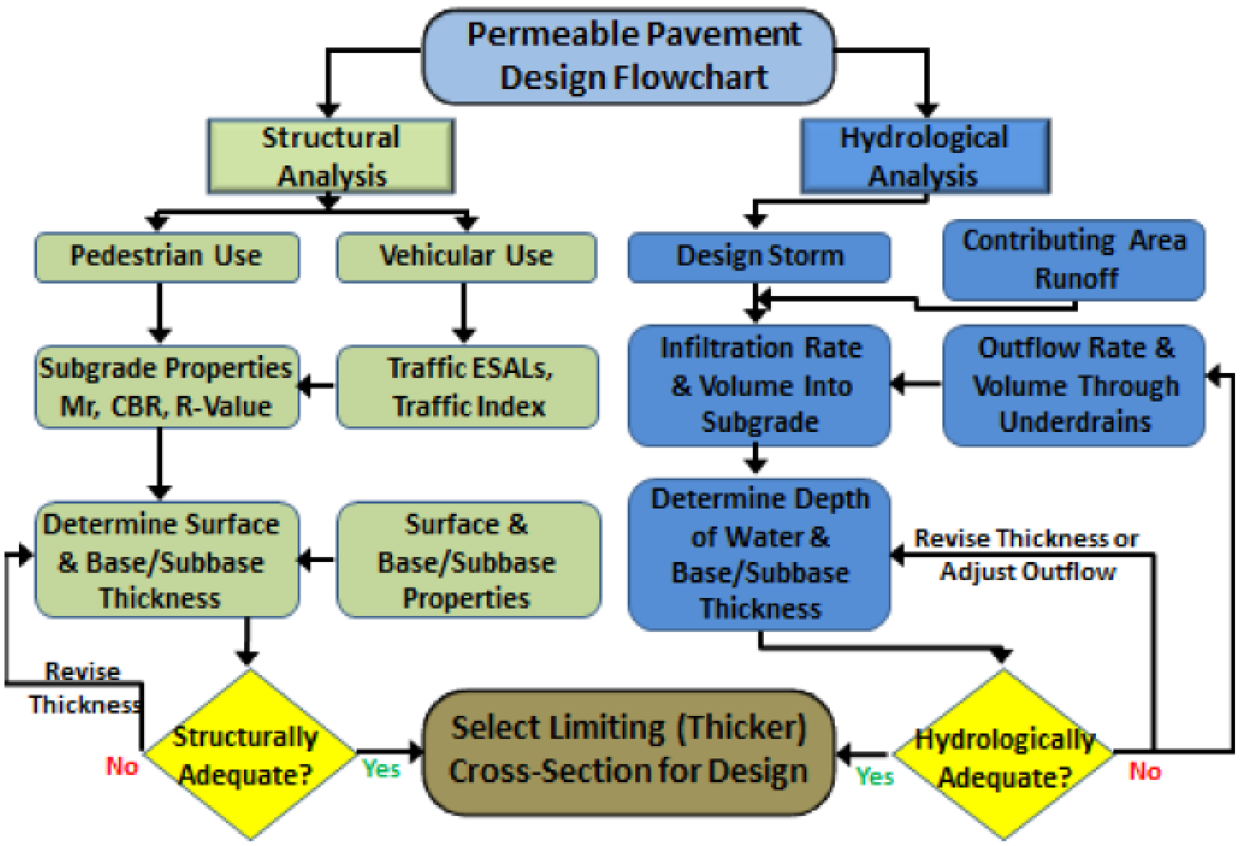


Figure 2. A conceptual full-depth permeable pavement shoulder design for runoff management on urban roads

Author's bio: ***Masoud Kayhanian*** is a research professor in the Department of Civil and Environmental Engineering, University of California, Davis.

Stantec

5 Case Studies



[Smith 2011]

Figure 5.1. Structural and hydrological design flowchart.

Stantec

Date	Name of Project	Location	Project	Square Feet
2007	Wetland Studies and Solutions Inc., (phase I)	Gainesville	Parking	6,000
2007	Kid's Domain Day Care	Leesburg	Parking	8,000
2008	Wetland Studies and Solutions Inc., (phase II)	Gainesville	Parking	8,000
2009	Pohanka Honda of Fredericksburg	Stafford County	Parking	209,000
2009	Lorton Center School Bus Parking	Lorton	Parking	13,000
2009	Shenandoah University (The McKown Plaza)	Winchester	Plaza	5,000
2009	Residential Driveway (colored pervious conc.)	Lorton	Driveway	8,000
2010	Loudoun County Public Schools Administraton	Ashburn	Parking	30,000
2010	Equinix Data Center	Ashburn	Walking Pat & Parking	17,000
2010	Glen Carlyn Park, Picnic Shelter	Arlington	Parking	7,900
2010	Dolly Madison Library	McLean	Parking	25,000
2010	The Club House at Fort Belvoir	Ft. Belvoir	Parking	4,500
2010	Residential Driveway (colored pervious conc.)	McLean	Driveway	3,500
2011	John Champs High School	Aldie	Parking	40,000
2011	Loudoun County Youth Shelter	Leesburg	Parking	9,000
2011	Residential Development (8 driveways)	Alexandria	Driveway	9,000
2011	Spring Hill Park	McLean	Sidewalk	9,300
2011	East Loudoun Respite Center	Sterling	Parking	3,700
2011	Belmont Ridge Elementary School (phase I)	Ashburn	Parking	10,000
2011	Hazmat Parking Lot	Arlington	Parking	25,000
2012	Residential Driveway	Arlington	Driveway	3,500
2012	Long Bridge Park	Crystal City	Sidewalk	15,500
2012	415 William Street (residential)	Fredericksburg	Driveway & Parking	1,100
2012	Potomac Library	Woodbridge	Plaza	1,500
2012	Belmont Ridge Elementary School (phase II)	Ashburn	Parking	8,500
2012	Brambleton Public Safety Center	Brambleton	Parking	48,000
2013	Fort Belvoir Shopping Center	Ft. Belvoir	Parking	100,000
2013	Lucas & Ross Group Home	Spotsylvania	Parking	62,000
2013	Lemone Road Elementary School	Falls Church	Parking	50,000
2013	Leesburg Toyota	Leesburg	Parking	29,000
2013	Middleburg Fire Department	Middleburg	Parking	45,000
2013	Loudoun Valley High School	Purcerville	Parking	23,000
2013	Hall Funeral Home	Purcerville	Parking	9,000

Stantec

Ft Belvoir - History

Full service inventory and inspection

- What is on base and what is the current performance?
- Integrated GIS database
- User Friendly decision making
- MS4 Documentation

...WEG (now Stantec) is currently under contract

Stantec

Building Better Highways in Canada

"When it comes to highway construction, no other material offers the benefits of concrete. Concrete highways are safe, economical and environmentally friendly – why settle for less?"

Pierre Boucher
President & Chief Executive Officer

Cement Association of Canada
Association Canadienne du Ciment

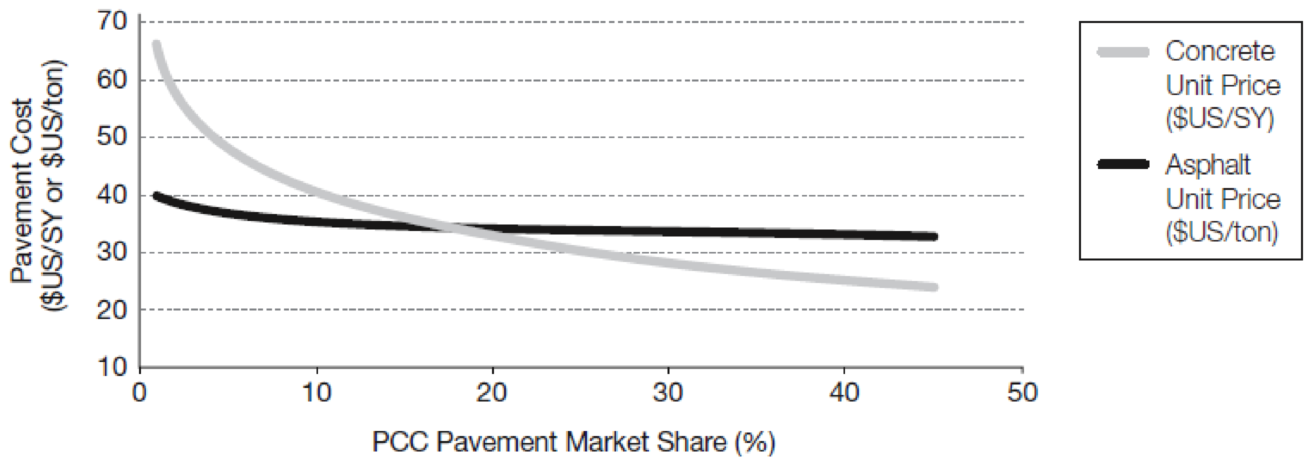
Stantec

A true alternative leading to better prices

A long-term commitment from governments to the use of rigid concrete pavements will lead to lower costs through increased competition between concrete and asphalt road builders.

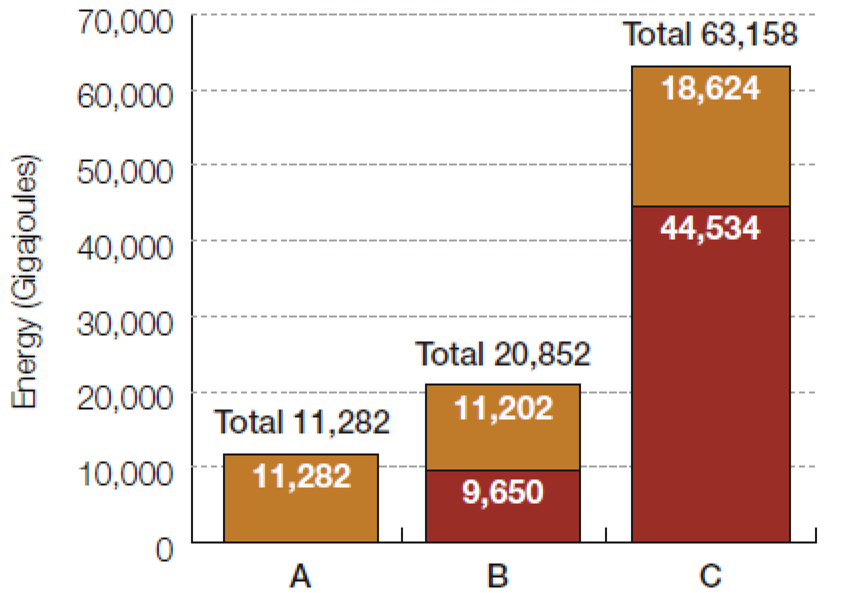
Data from the American Concrete Pavement Association confirms that American states truly committed to building concrete highways create competition between the concrete and asphalt paving industries resulting in lower unit costs for both concrete and asphalt highways.[4] This results in more roads paved for the same cost. Figure 2 illustrates the benefits of competition between pavement types on construction costs.

FIGURE 2: BENEFIT OF A TWO-PAVEMENT SYSTEM ON PAVEMENT COST



5-year average data (2000-2004) for 14 American states

FIGURE 3: COMPARATIVE EMBODIED PRIMARY ENERGY FOR TYPICALCANADIAN HIGH VOLUME HIGHWAY DESIGN



DEFINITIONS

Primary energy: the energy resources required by processes, including the energy input used to extract the energy resources.

Feedstock energy: the gross combustion heat for any material input, such as bitumen, which is considered an energy source, but is not being used as an energy source.

Embodied primary energy: the sum of primary energy and feedstock energy.

Pavement structure

A) Concrete pavement (concrete shoulders, no asphalt overlay)
B) Concrete pavement (asphalt shoulders and asphalt overlay)
C) Asphalt pavement

Referring to a 4-lane one kilometre highway.

Note: Concrete pavement option has feedstock component due to asphalt shoulders and overlay as part of the maintenance and rehabilitation schedule.

FBI Building

WEG (now Stantec) pursued a Design Build contract as part of a team proposing on this LEED Gold Facility

- Security Buffer
- “Covered” Parking
- Meet SFO & POR
- GSA Design Excellence Program

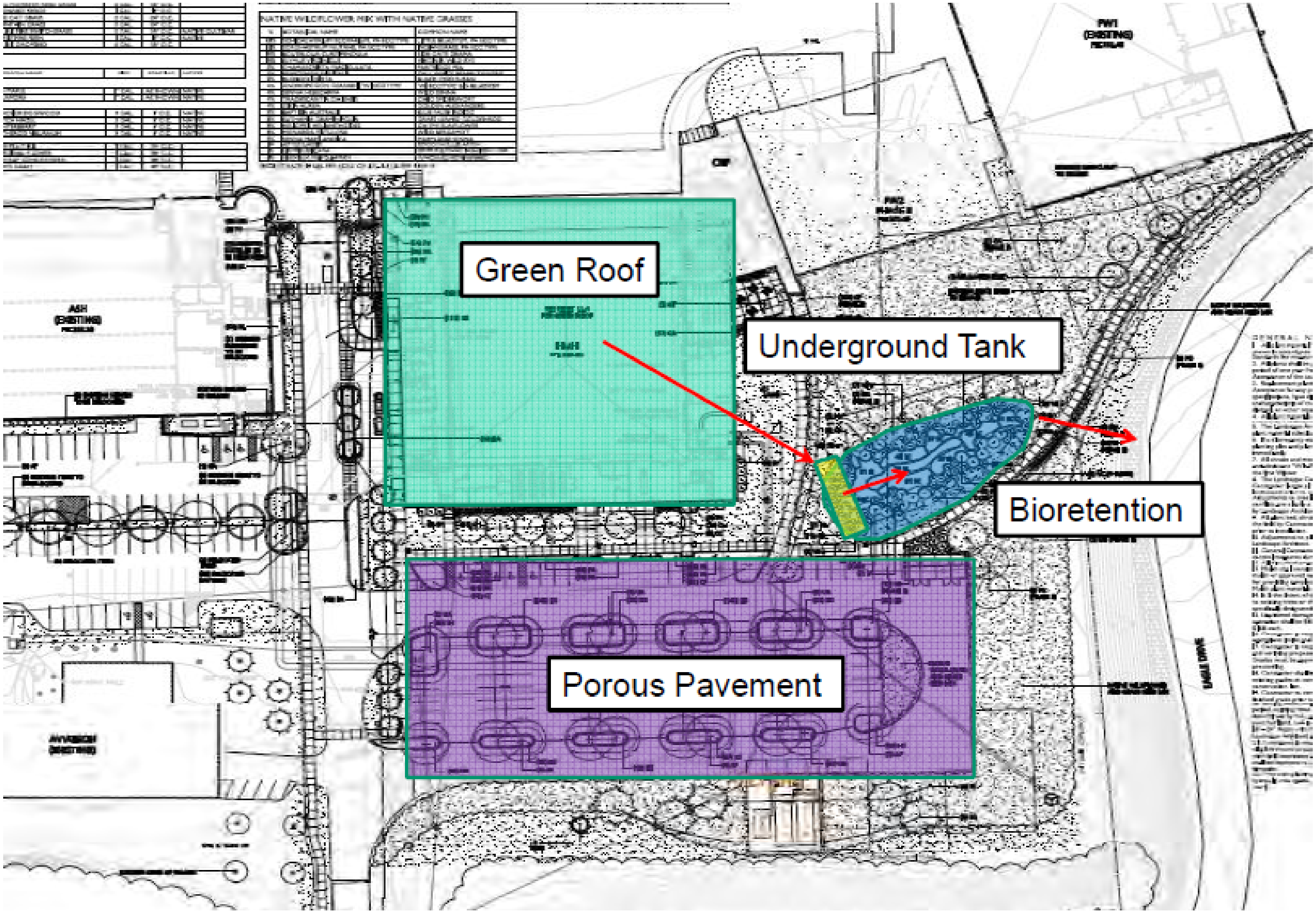
… renderings prepared by Skanska and SOM

Stantec

Research & Technology Park

- WEG (now Stantec) is part of a team providing sustainable and innovative building design using green development techniques.
- Design plans included:
  - Bioswales
  - Permeable Pavements
  - Rainwater Harvesting
  - Photovoltaics
  - Local Building Materials
  - Recycled Products
  - Innovative Wastewater Technologies
  - Daylighting Strategies
  - Climate Needs

… registered with the United States Green Building Council for the Leadership in Energy and Environmental Design (LEED) program and is considering Gold Level Certification.



Heritage Airport, VT

Stantec

Heritage Airport, VT

Stantec

THANK YOU.

Scott Blossom, P.E., CFM, LEED A.P.
scott.blossom@stantec.com
(757) 220-6869

Stantec

REFERENCES

1. US Department of Transportation Federal Highways Administration web site, Office of Highway Policy Information, Highway Statistics 2005. http://www.fhwa.dot.gov/policy/ohim/hs05/xls/hm12.xls
2. Tighe, S., Smith, T., Fung, R., *Concrete Pavements in Canada: A Review of their Usage and Performance*, Paper for Transportation Association of Canada Annual Conference, September 2001.
3. American Concrete Pavement Association, *Life Cycle Cost Analysis: A Guide for Comparing Alternate Pavement Analysis*, EB 220P, 2002.
4. Southeast Chapter American Concrete Pavement Association, *"Who says..."Concrete Pavement Costs Too Much?" Count on Concrete Pavement*, 2005.
5. American Concrete Pavement Association, *Whitetopping - State of the Practice*, Engineering Bulletin 210P
6. Gajda, J.W., Van Geem, M.G., *A Comparison of Six Environmental Impacts of Portland Cement Concrete and Asphalt Cement Concrete Pavement*, PCA R&D Serial No. 2068, Portland Cement Association, 1997.
7. The Athena Sustainable Materials Institute, *A Life Cycle Perspective on Concrete and Asphalt Roadways: Embodied Primary Energy and Global Warming Potential*, Ottawa, September 2006.
8. Taylor G.W., Patten, J.D., *Effects of Pavement Structure on Vehicle Fuel Consumption – Phase III*, prepared for Natural Resources Canada Action Plan 2000 on Climate Change and Cement Association of Canada, January 2006.
9. Taylor G.W., Dr. Farrell, P. and Woodside A., *Additional Analysis of the Effect of Pavement Structure on Truck Fuel Consumption*, prepared for Government of Canada Action Plan 2000 on Climate Change, Concrete Roads Advisory Committee, August 2002.
10. See above, note 8.
11. See above, note 9.
12. Nova Scotia Transportation and Public Works, *Asphalt Concrete Pavement and Portland Cement Concrete Pavement, Highway 104, Cumberland County, Year 5 of 5 Year Study*, October 1999.
13. The Transtec Group, *Pavement Roughness Progression Case Study*, July 2006.
14. Federal Highway Administration, *Tire-Pavement Noise and Safety Performance*, Publication No. FHWA-SA-96-068,1996.
15. See above, note 12.