SESWA Regional Seminar
BMP SELECTION CRITERIA

Doug Beisch - Principal
Stantec

Stantec

March 31, 2017

Goals and Objectives

- Design Goals and Objectives
- Multi-Function BMPs
- Innovative Approaches

Background Questions:

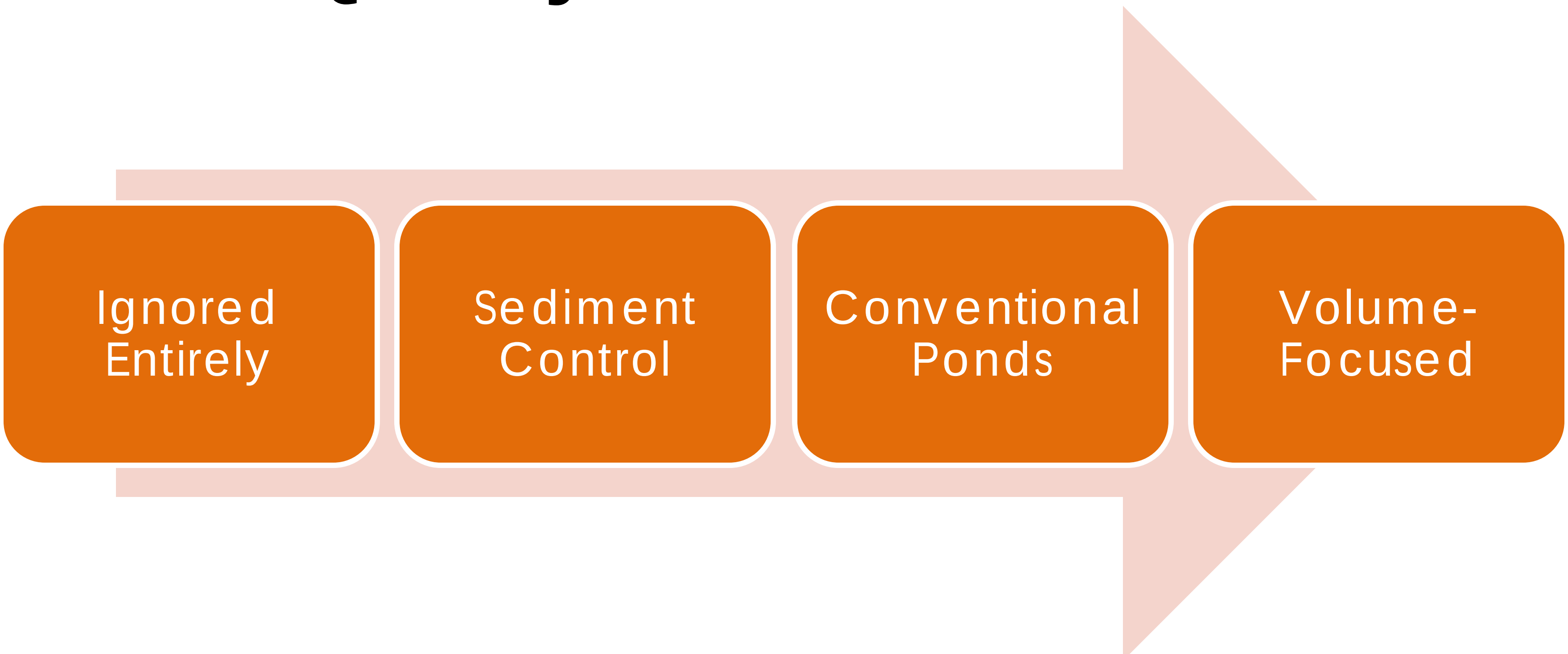
- How many of you are **designers**?
- How many of you **review and approve plans**?
- How many of you **routinely see "LID" approaches** incorporated into projects?

Stantec

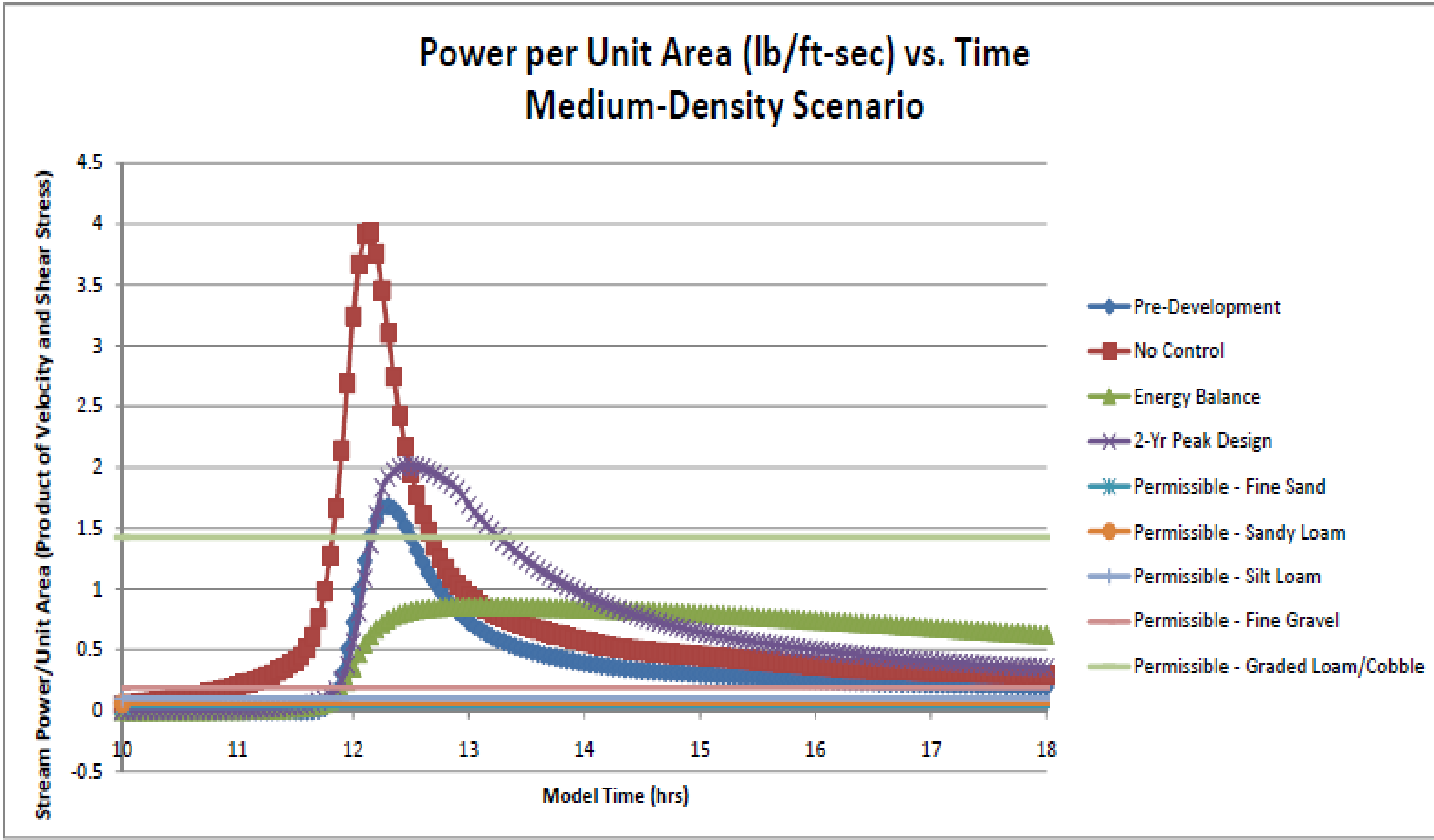
BMP Design Goals and Objectives

- Site Drainage
- Erosion and Sediment Control
- Runoff Quality Management
- Receiving Channel Protection
- Flood Control

Evolution of Approaches:
Runoff Quality

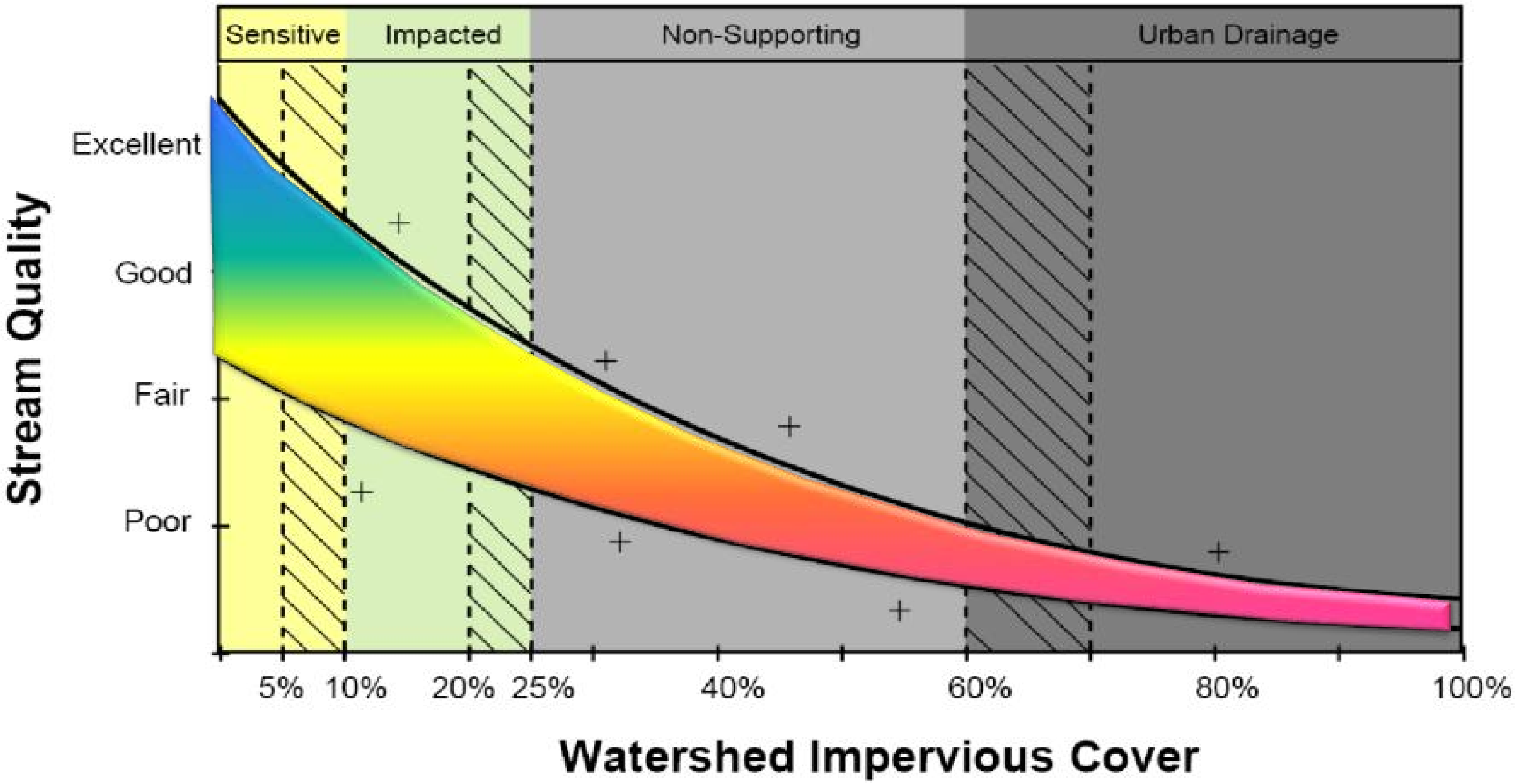



USGS, 2012


Power per Unit Area (lb/ft-sec) vs. Time
Medium-Density Scenario
Stream Power/Unit Area (Product of Velocity and Shear Stress)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
10
11
12
13
14
15
16
17
18
Model Time (hrs)
Pre-Development
No Control
Energy Balance
2-Yr Peak Design
Permissible - Fine Sand
Permissible - Sandy Loam
Permissible - Silt Loam
Permissible - Fine Gravel
Permissible - Graded Loam/Cobble

Stantec

Impervious Cover Model



Stantec

Managed Turf

- Documented impacts from turf management activities:
  - Fertilization;
  - Pest management;

Site Runoff Coefficients (Rv)[1]

Cover	HSG A	HSG B	HSG C	HSG D
Forest/Open	**0.02**	**0.03**	**0.04**	**0.05**
Managed Turf / Disturbed Soil	**0.15**	**0.20**	**0.22**	**0.25**
Impervious Cover	**0.95**	**0.95**	**0.95**	**0.95**

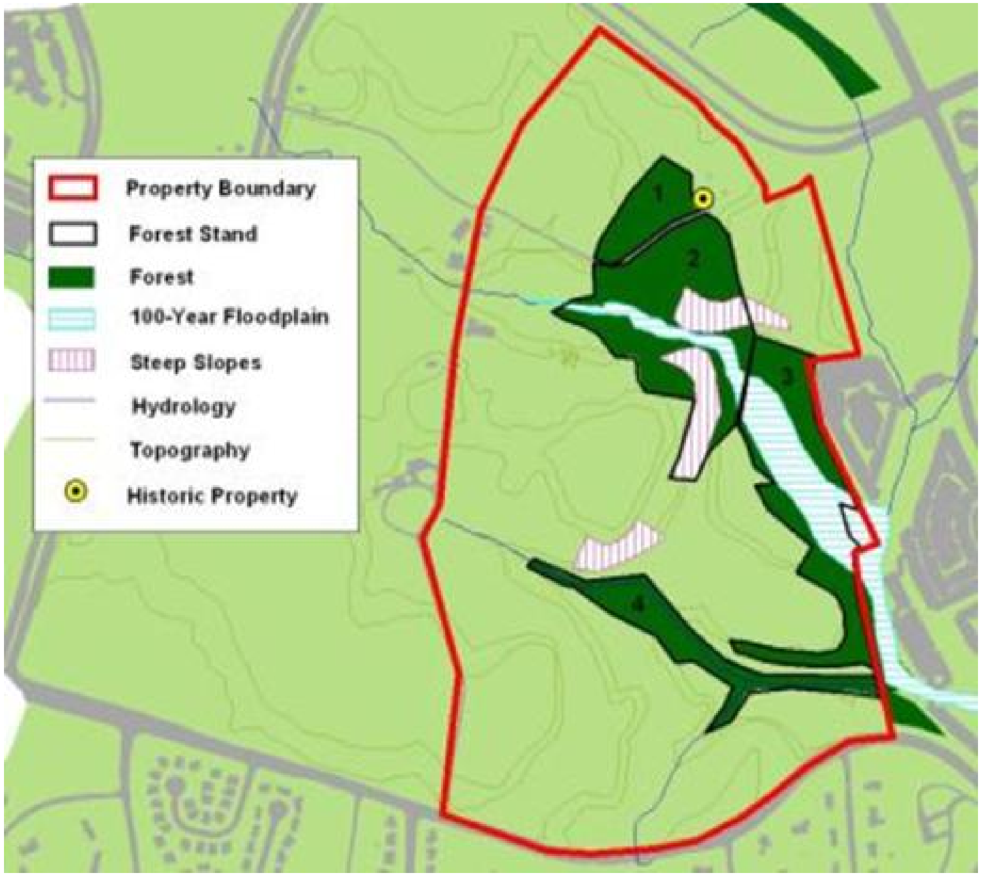
[1] *Center for Watershed Protection – Technical Memorandum: The Runoff Reduction Method; 4/18/08*

Pitt et al (2005), Lichter and Lindsey (1994), Schueler (2001a, 2001b, 1987), Legg et al (1996), Pitt et al (1999), and Cappiella et al (2005)

First Step in BMP Selection

Environmental Site Inventory & Assessment

- Forest conservation
- Suitable soils
- Steep slopes
- Drainage
- Wetlands
- Zero-order streams
- Buffers
- Sensitive areas
- Limits of disturbance
- Computed nutrient loads & tv



Stantec

Site and Subdivision Planning

- Resource Assessment
- Conservation/Preservation
- Resource Enhancement and Restoration
- Floodplain Protection
- Maintaining Natural Drainage Patterns
- Disconnecting Impervious Cover

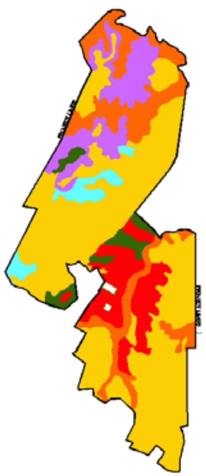
Stantec

The Starting Point - Resource Assessment

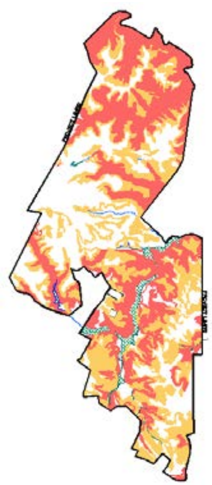
- Aquatic Resources
  - Stream Channel Condition Assessments
  - Geomorphic – Channel Stability
  - Hydrologic/Hydraulic Modeling
  - Bioassessment - Macroinvertebrates
  - Stream Condition Units (mitigation/impacts)
  - Perenniality Studies
  - Wetland Functional Assessments
- Terrestrial Resources
  - Forest Stand Delineations/Forest Cover Mapping
  - Buffer Assessments
  - Rare Plant Surveys
  - Inventory of existing erosional features

Stantec

Suitability Screening: New Development



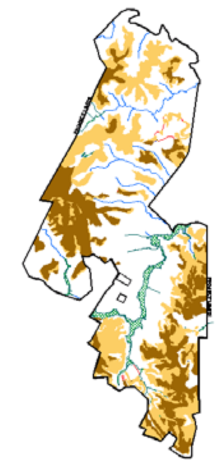
Permeability



Slope

Depth to GW

Land Planning



Overall IMP Suitability

Conservation/Direct Runoff to Natural Areas (Resource Enhancement)

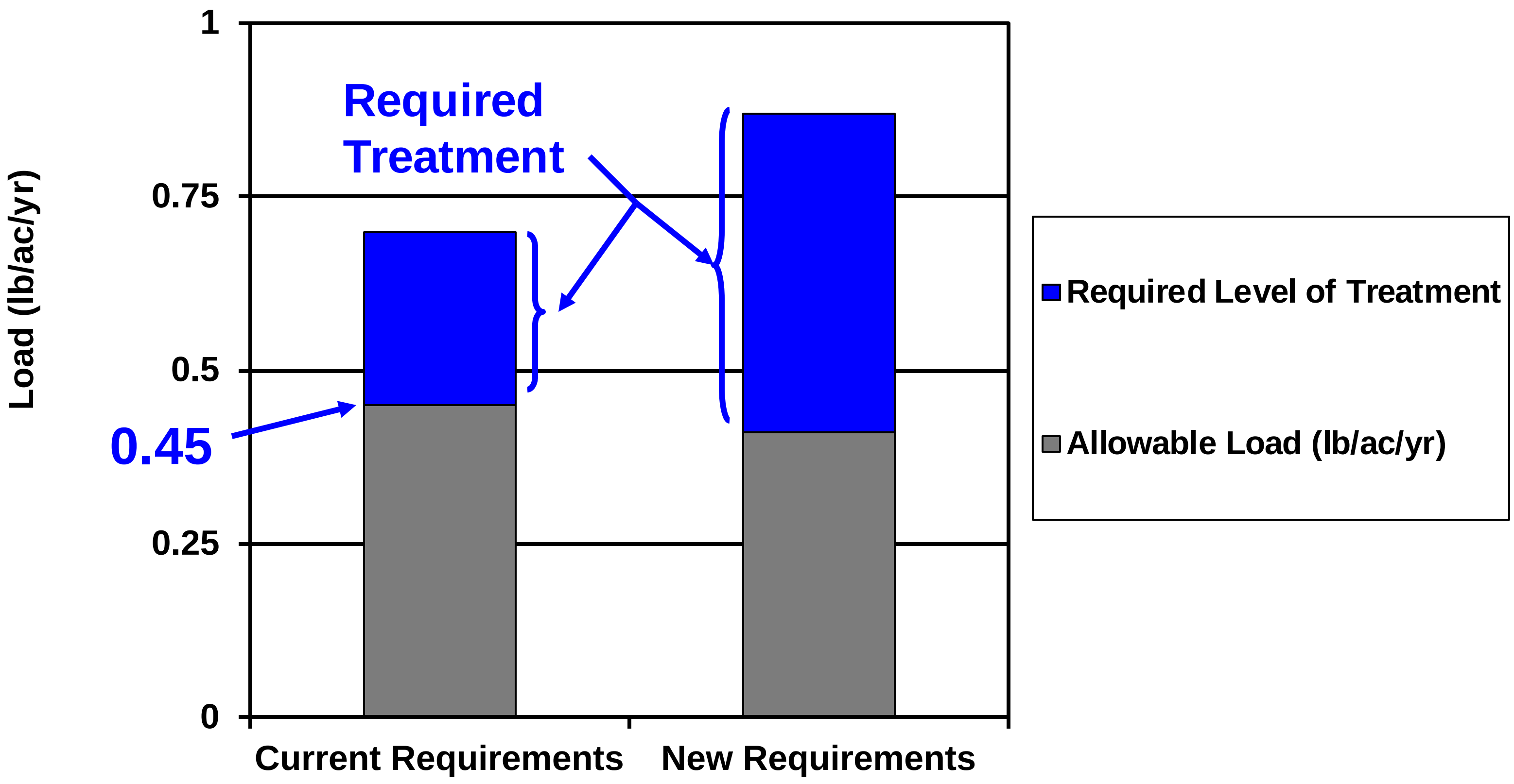
- Opportunities
  - Buffer Enhancement
  - Reforestation/ Afforestation
  - Channel and Wetland restoration/ enhancement
  - Soil amendments/restoration
- All have measurable effects of runoff characteristics, erosion, sed. transport

Stantec

Maintain Natural Drainageways (Floodplain Management & Protection)

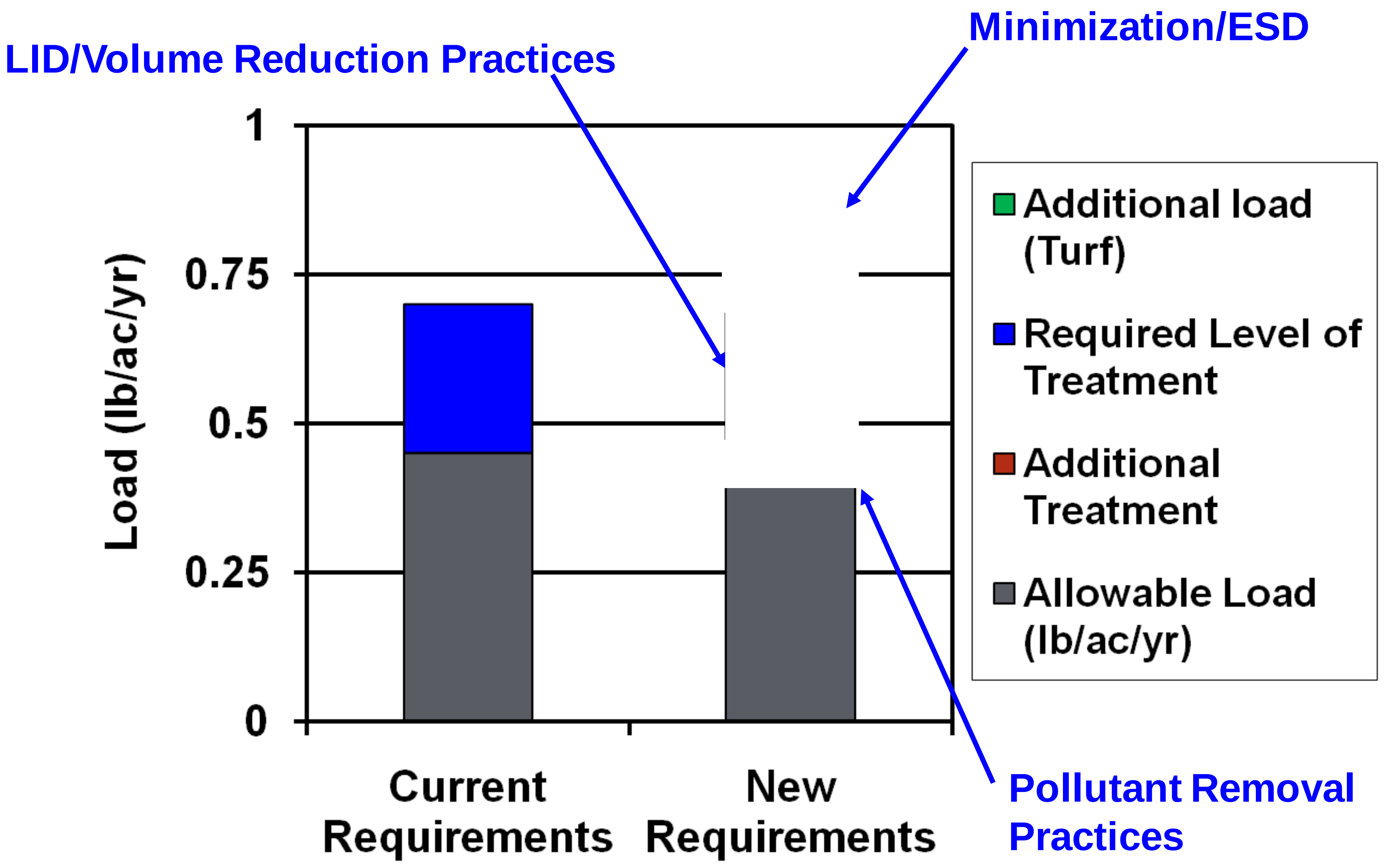
- Floodplain mapping and protection
- Floodplain Conveyance - relief culverts and open bottom crossings
- Floodplain Enhancements – reforestation, added flood conveyance, wetland creation, reconnection, removal of obstructions
- Natural Channel design – stable sediment transport

Water Quality - Treatment



Stantec

Treatment Options



Stantec

Stormwater Practices Differ Sharply in Ability to Reduce Runoff Volume

Wet Ponds, ED Ponds and Constructed Wetlands and Filters Reduce Runoff Volumes by zero to 10%

Bioretention, Infiltration, Dry Swales, Soil Amendments, disconnection, and Related Practices Reduce Runoff Volumes by 50 to 90%

Stantec

Practice	Design Level	Runoff Reduction	TN EMC Removal[3]	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal [6]
Rooftop Disconnect	*1 [2]*	*25 to 50 [1]*	*0*	*25 to 50 [1]*	*0*	*25 to 50 [1]*
	No Level 2 Design					
Sheet Flow to Veg. Filter or Conserv. Open Space	*1*	*50*	*0*	*50*	*0*	*50*
	2 [5]	*50 to 75 [1]*	*0*	*50 to 75 [1]*	*0*	*50 to 75 [1]*
Grass Channels	*1*	*10 to 20 [1]*	*20*	*28 to 44 [1]*	*15*	*24 to 41 [1]*
	No Level 2 Design					
Soil Compost Amendment	Can be used to Decrease Runoff Coefficient for Turf Cover at Site. See the design specs for Rooftop Disconnection, Sheet Flow to Vegetated Filter or Conserved Open Space, and Grass Channel					
Vegetated Roof	*1*	*45*	*0*	*45*	*0*	*45*
	2	*60*	*0*	*60*	*0*	*60*
Rainwater Harvesting	*1*	*Up to 90 [3, 5]*	*0*	*Up to 90 [3, 5]*	*0*	*Up to 90 [3, 5]*
	No Level 2 Design					
Permeable Pavement	*1*	*45*	*25*	*59*	*25*	*59*
	2	*75*	*25*	*81*	*25*	*81*
Infiltration Practices	*1*	*50*	*15*	*57*	*25*	*63*
	2	*90*	*15*	*92*	*25*	*93*
Bioretention Practices	*1*	*40*	*40*	*64*	*25*	*55*
	2	*80*	*60*	*90*	*50*	*90*
Urban Bioretention	*1*	*40*	*40*	*64*	*25*	*55*
	No Level 2 Design					
Dry Swales	*1*	*40*	*25*	*55*	*20*	*52*
	2	*60*	*35*	*74*	*40*	*76*
Wet Swales	*1*	*0*	*25*	*25*	*20*	*20*
	2	*0*	*35*	*35*	*40*	*40*
Filtering Practices	*1*	*0*	*30*	*30*	*60*	*60*
	2	*0*	*45*	*45*	*65*	*65*
Constructed Wetlands	*1*	*0*	*25*	*25*	*50*	*50*
	2	*0*	*55*	*55*	*75*	*75*
Wet Ponds	*1*	*0*	*30 (20) [4]*	*30 (20) [4]*	*50 (45) [4]*	*50 (45) [4]*
	2	*0*	*40 (30) [4]*	*40 (30) [4]*	*75 (65) [4]*	*75 (65) [4]*
Ext. Det. Ponds	*1*	*0*	*10*	*10*	*15*	*15*
	2	*15*	*10*	*24*	*15*	*31*

Stantec

Multi-Function Practices

	Site Design	Runoff Reduction	Pollutant Removal
1. Rooftop Disconnection	✓	✓	
2. Filter Strip	✓	✓	
3. Grass Channel		✓	✓
4. Soil Amendments	✓*	✓	
5. Green Roof		✓	
6. Rain Tanks & Cisterns		✓	
7. Permeable Pavement		✓	✓
8. Infiltration		✓	✓
9. Bioretention		✓	✓
10. Dry Swales		✓	✓
12. Filtering Practices			✓
13. Constructed Wetlands			✓
14. Wet Ponds			✓
15. ED Ponds		✓	✓

Tools in the Toolbox

1. Impervious Disconnection
2. Sheetflow to Conservation Area/Filter Strip
3. Grass Channels
4. Soils Compost Amendments
5. Vegetated Roofs
6. Rainwater Harvesting
7. Permeable Pavement
8. Infiltration
9. Bioretention (including Urban Bioretention)
10. Dry Swales
11. Wet Swales
12. Filtering Practices
13. Constructed Wetlands
14. Wet Ponds
15. Dry Extended Detention Ponds

Rooftop/Impervious Area Disconnection

Simple Disconnection

Rainwater Harvesting & Cisterns;

Micro-Infiltration (dry wells);

Rain Gardens Urban Planter

Stantec

Sheet Flow to a Vegetated Filter Strip or Conserved Open Space

Filter Strip & Open Space Design Criteria

Design Issue	Conserved Open Space	Vegetated Filter Strip
Soil and Vegetative Cover (Sections 6.1 and 6.2)	Undisturbed soils and native vegetation	Amended soils and dense turf cover or landscaped with herbaceous cover, shrubs, and trees
Overall Slope and length (parallel to the flow) (Section 5)	0.5% to 3% Slope – Minimum 35 ft length 3% to 6% Slope – Minimum 50 ft length The first 10 ft. of filter must be 2% or less in all cases [2]	1% [1] to 4% Slope – Minimum 35 ft. length 4% to 6% Slope – Minimum 50 ft. length 6% to 8% Slope – Minimum 65 ft. length The first 10 ft. of filter must be 2% or less in all cases
Contributing Area of Sheet Flow (Section 5)	Maximum flow length of 150 ft. from adjacent pervious areas; Maximum flow length of 75 ft. from adjacent impervious areas	
Level Spreader for dispersing Concentrated Flow (Section 6.3)	Length of ELS [6] Lip = 13 lin. ft. per each 1 cfs of inflow if area has 90% Cover [3] Length = 40 lin. ft. per 1 cfs for forested or re-forested Areas [4] (ELS [6] length = 13 lin.ft. min; 130 lin.ft. max.)	Length of ELS [6] Lip = 13 lin.ft. per each 1 cfs of inflow (13 lin.ft. min; 130 lin.ft. max.)
Construction Stage (Section 8)	Located outside the limits of disturbance and protected by ESC controls	Prevent soil compaction by heavy equipment
Typical Applications (Section 5)	Adjacent to stream or wetland buffer or forest conservation area	Treat small areas of IC (e.g., 5,000 sf) and/or turf-intensive land uses (sports fields, golf courses) close to source
Compost Amendments (Section 6.1)	No	Yes (B, C, and D soils) [5]
Boundary Spreader (Section 6.3)	GD [6] at top of filter	GD [6] at top of filter PB [6] at toe of filter

[1] A minimum of 1% is recommended to ensure positive drainage.

[2] For Conservation Areas with a varying slope, a pro-rated length may be computed only if the first 10 ft. is 2% or less.

[3] Vegetative cover is described in **Section 6.2**.

[4] Where the conserved open space is a mixture of native grasses, herbaceous cover and forest (or re-forested area), the length of the ELS [6] Lip can be established by computing a weighted average of the lengths required for each vegetation type. Refer to **Section 6.3** for design criteria

[5] The plan approving authority may waive the requirement for compost amended soils for filter strips on B soils under certain conditions (see **Section 6.1**).

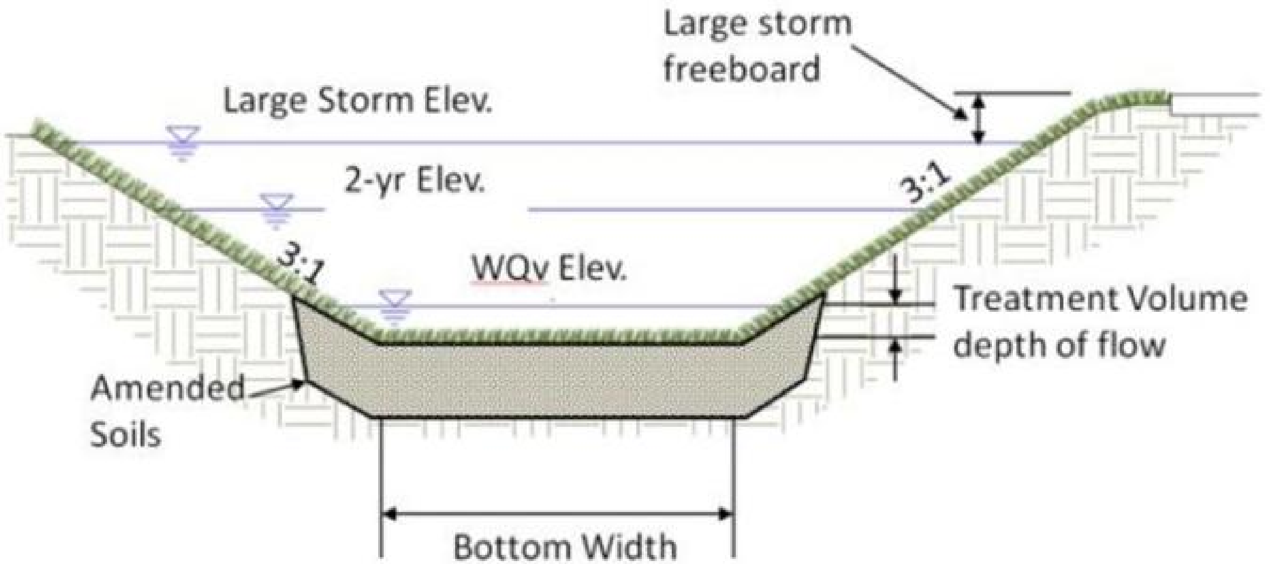
[6] ELS = Engineered Level Spreader; GD = Gravel Diaphragm; PB = Permeable Berm.

Soil Amendments

Grass Channels

Key Design Consideration: Soils

- Infiltration is greatest in HSG A soils;
- Infiltration gradually decreases in HSG B, C and D soils;
- HSG C and D soils lining the bottom of the Grass Channel can be amended to improve performance



Stantec

Permeable Pavement

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)

Stantec

Bioretention

Summary of Stormwater Functions[1]

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR)	40%	80%
Total Phosphorus (TP) EMC Reduction[1] by BMP Treatment Process	25%	50%
Total Phosphorus (TP) Mass Load Removal	55%	90%
Total Nitrogen (TN) EMC Reduction[1] by BMP Treatment Process	40%	60%
Total Nitrogen (TN) Mass Load Removal	64%	90%
Channel and Flood Protection	• Use the Virginia Runoff Reduction Method (VRRM) Compliance Spreadsheet to calculate the Curve Number (CN) Adjustment *OR* • Design extra storage (optional; as needed) on the surface, in the engineered soil matrix, and in the stone/underdrain layer to accommodate a larger storm, and use NRCS TR-55 Runoff Equations[2] to compute the CN Adjustment.	

[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)

Stormwater Quantity Analysis Considering Volume

Treatment Volume & BMP Sizing

$$Tv_{BMP} = \frac{(P \times Rv_{composite} \times A)}{12}$$

Where:

Tv_{BMP} = Design Treatment Volume from the contributing drainage area to the stormwater practice (does not include remaining runoff from upstream practices)

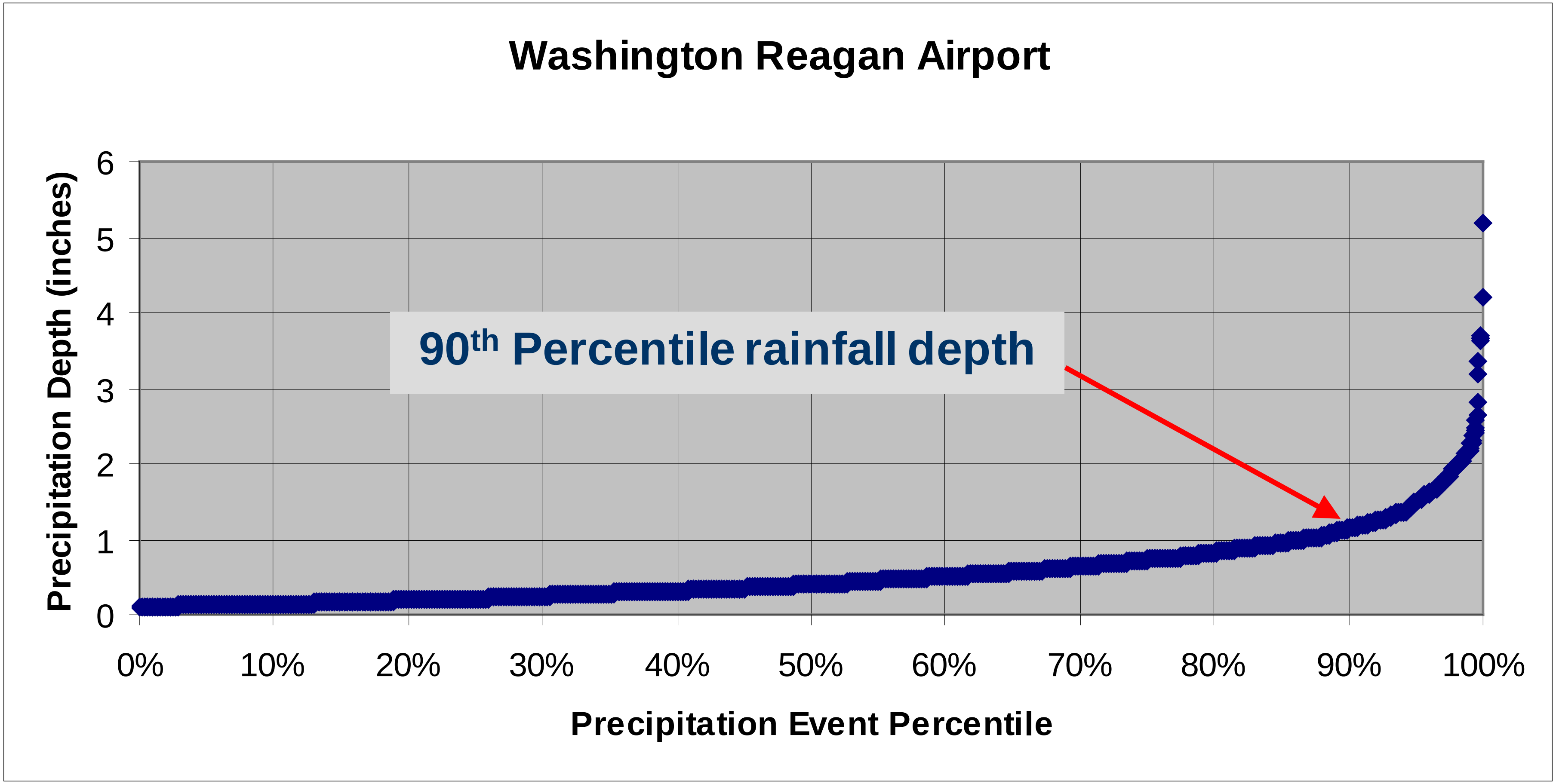
P **= 90th Percentile rainfall depth = 1"**

$Rv_{composite}$ = Composite runoff coefficient

A = Contributing drainage area to the stormwater practice.

Stantec

Design Rainfall = 90th percentile rainfall depth = 1”



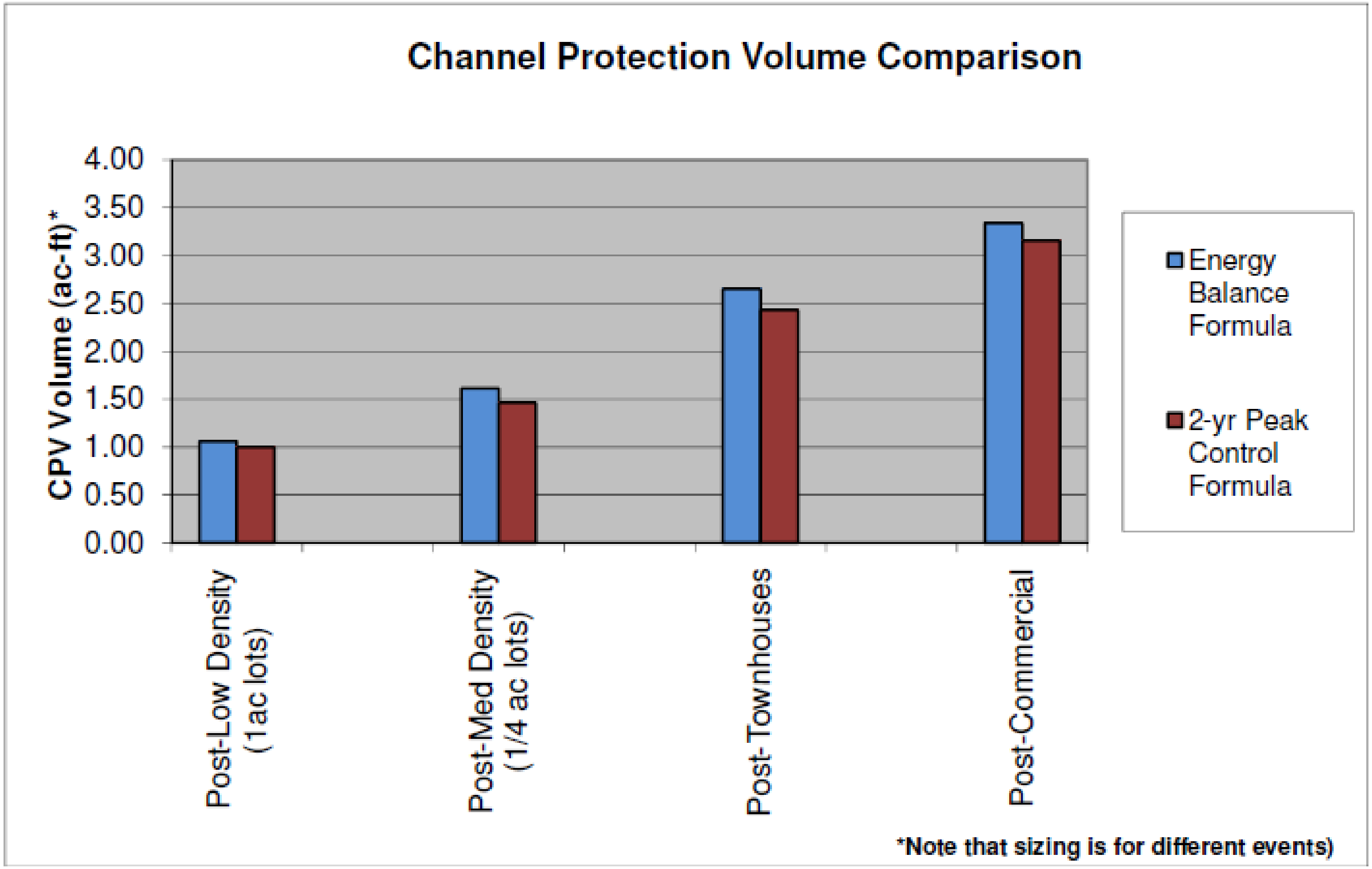
1” annual average: Washington Reagan Airport, Richmond Airport, Harrisonburg, Lynchburg, Bristol

Small Storm Hydrology

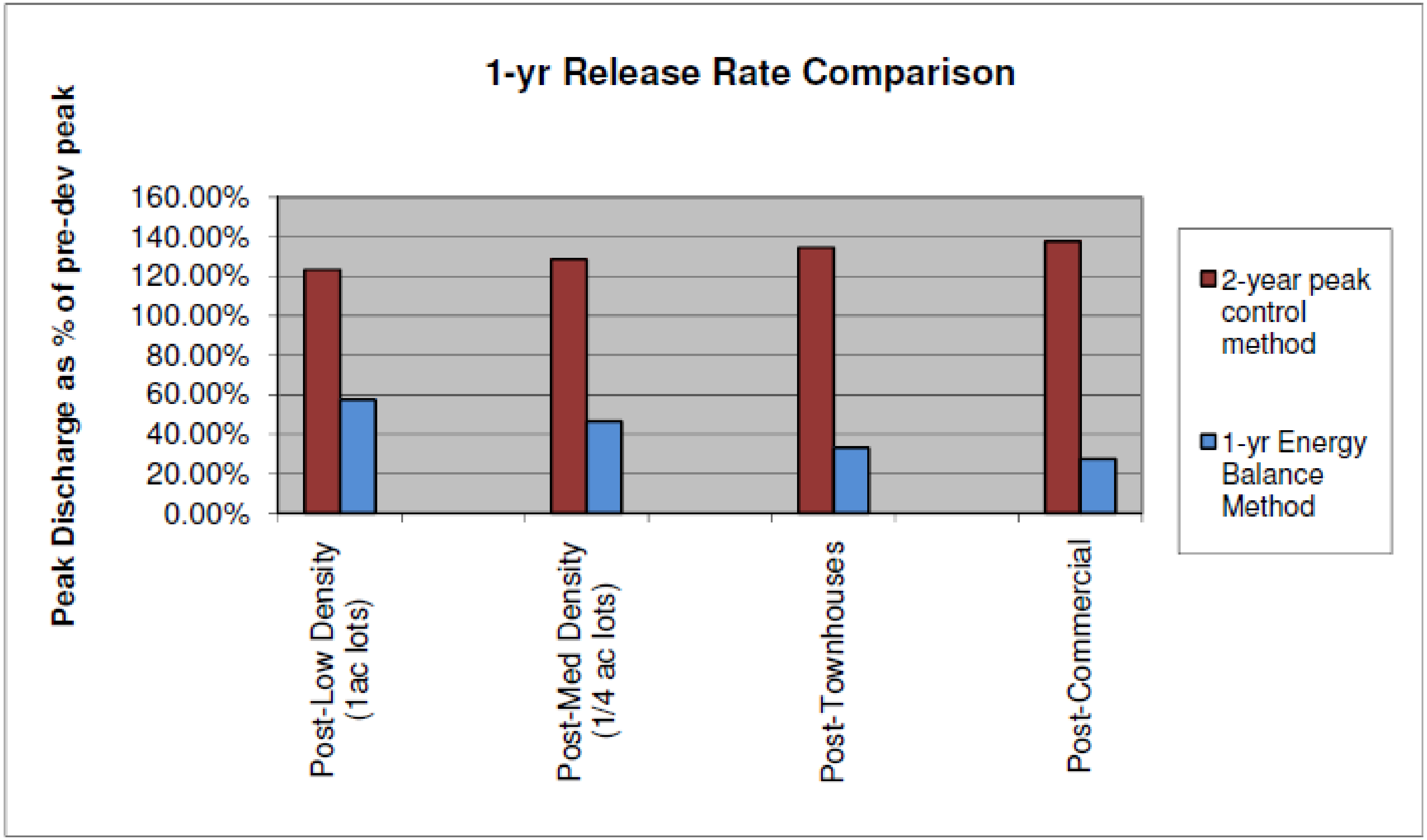
- Volume Management focused on small storms
- Focus is on minimizing increases in stream power and energy
- Replicating depressional storage and abstraction from natural watersheds

Stantec

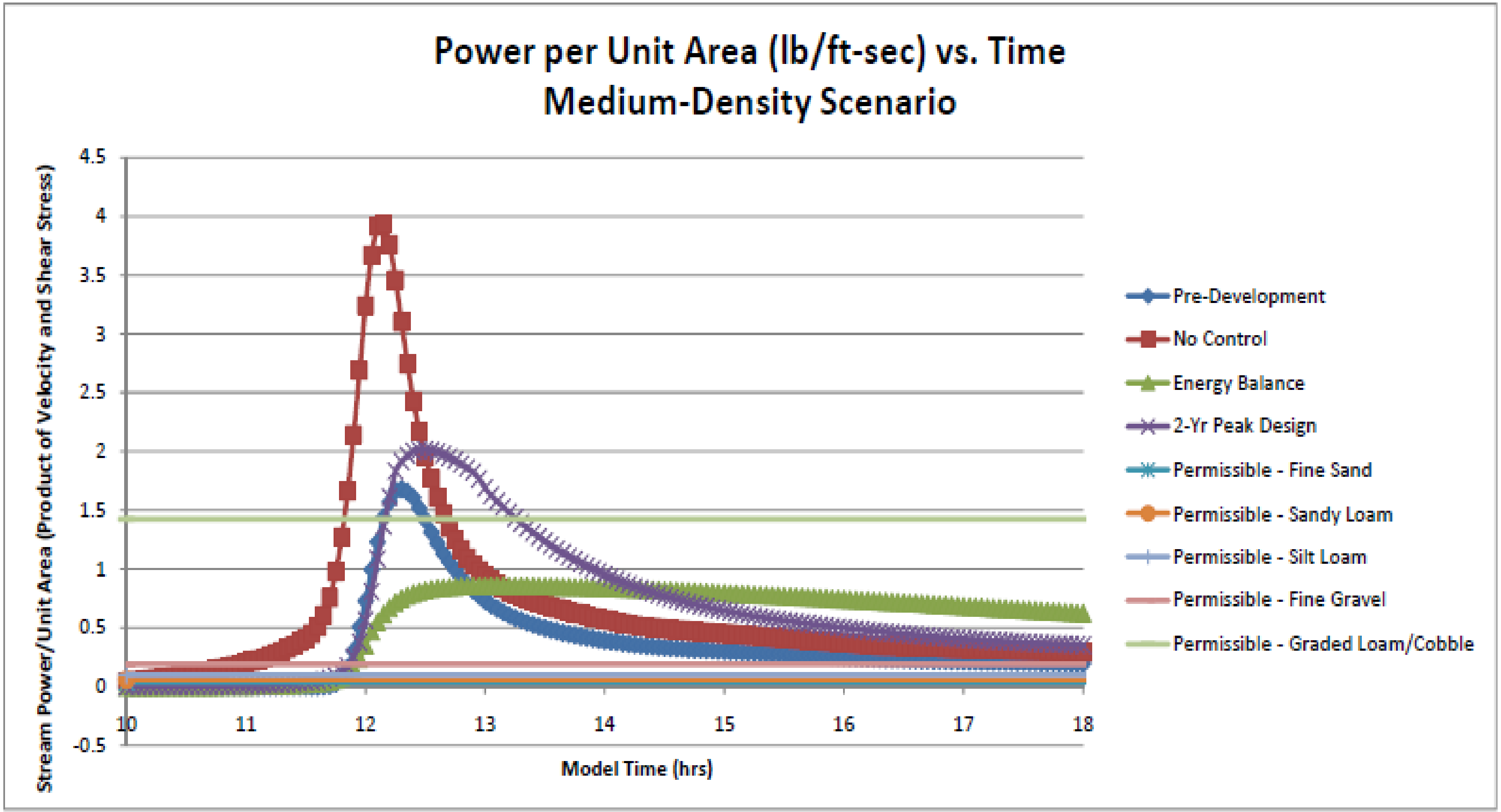
Sizing Comparison *(+ 5-10%)*



Release Rate Comparison



Stream Power Comparison



Challenge

- Provide quantity “credit” for distributed retention practices
- Avoid Complex routing/modeling
- Allow designers to target volume as a primary metric (quantity and quality)
- Various methods explored

Table 4. Review of Recent Research on Volumetric Runoff Reduction by LID Practices		
LID Practice	**% Runoff Reduction**	Reference
Bioretention	99	Dietz and Clausen (2006)
Bioretention	58	Seters et al (2006)
Bioretention	98	Rushton (2002)
Bioretention	50	Hunt et al (2006)
Bioretention	40 to 60	Smith and Hunt (2007)
Bioretention	75	Ballestro et al (2006)
Bioretention	80	Traver et al (2006)
Bioretention	73	Lloyd et al (2002)
Biofiltration Swale	98	Horner et al (2003)
Biofiltration Swale	94	Jefferies (2004)
Bioflitration Swale	46 to 54	Stagge (2006)
Permeable Pavement	75	Rushton (2002)
Permeable Pavement	99	Seters et al (2006)
Permeable Pavement	95 to 97	Traver et al (2006)
Permeable Pavement	60 to 90	Hunt and Lord (2006)
Permeable Pavement	50	Jefferies (2004)
Rainwater Harvesting	60 to 90	Coombes et al (2004)

Volume Reduction: Hydrograph Modification

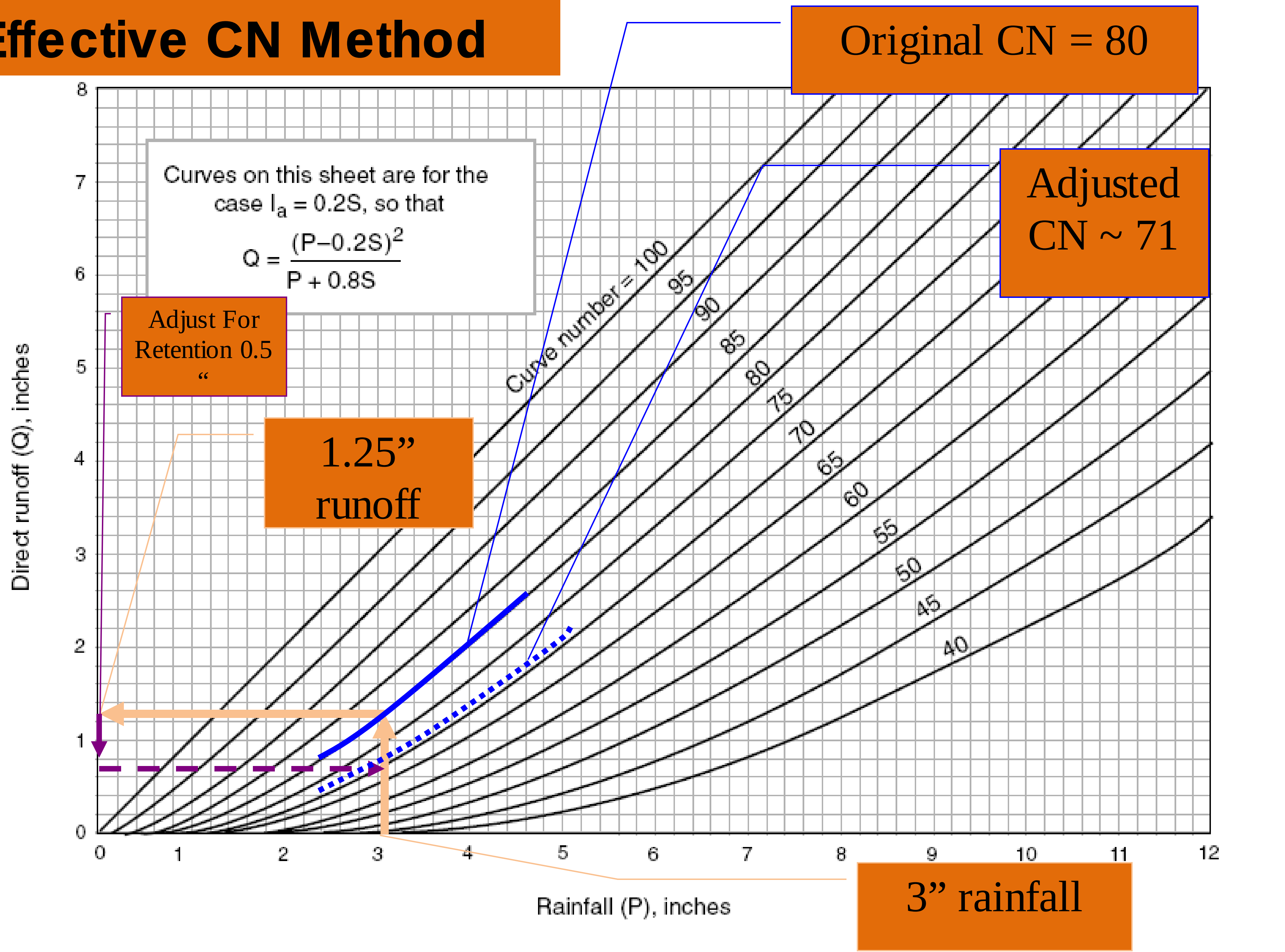
Objective: Account for hydrologic effect of distributed retention storage;

Simplifying Assumptions:

- Assume retention is uniformly distributed if considering multiple features or sub-areas;
- Assume negligible discharge from under-drains (if any)

Stantec

Effective CN Method



Site Parameters:~39 Ac, Pre-CN=70, Post-CN=80, Lag time = 20 min(pre/post)

Design Approach	Original CN	Adjusted $CN_{(1\text{-year})}$	Runoff (in)	Add'l Detention Storage Req'd (ft^3)	Treatment Approach
Conventional Design	80	80	1.25	73000	Treat with 2 acre wet pond
LID Practices	80	75	0.95	37000	Bioretention, Grassed Channels w/ soil amendments
Better Site Design with LID	80	73	0.85	28000	Reduce Impervious Cover, Reduce Turf Acreage + above
Pre-Development	70	N/A	0.71	N/A	N/A

Stantec

	Recurrence Interval		
	1-yr	2-yr	10-yr
Total Rainfall (in)	2.6	3.5	5.6
Pre-dev CN	70	70	70
Pre-Dev Runoff (in)	0.50	1.01	2.49
Post-Dev CN	80	80	80
Runoff (in.)	0.96	1.64	3.43
Runoff Reduction Vol. (in.)	0.27	0.27	0.27
Net Runoff (w/ RRM, in)	0.69	1.37	3.16
CN Adjusted for RRM	75	76	77
% Redux In Runoff Volume	28.0%	16.4%	7.9%

Questions?

Doug Beisch - Principal
Doug.Beisch@Stantec.com
757-810-2687

Special Thanks to the **Center for Watershed Protection** for helping to organize training materials for Stantec and the Virginia DEQ. Most figures/images sourced from Virginia DEQ training materials compiled by Stantec and CWP.

Stantec