MIDS Work Group Meeting
May 20, 2010

Credit Calculations and Calculator Functions

Today's Goals
The Foundation for the Credits & Calculator

- Discuss proposed calculations
  - Performance goal requirement
  - Volume reductions provided by various BMPs
  - Pollutant reductions provided by various BMPs
- Receive feedback and validation
  - Calculation methods
  - Ideas for encouraging innovative stormwater management while providing realistic credits

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Future Topics

- Alternative Compliance/Performance Goals for:
  - Linear sites
  - Redevelopment sites
  - Sites with restrictions
- Fine Tune Pollutant and Volume Reduction Estimates
- Definitions
- Triggers

Background:
Consensus on Performance Goal from April Work Group Meeting

"For new, nonlinear developments that create more than one acre of new impervious surface on sites without restrictions, stormwater runoff volumes will be controlled and the post-construction runoff volume shall be retained on site for 1.1 inches of runoff from impervious surfaces statewide."

Two primary functions of credit calculator:

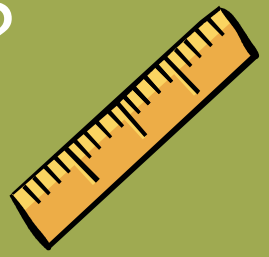
- Quantify the performance goal requirement
  - How much volume must be retained?
  - How many pounds of pollutants are removed annually (for alternative compliance, TBD)
- Determine if project meets performance goal
  - How much volume is retained?
  - How many pounds of TSS and TP are removed on an average annual basis?

Challenge

- Performance goal is not tied to a timeframe
  - "…1.1 inches of runoff from impervious surfaces"
- However, Work Group wants to know the pounds of TP and TSS removed annually
- Need to make a connection

Calculator Function 1A: Determine Volume Requirement

- How much volume must be retained?



1.1 inch **X**  = Required Retention Volume

Calculator Function 1B: Determine Pollutant Removal Requirement

- For non-restricted sites, conformance to volume requirement achieves pollutant removal requirement; no additional requirement needed

% Imperviousness	% Removal	
	TP	TSS
10	78%	90%
30	92%	97%
50	95%	98%
70	96%	99%
90	96%	99%

Removal percentages for 10-acre site with B soils and bioretention basin sized for 1.1" times the proposed impervious surface area

Calculator Function 1B: Determine Pollutant Removal Requirement (Phase 2)

- Linear and redeveloped sites and sites with restrictions – requirement to be determined

Site	Soil				Restrictions
	A	B	C	D	Karst, bedrock, groundwater, etc.
New Residential	X	X	X		
New Commercial/Industrial	X	X	X		
New Linear					
Redeveloped Residential					
Redeveloped Commercial/Industrial					
Redeveloped Linear					
Redeveloped Ultra Urban					
Potential Stormwater Hotspots					

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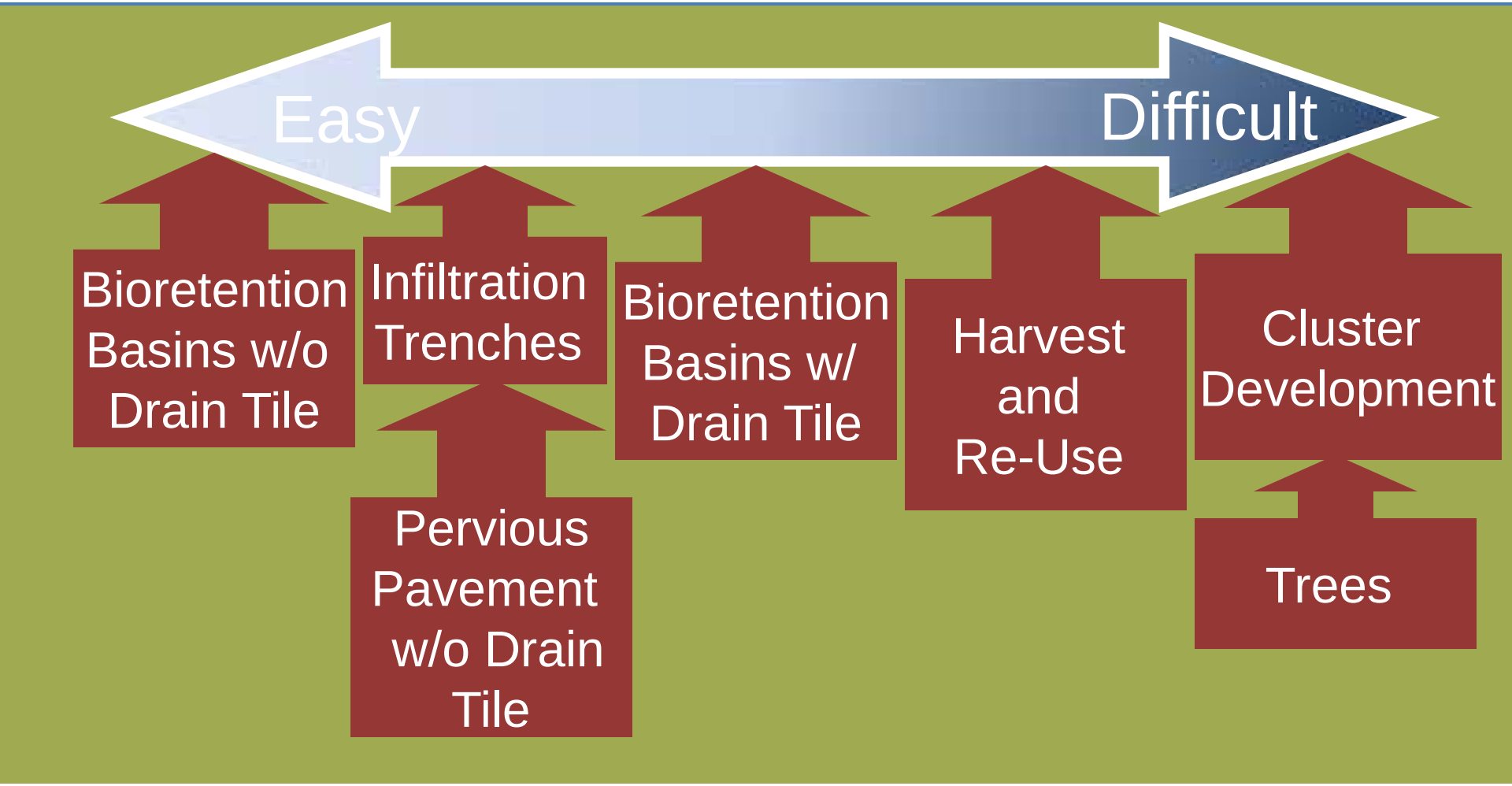
Calculator Function 2: Determine Volume Retained by BMPs

Quantifying Reductions in Volumes from BMPs



Some Easy to Quantify Volume-Reducing BMPs

- Bioretention basins/rainwater gardens*
- Infiltration trenches
- Pervious pavement*
- Underground infiltration
- Dry swales*
- Green roofs

*without drain tile

Some More Difficult to Quantify Volume-Reducing BMPs

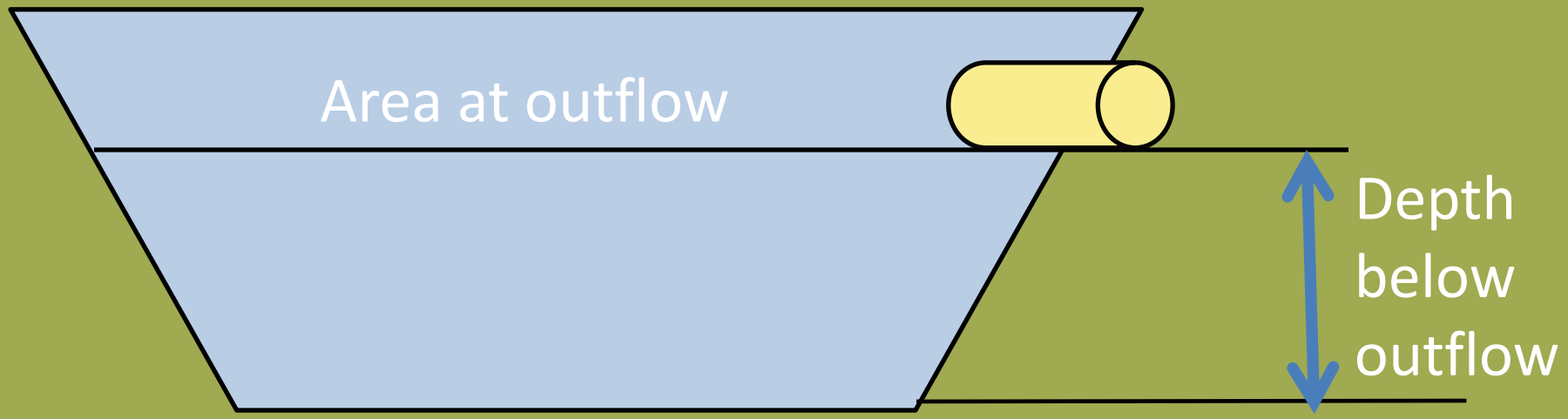
- Harvest/re-use
- Filter strips
- Grass channels
- Infiltration shelves (e.g., shelves at wet ponds)
- Trees/urban forestry
- Cluster development
- Enhanced operations

Methods to Determine Volume Retention

- Calculate volume for easy-to-quantify BMPs
- Use reported average reduction percentages for harder-to-define BMPs

Example:

Easy-to-Quantify BMP Volume Calculation
Bioretention basin without drain tile



Bottom surface area & Underlying soil type

Example:

Easy-to-Quantify BMP Volume Calculation
Bioretention basin without drain tile

Parameter	Inputs Example
Bottom Surface Area (square feet)	1500
Area at Outflow (square feet)	1900
Depth below Outflow (feet)	1.1
Underlying Soil Type	B - SM

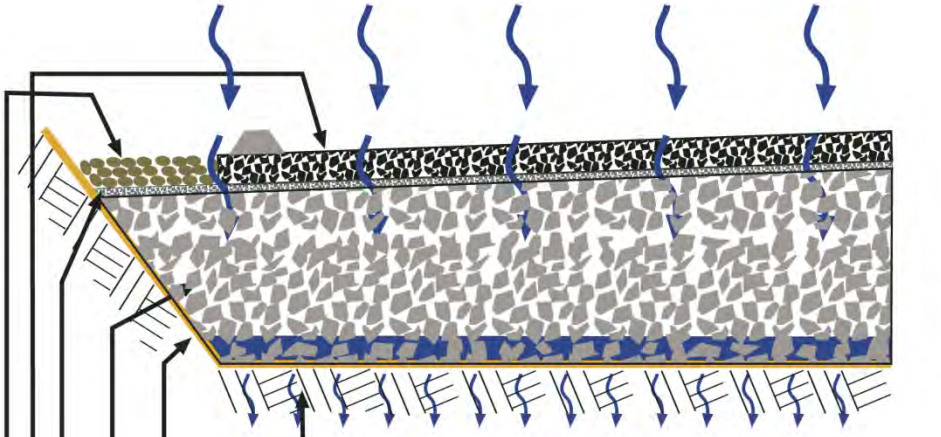
Example:

Easy-to-Quantify BMP Volume Calculation

Bioretention basin without drain tile

Parameter	Output Example
Infiltration Rate (inches/hour)	0.6
Drain Dry Time (hours)	22
Drains Dry Within Required Time	Yes
Volume Retained (cubic feet)	1870

Example:
Easy-to-Quantify BMP volume calculation
Porous pavement



Uncompacted Subgrade - Keeps permeability high to allow as much infiltration as possible

Non-Woven Geotextile - Protects stone recharge bed above from contamination and allows water to flow through to the soil.

Stone Recharge Bed - Heart of system. Large, single size, crushed stone with 40% voids stores storm water for infiltration.

Choker Course - Single size crushed aggregate (1/2-inch) stabilizes surface for paving.

Open-Graded Asphalt Pavement - An open-graded asphalt mix with that is porous, allowing storm water to flow through surface into stone recharge bed.

Unpaved Stone Edge - A backup system in case the pavement surface should ever become sealed. Storm water can flow off pavement surface to stone edge and into stone recharge bed.

Source: National Asphalt Pavement Association

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Example:
Easy-to-Quantify BMP volume calculation
Porous pavement

Parameter	Inputs Example
Porosity of media/stone recharge bed (ft^3/ft^3)	0.4
Width (ft)	32
Length (ft)	100
Depth (ft)	1
Underlying soil type	B-SM

Example:
Easy-to-Quantify BMP Volume Calculation
Porous pavement

Parameter	Output Example
Infiltration Rate (inches/hour)	0.6
Drain Dry Time (hours)	22
Drains Dry Within Required Time	Yes
Volume Retained (cubic feet)	1280

Example:
More Difficult to Quantify BMP Volume Reduction
Grass Channel

- Use values reported in literature
- Reduce volume conveyed through grass channel by 10%

BMP	Volume Reduction %
Bioretention/Rainwater Garden	Calculate
Biofiltration	40%*
Infiltration Basin/Trench	Calculate
Permeable Pavement	Calculate
Grass Channel	10%
Dry Swale	40 or 60%*
Wet Swale	0%
Filter Strips	25-50%
Sand Filters	0%
Green Roofs	Calculate
Wet Pond	0%
Infiltration Shelf at Wet Pond	0%?

Calculator Function Summary (so far)

- Function 1:
  - Determine Volume Retainage Requirement
  - Determine Pollutant Reduction Requirement
    - Achieving volume retainage, conforms to pollutant reduction requirement
    - Phase 2 will determine performance goal for other sites/alternative compliance
- Function 2:
  - Determine Proposed Volume Retainage

Calculator Function 3: Determine the pollutant load reductions from BMPs

Making the Connection:
Performance Goal to Pollutant Removal

- Volume control performance goal is SIMPLE

1.1 inch **X**  **=** Required Retention Volume

- Goal not time dependent (instantaneous)
  - BMP must retain required volume whether it occurs in ½-hour or 12 hours

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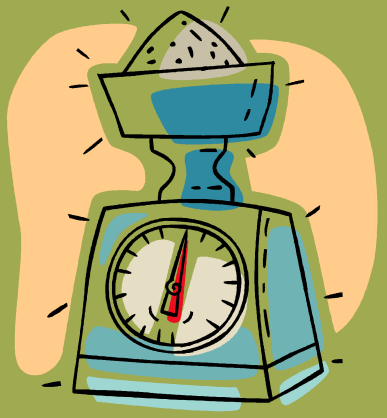
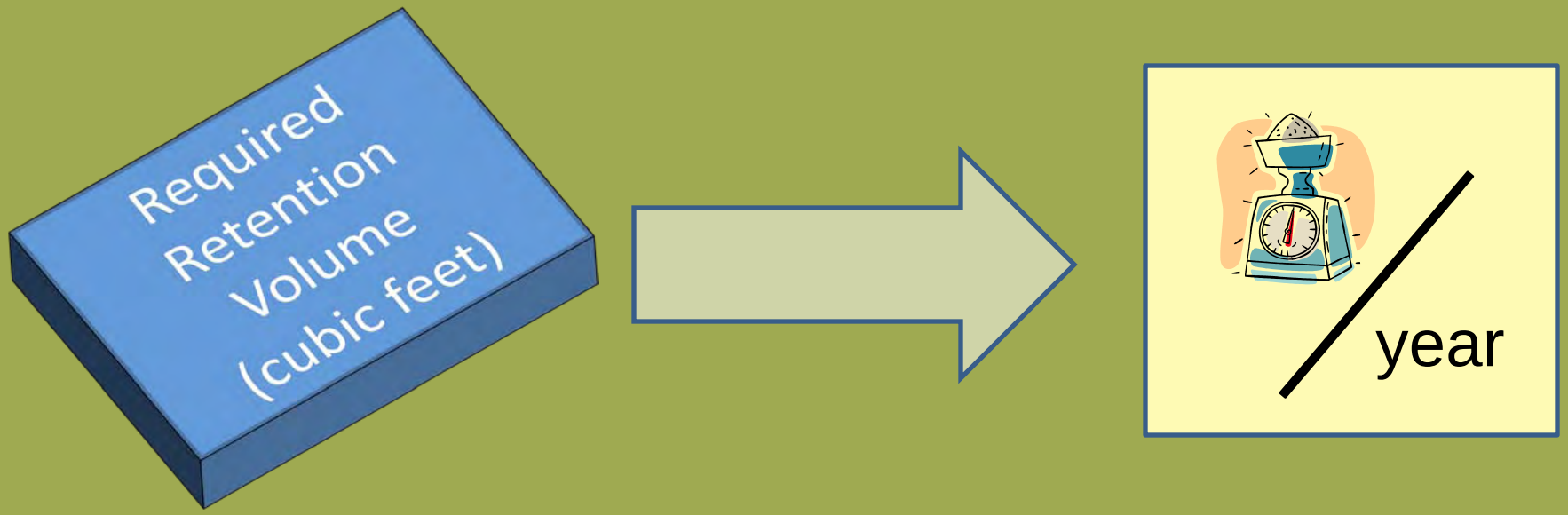
Making the Connection:
Performance Goal to Pollutant Removal

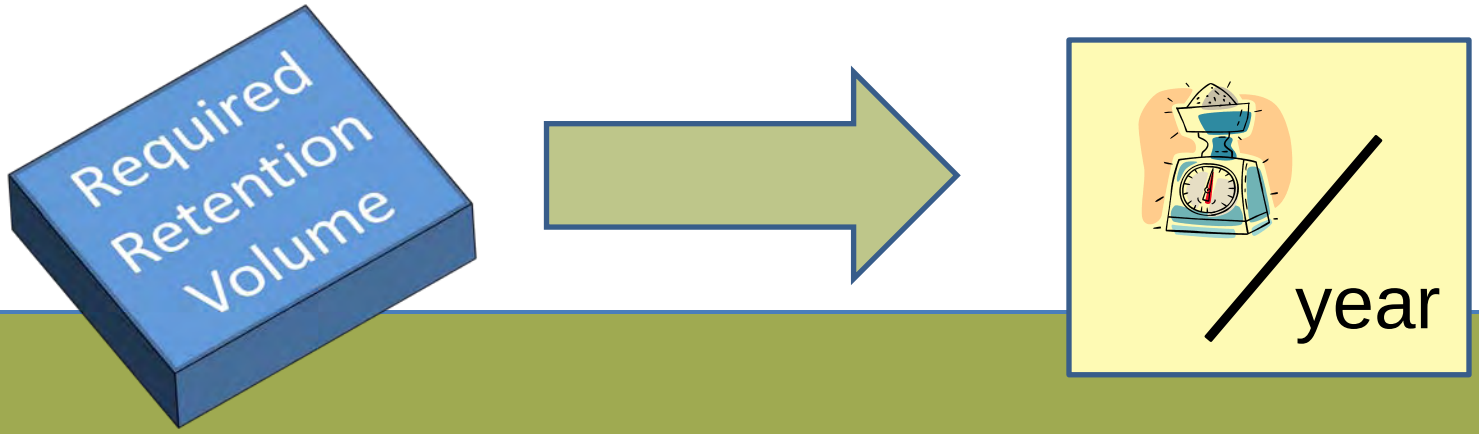
- Work Group wants calculator to determine pollutant load reduction on an annual basis

- TP and TSS removal to be reported in pounds per year



Challenge:
How to make the connection?

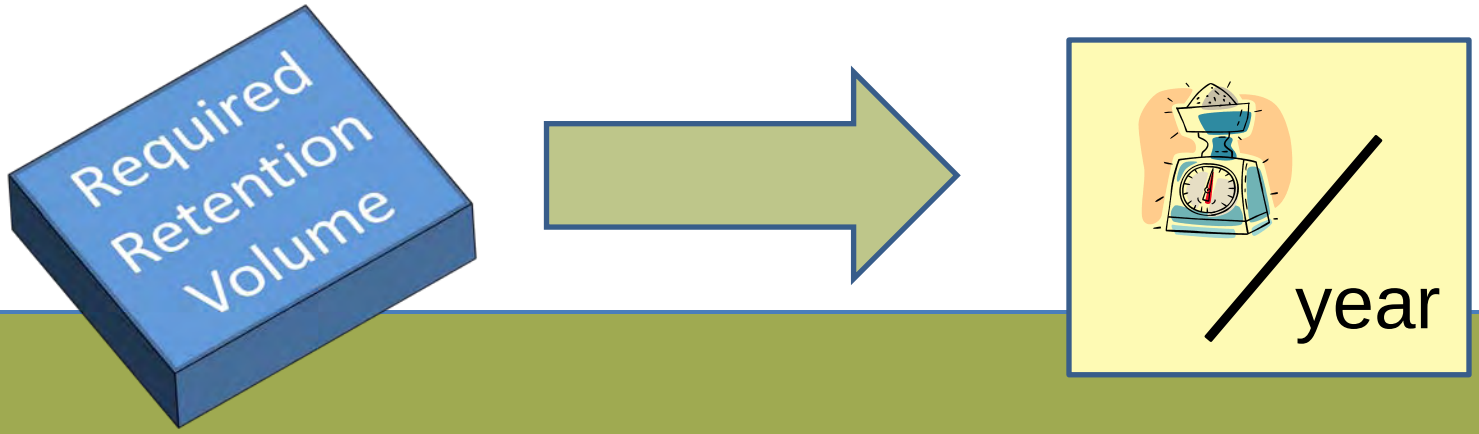




1. Use “Simple Method” to Calculate Annual Pollutant Load from Site (w/o BMP)

2. Estimate Pollutant Removal (%) from BMP(s)

3. Apply Pollutant Removal % to Annual Load to Determine Annual Pollutant Load Reduction



1. Use “Simple Method” to Calculate Annual Pollutant Load from Site (w/o BMP)

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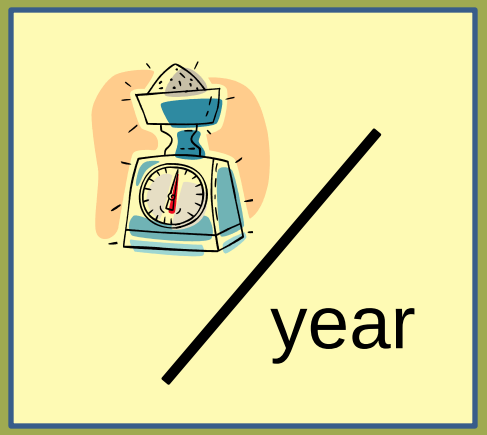
Pollutant Loading Basics



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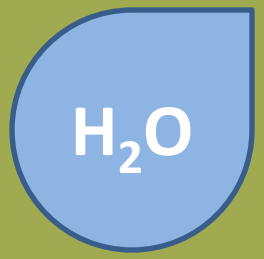


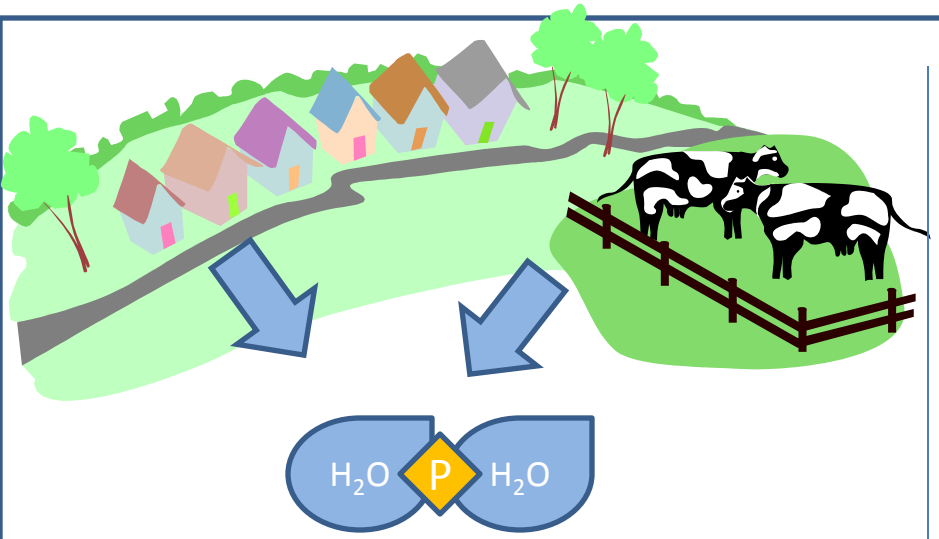
X

Pollutant Load [mass/time]

Runoff Volume

Pollutant Concentration

Can Decrease Pollutant Loading By Reducing Runoff Volume

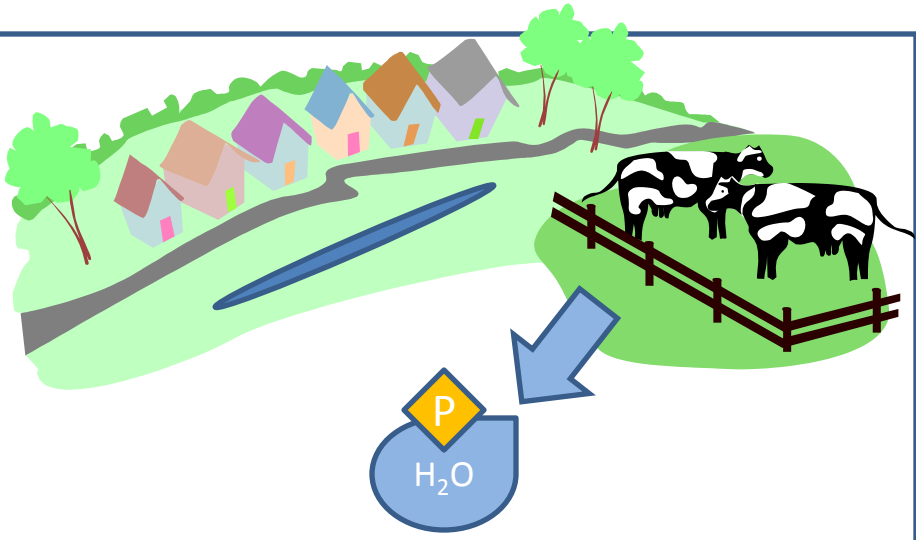


If P = 10 mg/L

and

= 2 Liters

Pollutant Load = 20 mg



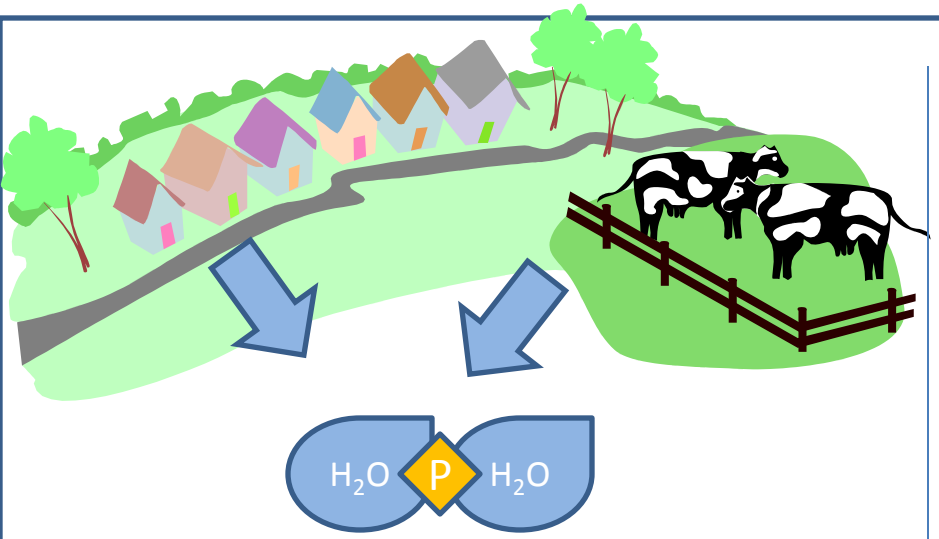
If P = 10 mg/L

and

= 1 Liter

Pollutant Load = 10 mg

Or Can Decrease Pollutant Loading By Reducing Pollutant Concentration

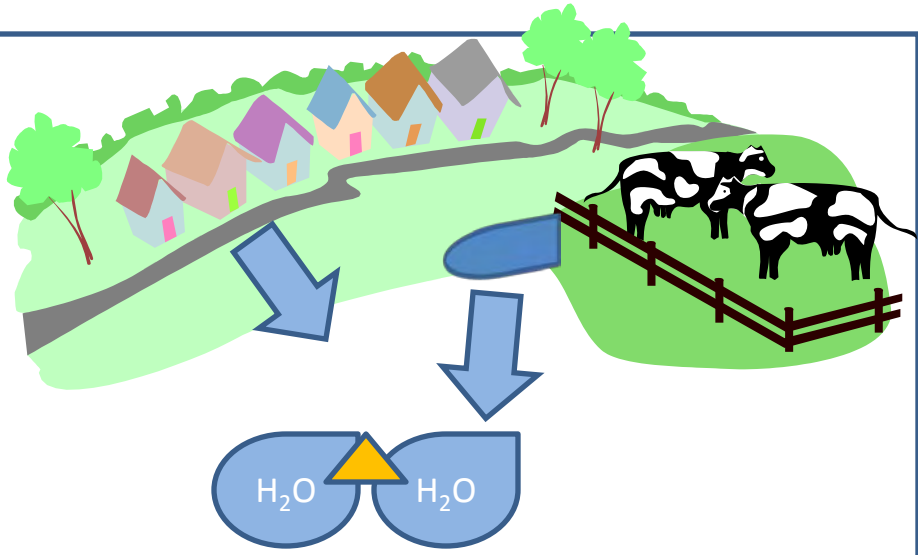


If P = 10 mg/L

and

= 2 Liters

Pollutant Load = 20 mg



If P = 5 mg/L

and

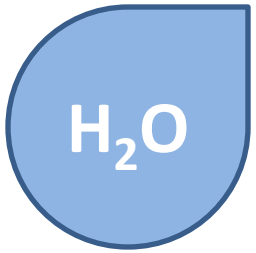
= 2 Liter

Pollutant Load = 10 mg

Calculating Annual Pollutant Load: The Simple Method

- Equation developed by Tom Schueler in 1987
- Estimates pollutant loads on an annual basis
- Requires easily obtainable data:
  - Annual precipitation
  - Watershed and imperviousness areas
  - Pollutant concentration

The Simple Method: Annual Runoff Volume



$$R = A^* P * P_j * R_v \div 12$$

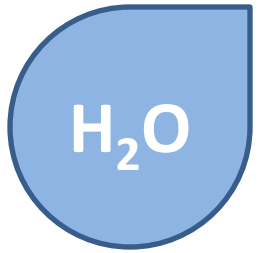
- R = Annual runoff (acre-feet)

The Simple Method: Annual Runoff Volume

$$R = A^* P * P_j * R_v \div 12$$

- R = Annual runoff (acre-feet)
  A = Drainage Area (acres)

The Simple Method: Annual Runoff Volume



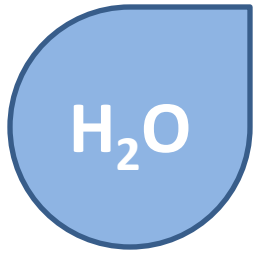
$$R = A^* P * P_j * R_v \div 12$$

R = Annual runoff (acre-feet)

A = Drainage Area (acres)

P = Annual rainfall (inches)

The Simple Method: Annual Runoff Volume



$$R = A^* P * P_j * R_v \div 12$$

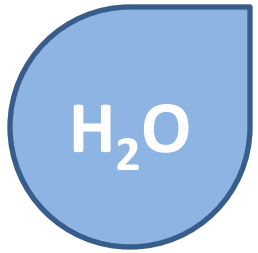
R = Annual runoff (acre-feet)

A = Drainage Area (acres)

P = Annual rainfall (inches)

P_j = Fraction of annual rainfall events that produce runoff (usually 0.9)

The Simple Method: Annual Runoff Volume



$$R = A^* P * P_j * R_v \div 12$$

- R = Annual runoff (acre-feet)
- A = Drainage Area (acres)
- P = Annual rainfall (inches)
- P_j = Fraction of annual rainfall events that produce runoff (usually 0.9)
- R_v = Runoff coefficient, which expresses the fraction of rainfall that is converted into runoff.

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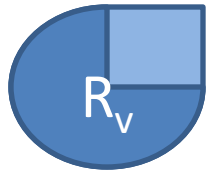
Runoff Coefficient (Rv): Fraction of rainfall that runs off



Simple Approach:

Rv = 0.05 + 0.009 *  %

Examples:

- For site with 20% impervious,

Rv = 0.05 + 0.009 * 20 = 0.23

- For site with 100% impervious,

Rv = 0.05 + 0.009 * 100 = 0.95

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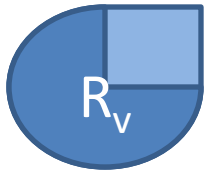
Runoff Coefficient (Rv): Fraction of rainfall that runs off



More Complex:

$= Rv_I *$  $\% + Rv_T *$  $\% + Rv_F *$ 

Where,

= % of site in Impervious Cover

= % of site in Turf Cover

= % of site in Forest Cover

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Treatment Volume: Site Runoff Coefficients (Rv)[1]

Cover	HSG A	HSG B	HSG C	HSG D
Forest	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

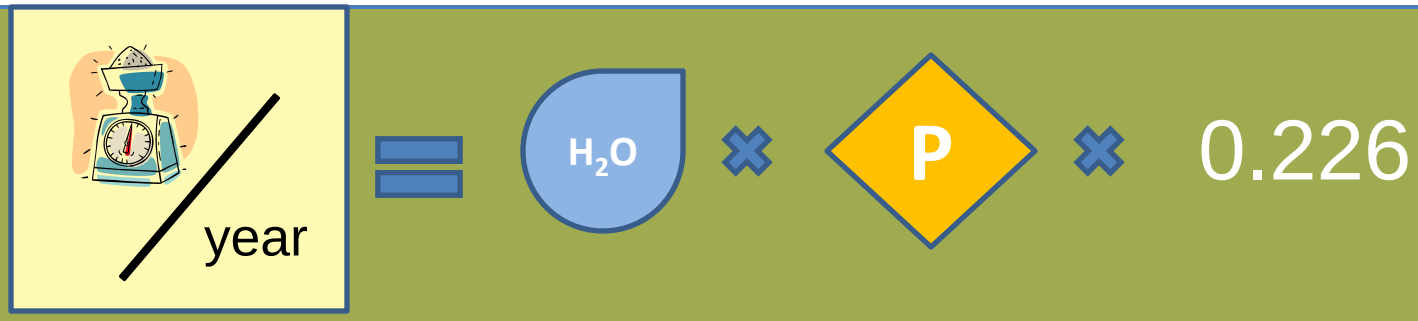
*Forest coefficient adjusted for assessing compliance

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)

So far, we've calculated the runoff volume entering the BMP

- Annual runoff volume

The Simple Method: Annual Pollutant Load



L = Annual pollutant load (lbs/year)

= Annual runoff volume (acre-feet)

= Pollutant concentration (mg/l)

0.226 = Unit conversion factor

What P should be used?

Event Mean Concentration (EMC)

- Average concentration of a pollutant in runoff for a monitored runoff event

The Simple Method: Total Phosphorus EMCs

Table 8.7 Typical Event Mean Concentrations for Total Phosphorus	
Land Cover/Land Use	**Total Phosphorus (mg/L)**
Cropland[1]	0.32
Forest/Shrub/ Grassland[1]	0.04
Open Water[1]	0.01
Wetlands[1]	0.01-0.04*
Freeways[2]	0.25
Commercial[1,2]	0.22
Farmsteads[1]	0.46
Industrial[1,2]	0.26
Residential[2]	0.30
Multi-Family Residential[1,2]	0.27-0.32
Park and Recreation[1]	0.04
Open Space[1,2]	0.31
Public/Semi Public (Institutional)[1,2]	0.18

- Typical EMCs often vary by land use
- MN Stormwater Manual *suggests* using 0.30 mg/L for Simple Method (Appendix L)

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The Simple Method: Total Suspended Solids EMCs

Land Cover/ Land Use	TSS (mg/L)
Residential	48
Commercial	43
Industrial	77
Institutional	17
Freeways	99
Open Space	51

Source: Robert Pitt, University of Alabama, 2003

The Simple Method
Full equation

$$L = [(P)(P_j)(R_v)/12] (C) (A) (2.72)$$

L = Load of pollutant (lbs/yr)

P = Rainfall depth per year (in)

P_j = Fraction of rainfall events that produce runoff

R_v = Runoff coefficient – expresses the fraction of rainfall which is converted to runoff (Rv = 0.05 + 0.009 * Imperviousness)

C = Flow-weighted mean concentration of pollutant in runoff (mg/l)

A = Site area (ac)

12 and 2.72 = unit conversions

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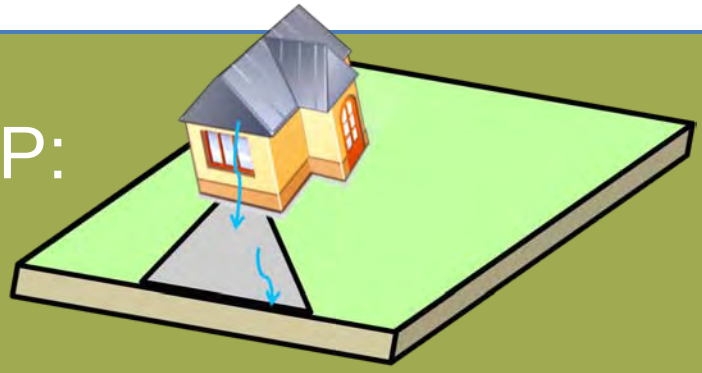
Use Simple Method to Calculate Pollutant Loading from Site



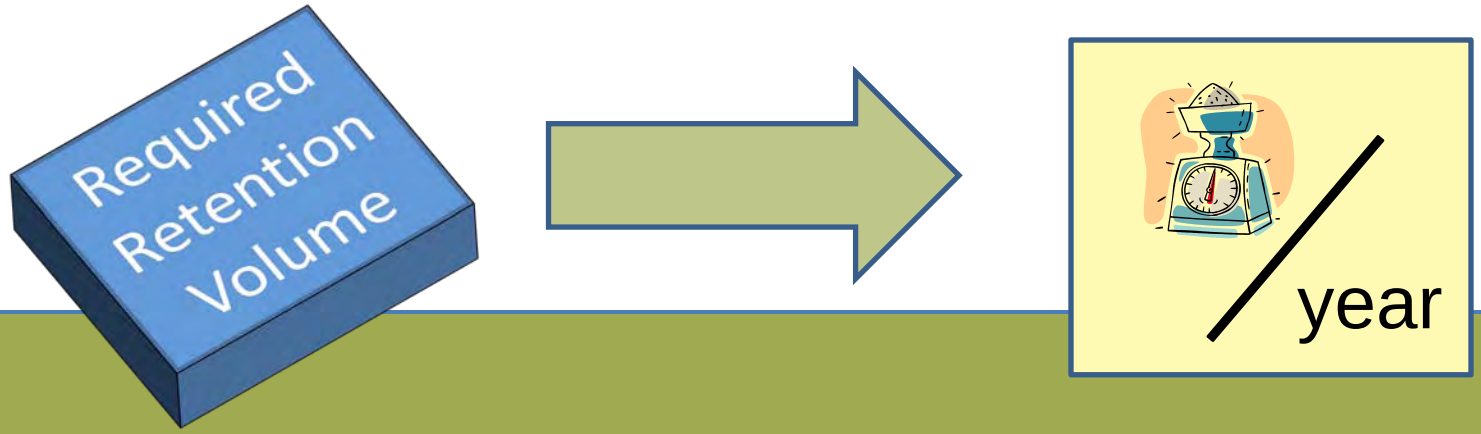
Loading Example from site w/o BMP:

Ten Acre Site, 30% Impervious

Annual Runoff Volume ~ 7 acre-feet

Total Phosphorus Loading = 5.8 lbs/year

Stretch and Re-Caffeinate



1. Calculate Annual Pollutant Load from Site (w/o BMP)

2. Estimate Pollutant Removal (%)

3. Apply Removal % to Annual Load to Determine Annual Pollutant Load Reduction

Calculating Pollutant Removal from Volume Control BMPs

- Pollutant removal primarily occurs through the reduction of volume
  - Infiltration
  - Interception
  - Evapotranspiration
  - Rainwater Harvesting

Calculating Pollutant Removal from Volume Control BMPs

- Assume 100% Pollutant Removal from Volume Retained
- For Volume NOT retained by BMP, assume 0% - 100% Pollutant Removal
  - Depending on BMP
  - Depending on if BMP is designed online or offline

Calculating Pollutant Removal from Volume Control BMPs

Total % Pollutant Removal $= \%RVR + [(100 - \%RVR) \times \%PR]$

Where,

%RVR = % Annual Runoff Volume Retained

%PR = % Pollutant Removal (as defined by change in EMC as runoff flows in and out of BMP)

Approach very similar to that used in Virginia Calculator

- Developed by the Center for Watershed Protection for the Chesapeake Stormwater Network and State of Virginia

Calculating Pollutant Removal from Volume Control BMPs

Total % Pollutant Removal $= \%RVR + [(100 - \%RVR) \times \%PR]$

Calculating Pollutant Removal from Volume Control BMPs: Example 1

BMP with 100% Runoff Volume Retained (RVR):

Total % Pollutant Removal

$$= \%RVR + \left[(100 - \%RVR) \times \%PR \right]$$

$$= 100\% + \left[(100 - 100) \times \%PR \right]$$

(100 - 100) → 0

$$= 100\%$$

Calculating Pollutant Removal from Volume Control BMPs: Example 2

BMP with NO volume reduction, but 75% pollutant removal (%PR):

Total % Pollutant Removal

$$= \%RVR + [(100 - \%RVR) \times \%PR]$$

$$= \cancel{\%RVR}^{\,0} + [(100 - 0\%) \times 75\%]$$

$$= 75\%$$

Calculating Pollutant Removal from Volume Control BMPs: Example 3

BMP with 60% runoff volume retention (%RVR), and 40% pollutant removal (%PR):

Total % Pollutant Removal

$$= \%RVR + [(100 - \%RVR) \times \%PR]$$

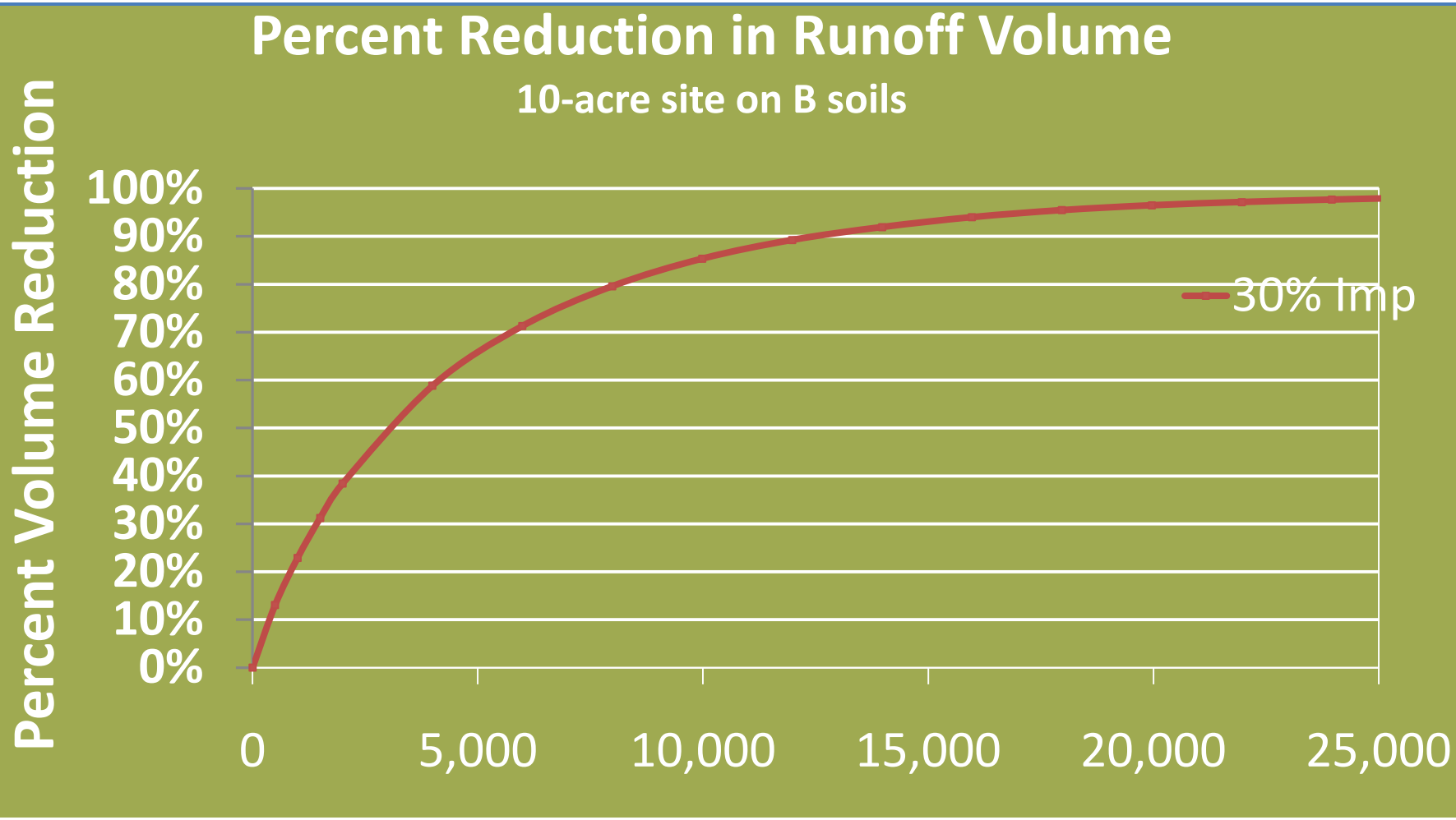
$$= 60\% + [(100 - 60\%) \times 40\%]$$

$$= 76\%$$

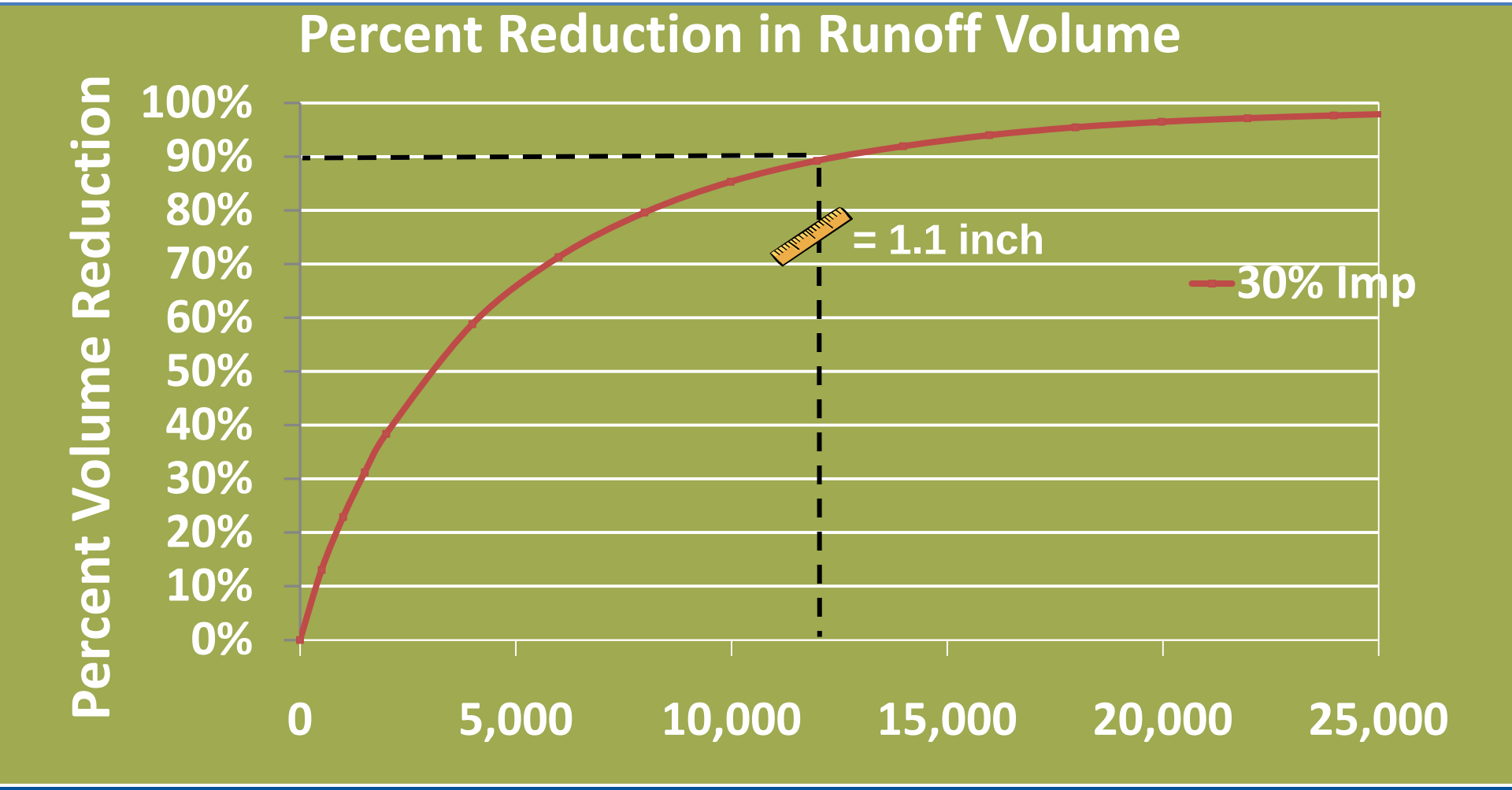
How will %RVR be calculated?

- Runoff volume retention varies with BMP size for most BMPs
- So, what is the relationship between BMP size and annual runoff volume removal?
  - Use performance curves for easy-to-quantify BMPs

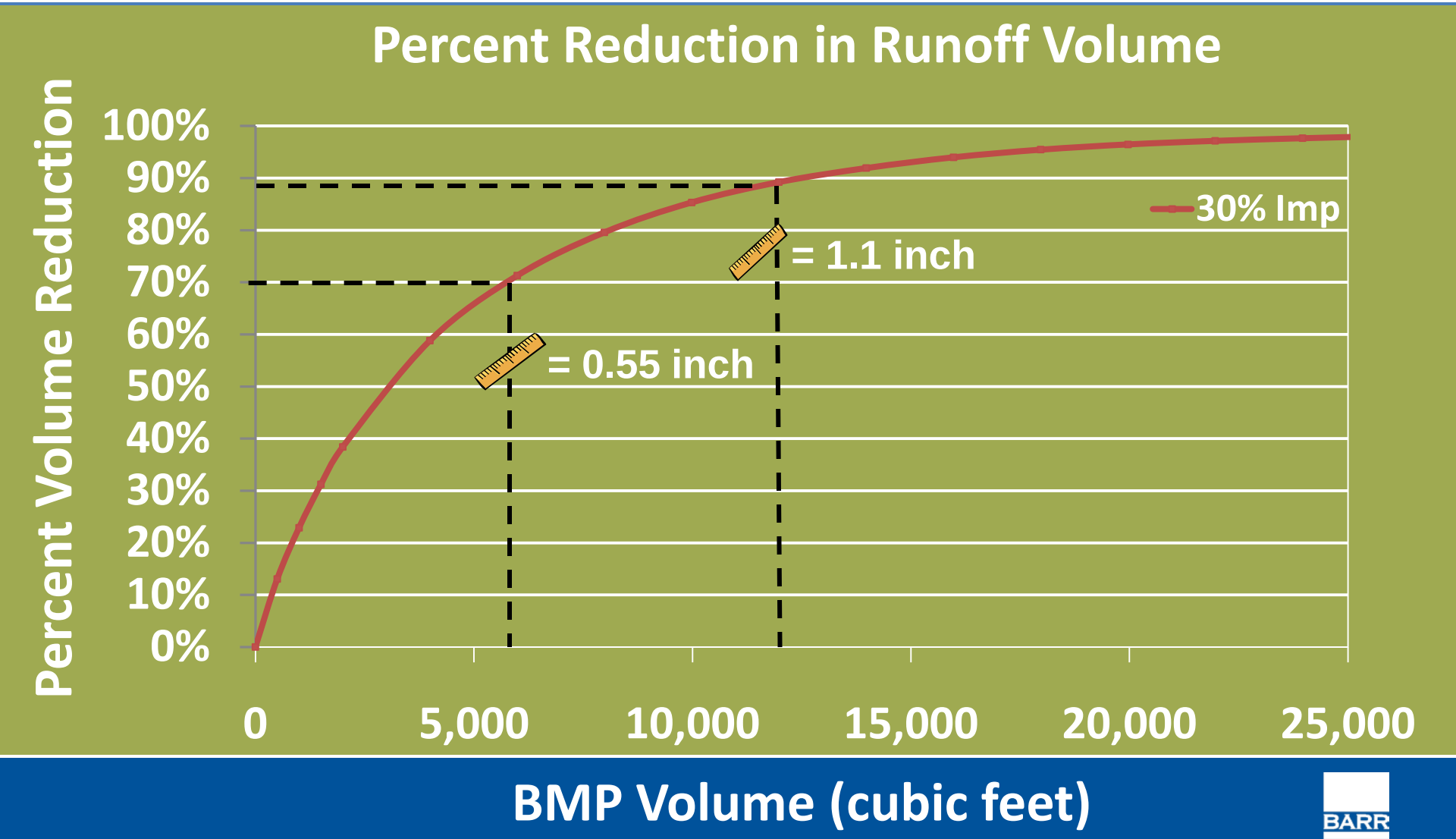
Performance Curves to Determine Percent Annual Volume Retained



Performance Curves to Determine Percent Annual Volume Retained



Performance Curves to Determine Percent Annual Volume Retained



How to Calculate % Annual Volume Removed?

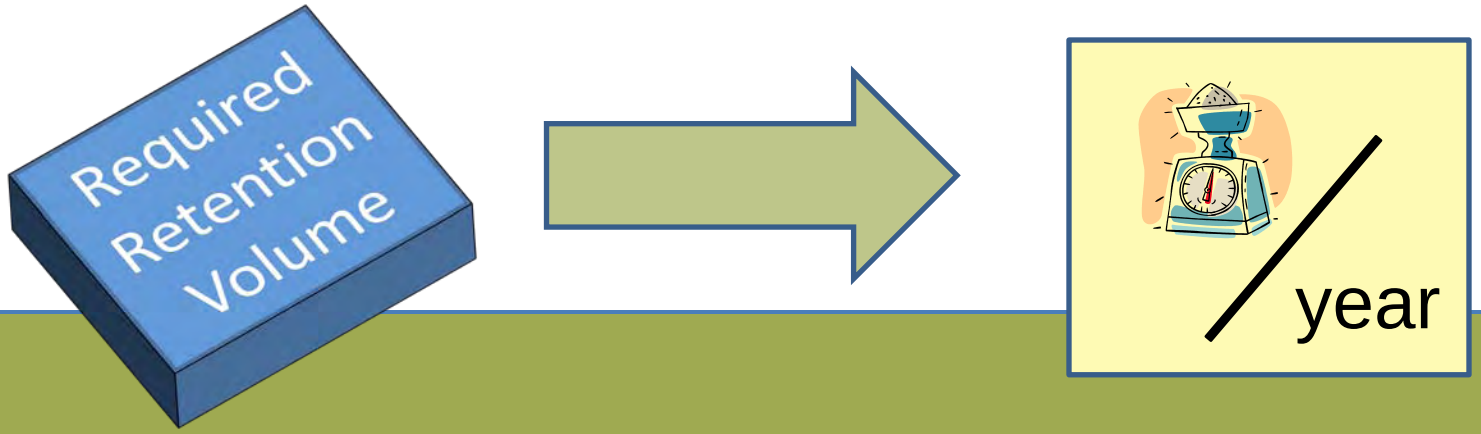
- For other volume control BMPs, where development of performance curves will be too complex, use volume reduction % from literature
  - For example, grass channel 10% - 20% volume reduction

BMP	Volume Reduction %
Bioretention/Rainwater Garden	Calculate
Biofiltration	40%*
Infiltration Basin/Trench	Calculate
Permeable Pavement	Calculate
Grass Channel	10%
Dry Swale	40 or 60%*
Wet Swale	0%
Filter Strips	25-50%
Sand Filters	0%
Green Roofs	Calculate
Wet Pond	0%
Infiltration Shelf at Wet Pond	0%?

How to Estimate % Pollutant Removal?

- Use modeling to estimate, where applicable
- Use available literature

BMP	TP % PR	TSS % PR
Bioretention/Rainwater Garden	50-100	85-90
Biofiltration	25-50	60-85
Infiltration Basin/Trench	25-100	85-100
Permeable Pavement	25-85	75-90
Grass Channel	15-50	50-87
Dry Swale	20-50	50-87
Wet Swale	20-50	69-87
Filter Strips	0-45	30-73
Sand Filters	0-65	70-92
Green Roofs	0-100	0-90
Wet Pond	40-75	70-90
Infiltration Shelf at Wet Pond	?	?



1. Calculate Annual Pollutant Load from Site (w/o BMP) ~ 5.8 lbs TP/year

2. Estimate Pollutant Removal ~ 90% reduction

3. Apply Pollutant Removal % to Annual Load to Determine Annual Pollutant Load Reduction

Example: Calculating Annual Pollutant Load Reduction

Pollutant Load Reduction = Total % Pollutant Removal x Site Pollutant Load

= 90% x 5.8 lbs/year

= 5.2 lbs/year

SIMPLE,
right?

Questions? Comments? Suggestions?