Bioretention Hydrologic Modeling

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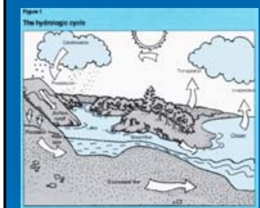
Presentation Overview

- Hydrologic Modeling
- Performance Standards
- Modeling Guidelines, Tools, Concepts
- Bioretention Types
- Applications
  - Flow Control
  - Water Quality Treatment
  - Combined Sewer Overflow Reduction
  - Wetland Protection

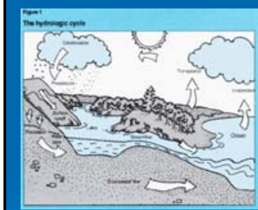
Hydrologic Modeling



Source: http://www.und.nodak.edu/

- Q: What is hydrologic modeling?
- A: Use of mathematical equations to estimate <u>runoff</u> based on:
  - weather patterns
  - landuse
  - soil
  - topography

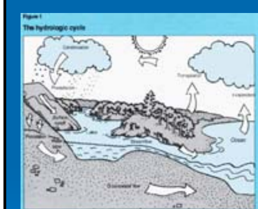
Hydrologic Modeling



Source: http://www.und.nodak.edu/

- Q: Why do we use hydrologic models?
- A1: Characterize hydrologic conditions
  - Predeveloped
  - Current
  - Post-project
- A2: Design mitigation
- A3: It's fun!

Hydrologic Modeling



Source: http://www.und.nodak.edu/

- Q: When does hydrologic modeling enter into your project?
- A: Start to finish
  - preliminary design (sizing)
  - final design (optimization)
  - demonstrate requirements met (permit submittals)

Performance Standards

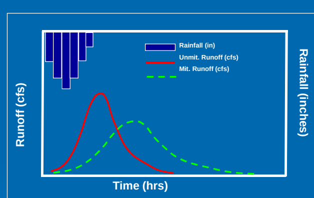
- **On-site Stormwater Management (MR #5) (NEW 2012)**
  - **Use BMP List (rain garden)**
    or
  - **Meet LID Performance Standard (match flow durations to pre-developed condition from 8% to 50% of the 2-year peak flow)**
- **Runoff Treatment (MR #6)**
  - **Infiltrate 91 percent of the total runoff volume through soil meeting Ecology treatment criteria (for infiltration BMPs)**
- **Flow Control (MR #7)**
  - **Match flow durations to pre-developed condition from 50% of the 2-year to the 50-year peak flow**
- **Other Flow Control Standards**
  - **Combined Sewer or Capacity Constrained Basins (peak-based standards)**

Hydrologic Modeling
Methods

- Single-event models
  - May be appropriate for conveyance sizing
- Continuous models
  - Required for sizing flow control (MR7) and treatment (MR6) BMPs
- Simplified sizing tools
  - Will be covered in class exercise

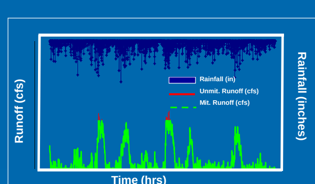
Hydrologic Modeling
Single-Event Methods

- Input single storm event
- Output peak flow rates
- Typical methods
  - SCS
  - SBUH
  - StormShed
  - SWMM
  - HEC-HMS



Hydrologic Modeling
Continuous Models

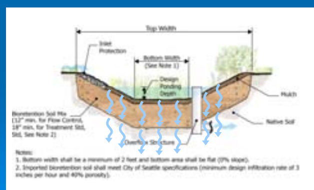
- Input long-term rain and evaporation
- Output continuous runoff, peak flow, & duration
- Typical programs
  - HSPF
  - WWHM
  - MGS Flood
  - KCRTS
  - SWMM
  - SUSTAIN
  - InfoWorks



Bioretention Types

Without Underdrain

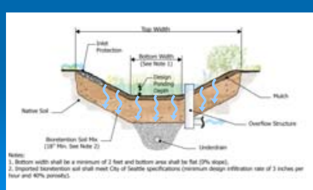
- Relies on infiltration to native soil
- Can meet on-site list requirement
- Can provide effective WQ treatment for some pollutants
- Can provide effective flow control and meet duration standard for many soil conditions



Bioretention Types

With Underdrain

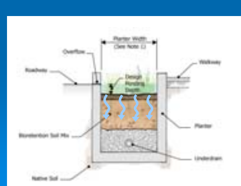
- Some infiltration to native soil
- Can meet on-site list requirement
- Can provide effective WQ treatment for some pollutants
- May not be able to meet duration standard alone, but can contribute as part of a system to achieve flow control goals (raised underdrain and orifice improve performance)



Bioretention Types

With Underdrain & Liner/Impermeable Container

- No infiltration to native soil
- Can meet on-site list requirement
- Can provide effective WQ treatment for some pollutants
- Cannot meet duration standard alone, but can contribute as part of a system to achieve flow control goals (orifice improves performance)



Current Modeling Guidelines

- Implicit Method (2005 LID Manual)
  - Lump surface ponding and storage in BR soil
  - Effective depth = ponding depth + BR soil depth x void ratio (%)
  - MGS Flood and WWHM3
  - Neglects movement of water through layers
- Explicit Method
  - Explicitly represents:
    - Surface ponding
    - Infiltration into BR soil and native soil
    - Storage in BR soil
    - Overflow
    - Underdrain flow
  - MGSFlood4, WWHM4,WWHM2012

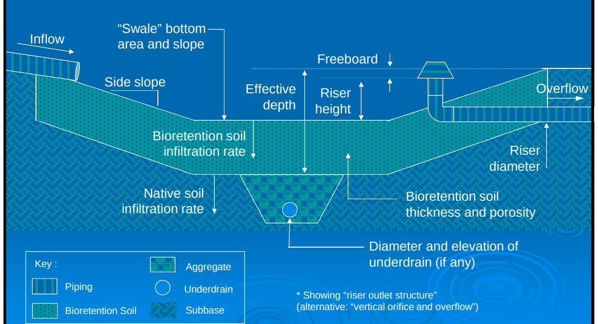
WWHM/MGSFlood Basics

Model Inputs

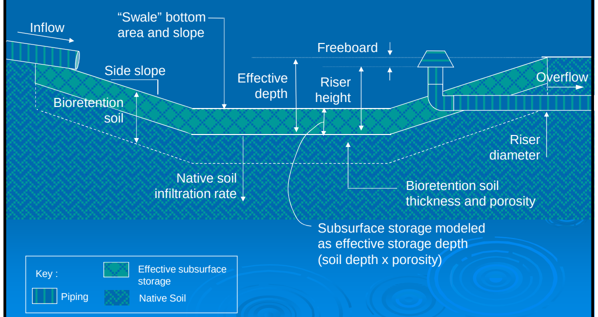
- Meteorological Data
  - Rainfall (5-min, 15-min, hourly)
  - Evaporation (daily)
- Land Cover Types
  - Impervious areas
    - Slope
  - Pervious areas
    - Vegetation
    - Soil type (A, B, C/D)
    - Slope
  - Regional calibrated parameters (Dinicola 1990)
- BMP Configurations

WWHM/MGSFlood Representation

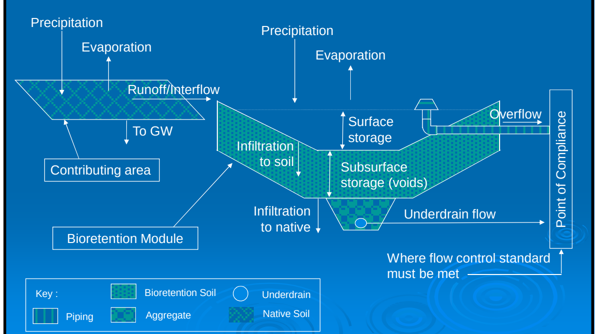
Bioretention Module Parameters- Explicit



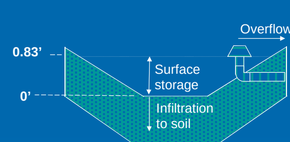
WWHM/MGSFlood Representation
Bioretention Module Parameters- Implicit



WWHM/MGSFlood Representation
Model Configuration



WWHM/MGSFlood Representation
Bioretention Surface Routing- Explicit



Surface SSD Table

Stage (ft)	Area (sf)	Storage (cf)	Infilt. (cfs)	Overflow (cfs)
0.0	0	0	0	0
0.2	304	243	0.0035	0
0.4	328	253	0.0038	0
0.6	352	263	0.0041	0
0.8	376	273	0.0044	0
0.9	388	278	0.0045	0.8
1.0	400	283	0.0046	1.5

Bioretention Sizing Examples

- Flow Control in Creek Basins (WWHM)
- Water Quality Treatment (WWHM)
- Flow Control for CSO Reduction (SWMM)

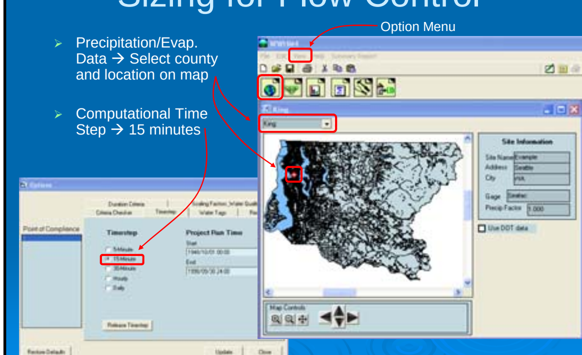
Flow Control in Creek Basin

WWHM4 Example- Explicit Method

- Site in Seattle
- Size bioretention cell to meet creek protection goal (Ecology flow duration standard)
- Predeveloped condition = forest on till
- Native soil is till (0.25 inch/hour design infiltration rate)
- Bioretention cell (12” ponding depth, no underdrain)
- Receiving runoff from 2,000 sf of impervious area (0.046 acres)
- Using bioswale module in WWHM4
- 15 minute time-step

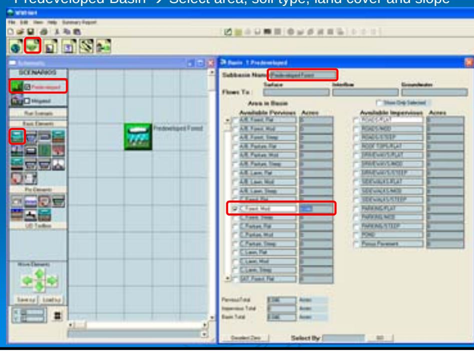
Sizing for Flow Control

- Precipitation/Evap. Data → Select county and location on map
- Computational Time Step → 15 minutes



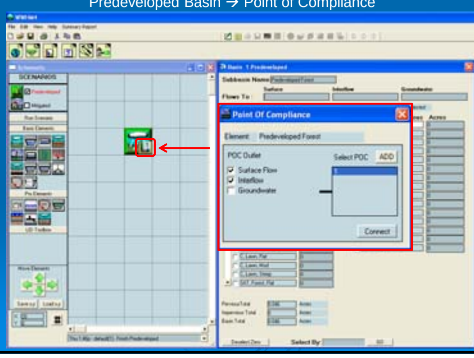
Sizing for Flow Control

Predeveloped Basin → Select area, soil type, land cover and slope



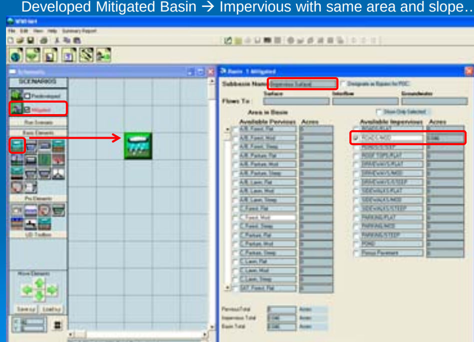
Sizing for Flow Control

Predeveloped Basin → Point of Compliance



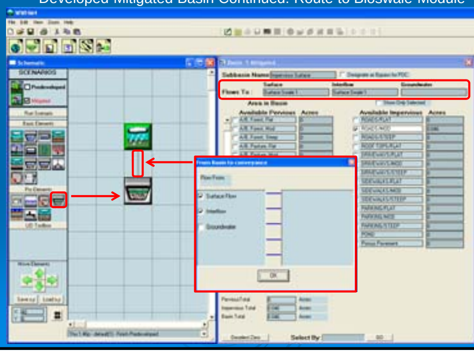
Sizing for Flow Control

Developed Mitigated Basin → Impervious with same area and slope….



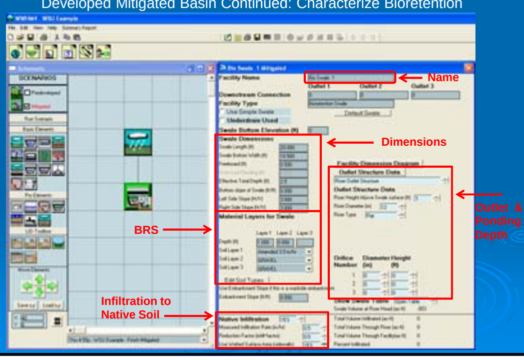
Sizing for Flow Control

Developed Mitigated Basin Continued: Route to Bioswale Module



Sizing for Flow Control

Developed Mitigated Basin Continued: Characterize Bioretention



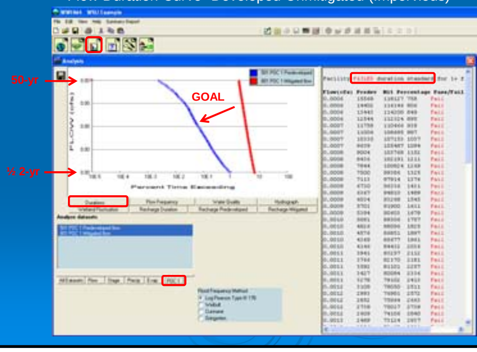
Sizing for Flow Control

Stage Storage Discharge Table

Stage (ft)	Area (acres)	Storage (acre-ft)	Dschrge (cfs)	Infiltration (cfs)	
Sub-surface Table				Native	
0.000000	0.008264	0.000000	0.000000	0.000000	
0.027473	0.008234	0.000059	0.000000	0.000000	
0.054945	0.008159	0.000120	0.000000	0.000000	
0.082418	0.008083	0.000181	0.000000	0.000000	
0.109890	0.008007	0.000243	0.000000	0.000000	
0.137363	0.007931	0.000305	0.000000	0.000000	
0.164835	0.007856	0.000369	0.000000	0.000000	
0.192308	0.007780	0.000433	0.000000	0.000000	
0.219780	0.007704	0.000498	0.000000	0.000000	
0.247253	0.007629	0.000564	0.000000	0.000000	
0.274725	0.007553	0.000631	0.000000	0.000000	
0.302198	0.007477	0.000698	0.000000	0.000000	
0.329670	0.007402	0.000767	0.000000	0.000000	
0.357143	0.007326	0.000836	0.000000	0.000000	
0.384615	0.007250	0.000906	0.000000	0.000000	
0.412088	0.007175	0.000977	0.000000	0.000000	
Surface Table				To Amended	Native(wetted surface)
1.000000	0.008264	0.002686	0.000000	0.016855	0.000714
1.027473	0.008340	0.002914	0.000000	0.016855	0.000714
1.054945	0.008416	0.003144	0.000000	0.017306	0.000733
1.082418	0.008492	0.003376	0.000000	0.017756	0.000752
1.109890	0.008567	0.003611	0.000000	0.018207	0.000771

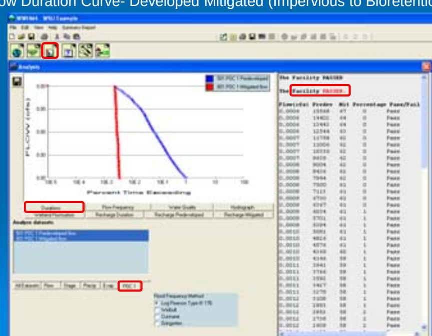
Sizing for Flow Control

Flow Duration Curve- Developed Unmitigated (Impervious)



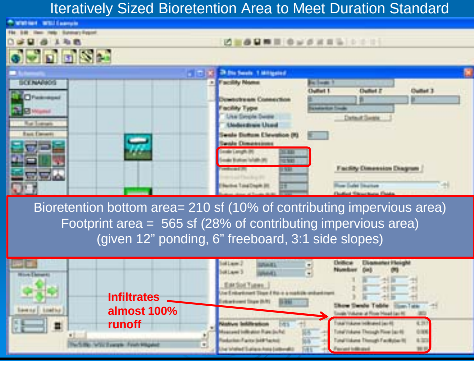
Sizing for Flow Control

Flow Duration Curve- Developed Mitigated (Impervious to Bioretention)



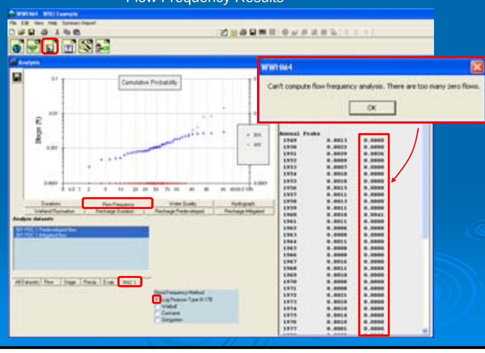
Sizing for Flow Control

Iteratively Sized Bioretention Area to Meet Duration Standard



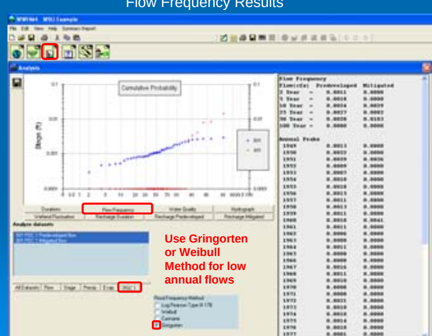
Sizing for Flow Control

Flow Frequency Results



Sizing for Flow Control

Flow Frequency Results

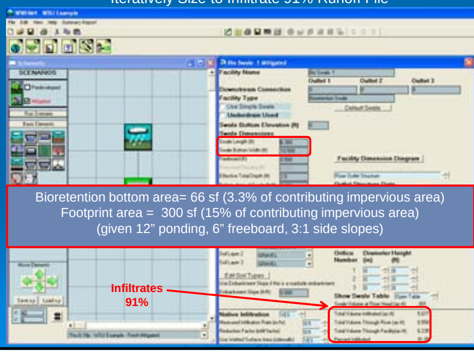


Water Quality Treatment

Same WWHM4 Example for Flow Control

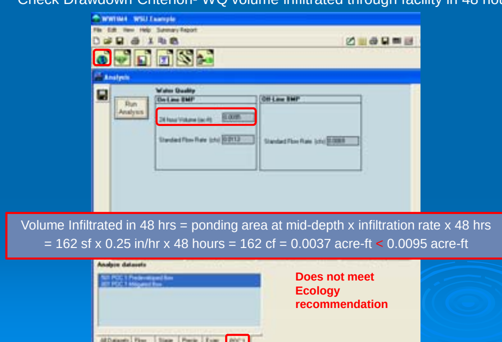
Sizing for Treatment

Iteratively Size to Infiltrate 91% Runoff File



Sizing for Treatment

Check Drawdown Criterion- WQ volume infiltrated through facility in 48 hours

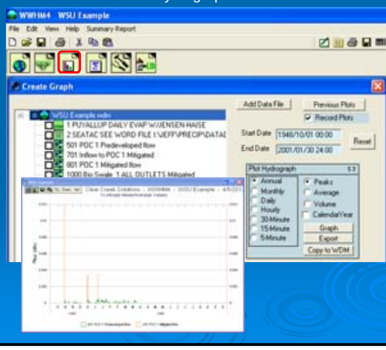


Further Analysis

WWHM4 Example

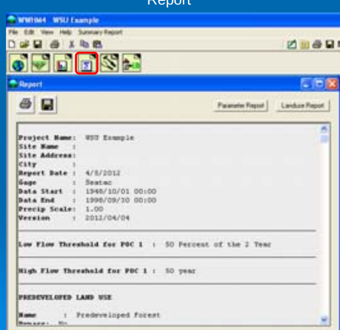
Further Analysis

Hydrograph



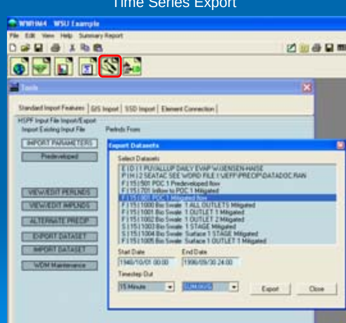
Further Analysis

Report



Further Analysis

Time Series Export



SWMM Basics

Model Inputs

- Environmental Protection Agency's (EPA's) Stormwater Management Model (SWMM)
- Meteorological Data Inputs
  - Rainfall and evaporation
- Land Surface Characteristics
- BMPs
  - LID controls allow explicit modeling of GSI

Table 5-1. Estimating Effective Impervious Surface Area

Subcatchment Type	Basis for TIA	Scaling Factor(s) (%)	Effective Impervious Surface (TIA × s)
ROW – informal	GIS or site survey	61	Calculated
ROW – curb and gutter	Site survey	95	Calculated
Parcel – w/existing IMP surface discharges directly to the public drainage system through a pipe or surface channel	Site survey	56	Calculated
Parcel – w/ existing IMP surface discharges to the private pervious surface or private drainage feature (e.g., rock pockets, large vegetated area)	Site survey	28	Calculated

GIS = geographic information system
IMP = impervious
ROW = right-of-way
TIA = total impervious area

SWMM Basics

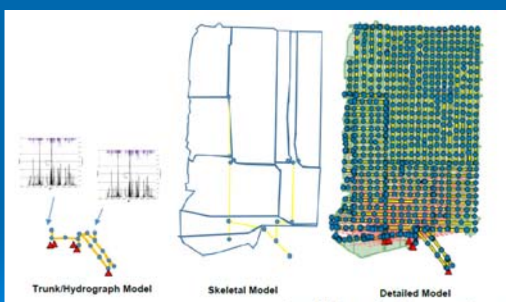
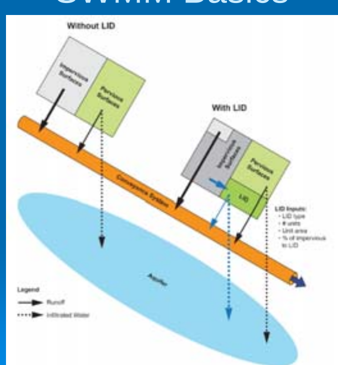


Figure 2-1. Example Model Structures and Scales

SWMM Basics



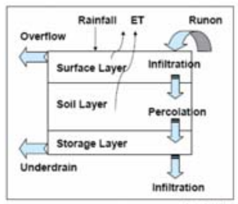
SWMM Basics

LID Controls

Table 12-1. Composition of Vertical Layers in SWMM5

GSI Type	Surface	Pavement	Soil	Storage	Underdrain
Bioretention	√		√	√	o
Porous Pavement	√	√		√	o
Bioswale	√		o	o	o

√ = required
o = optional
GSI = green stormwater infrastructure
SWMM = stormwater management model



Source: SWMM User's Guide

Figure 12-2. Flow Pathways between Vertical Layers Representing Bioretention

SWMM Basics

Bioretention Cell Parameters

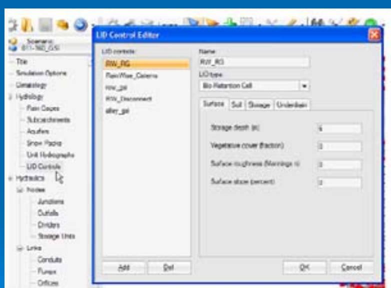


Figure 12-3. Graphical User Interface for the SWMM5 LID Control Editor

SWMM Basics

Bioretention Cell Parameters

Table 12-2. SWMM5 Input Parameters for Bioretention GSI

Vertical Layer	Property	Description	Unit, Field ID, or Data Type	Example Value	Data Source
Surface	Storage depth	Ponding depth (do not include freeboard)	Inches	6	GSI design
	Vegetation volume fraction	Fraction of layer volume filled with vegetation	Fraction	0.1	GSI Design
Soil	Thickness	Thickness of the soil layer	Inches	12 (without UD) 24 (with UD)	SPU
	Porosity	Volume of pore space relative to total soil volume	Fraction	0.4	Rawls et al., 1998
	Field capacity	Volume of pore water relative to total volume after the soil has drained fully by gravity	Fraction	0.13	Rawls et al., 1998, for loamy sand texture
	Wilting point	Volume of pore water relative to total volume for a well-dried soil in which only bound water remains	Fraction	0.04	Rawls et al., 1998, data; difference between total and effective porosity
	Conductivity	Hydraulic conductivity for the fully saturated soil	Inches/hour	3	SPU
	Conductivity slope	Slope of the curve of log conductivity versus soil moisture content	Dimensionless	10	SWMM guidance; average of value for sand plus value for silt loam
	Suction head	Soil capillary suction along the wetting front	Inches	2.42	Assumed; loamy sand

SWMM Basics

Bioretention Cell Parameters

Table 12-2. SWMM5 Input Parameters for Bioretention GI

Vertical Layer	Property	Description	Unit, Field ID, or Data Type	Example Value	Data Source
Storage	Height	Height of a gravel layer below the soil layer	Inches	1 (without UD) 6 (with UD)	SPU
	Void ratio	Volume of void space relative to the volume of solids in the layer	Ratio	0.667	(Equivalent to 0.4 porosity)
	Infiltration rate	Rate at which water infiltrates into the native soil below the storage layer	Inches/hour	Depends on background soil	To be provided by SPU or geotechnical analysis
	Clogging factor	Total volume of treated runoff it takes to completely clog the bottom of the layer divided by the void volume of the layer	Dimensionless	0	Not used
Underdrain	Drain coefficient	Coefficient of the equation that calculates the flow rate through the underdrain as a function of water level above the drain height	inches$^{1/2}$/hour	Depends on outlet size	SPU
	Drain exponent	Exponent of head in SWMM drain equation	Dimensionless	0.5 (orifice drain)	SWMM5 guidance
	Drain offset height	Height of underdrain pipe from the bottom of the layer or rain barrel	Inches	6	SPU

SWMM Basics

LID Usage Editor

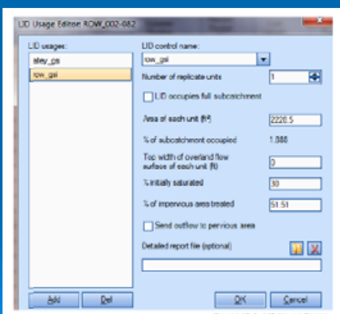


FIGURE 12-5. LID USAGE EDITOR

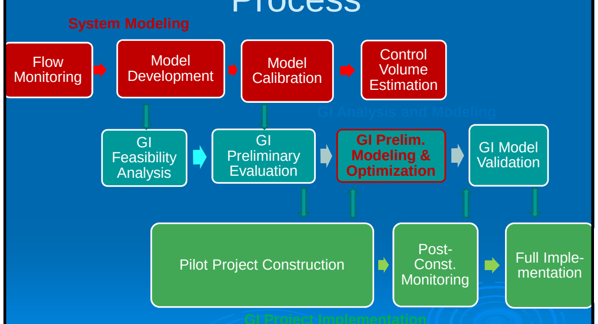
Combined Sewer Overflow Reduction

SWMM Example

Site Scale Optimization: Ballard Roadside Rain Gardens Pilot Project

The Pilot | The Problem | The Fix

Green Infrastructure Evaluation Process



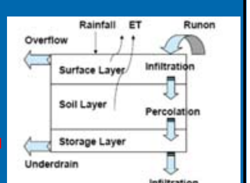
Green Infrastructure Modeling

RainWise Practices

Rain Gardens → Bio-retention Cell
Cisterns → Bio-retention Cell
(non-infiltrating with underdrain)

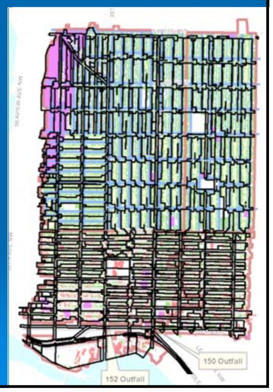
Right-of-way CIP Practices

Roadside Rain Gardens → Bio-retention Cell
Green Alleys → Porous Pavement

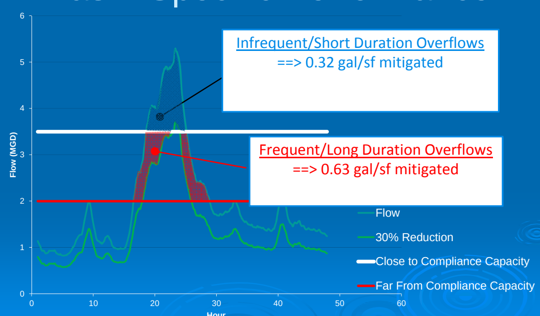


GI Modeling

- Modeled using EPA SWMM5
- 32-year long term simulations performed
- Feasibility Analysis overlaid with model subcatchment delineation to develop input files



Basin Scale Optimization: Basin-Specific Performance



Other metrics besides Control Volume reduction

Basin 150	Without GI	Reduction	% Reduction
Control Volume (MG)	0.60	0.16	26%
Events/year	12.2	5.0	41%
Annual Overflow Volume (MG/year)	3.52	0.97	28%
Basin 152	**Without GI**	**Reduction**	**% Reduction**
Control Volume (MG)	5.35	1.04	19%
Events/year	37.5	9.8	26%
Annual Overflow Volume (MG/year)	28.75	9.58	33%

Resources

- LID Technical Guidance Manual
  http://www.pierce.wsu.edu/Water_Quality/LID/LID_manual2005.pdf
- WWHM
  http://www.clearcreeksolutions.com/
- MGSFlood
  http://www.mgsengr.com/MGSFlood.html
- HSPF
  http://water.usgs.gov/software/HSPF/
- WDMUtils
  http://www.epa.gov/waterscience/basins/b3webdwn.htm

Questions and Answers

???

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