

Hydrologic Modeling for Vegetated Roofs, Rainwater Harvesting and LID Foundations

Robin Kirschbaum, PE, LEED AP 

Alice Lancaster, PE 

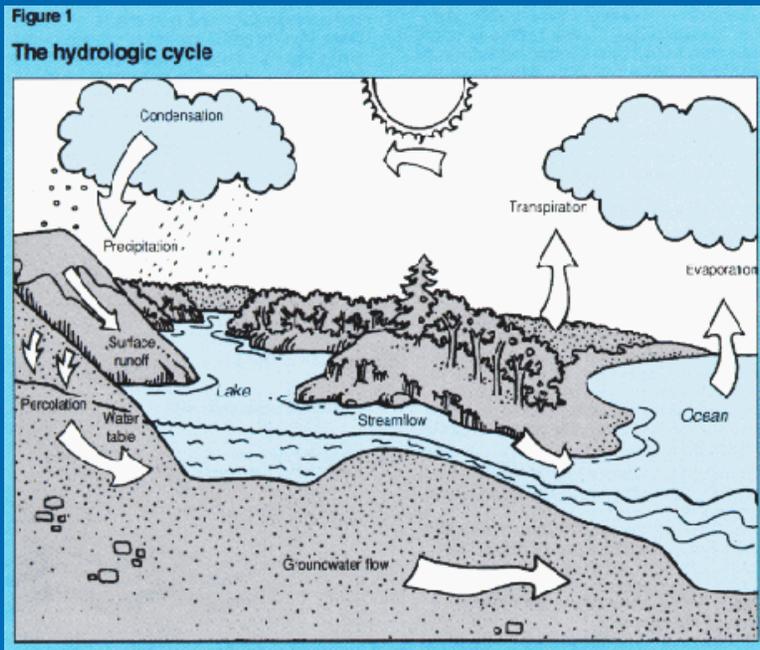
October 9, 2014

Presentation Outline

- Overview of Hydrologic Modeling
- Performance Standards
- Modeling Guidelines
 - Green Roofs
 - Pin Foundations
 - Detention Cisterns
 - Harvesting Cisterns
- Examples



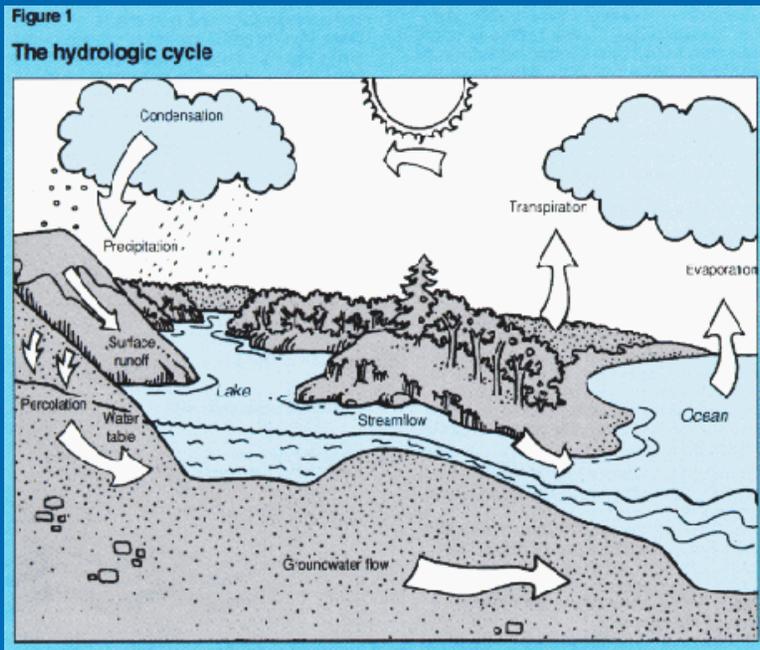
Hydrologic Modeling



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

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

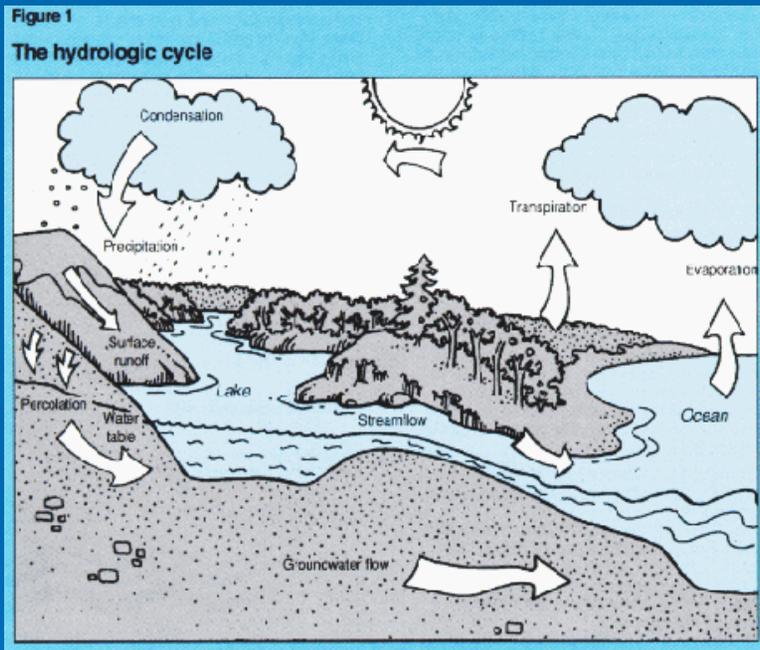
Hydrologic Modeling



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!

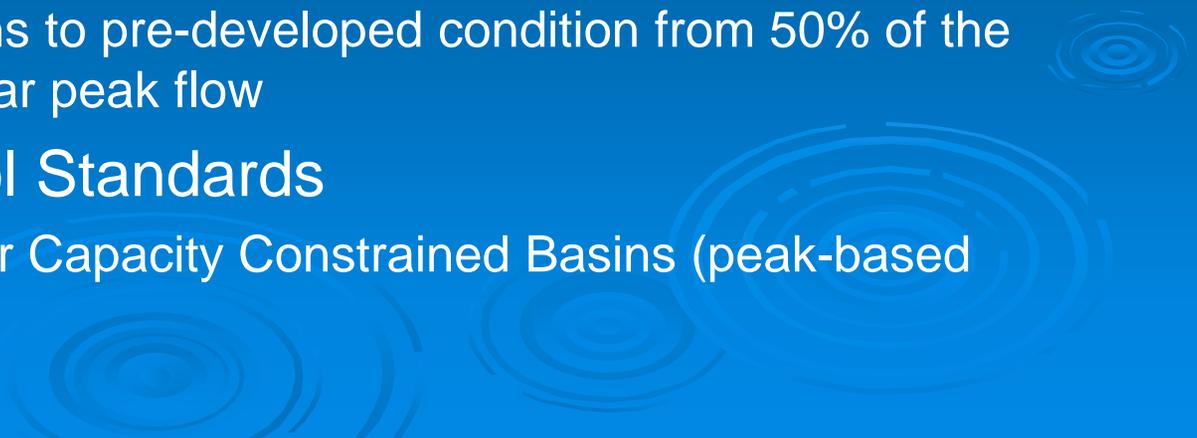
Hydrologic Modeling



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

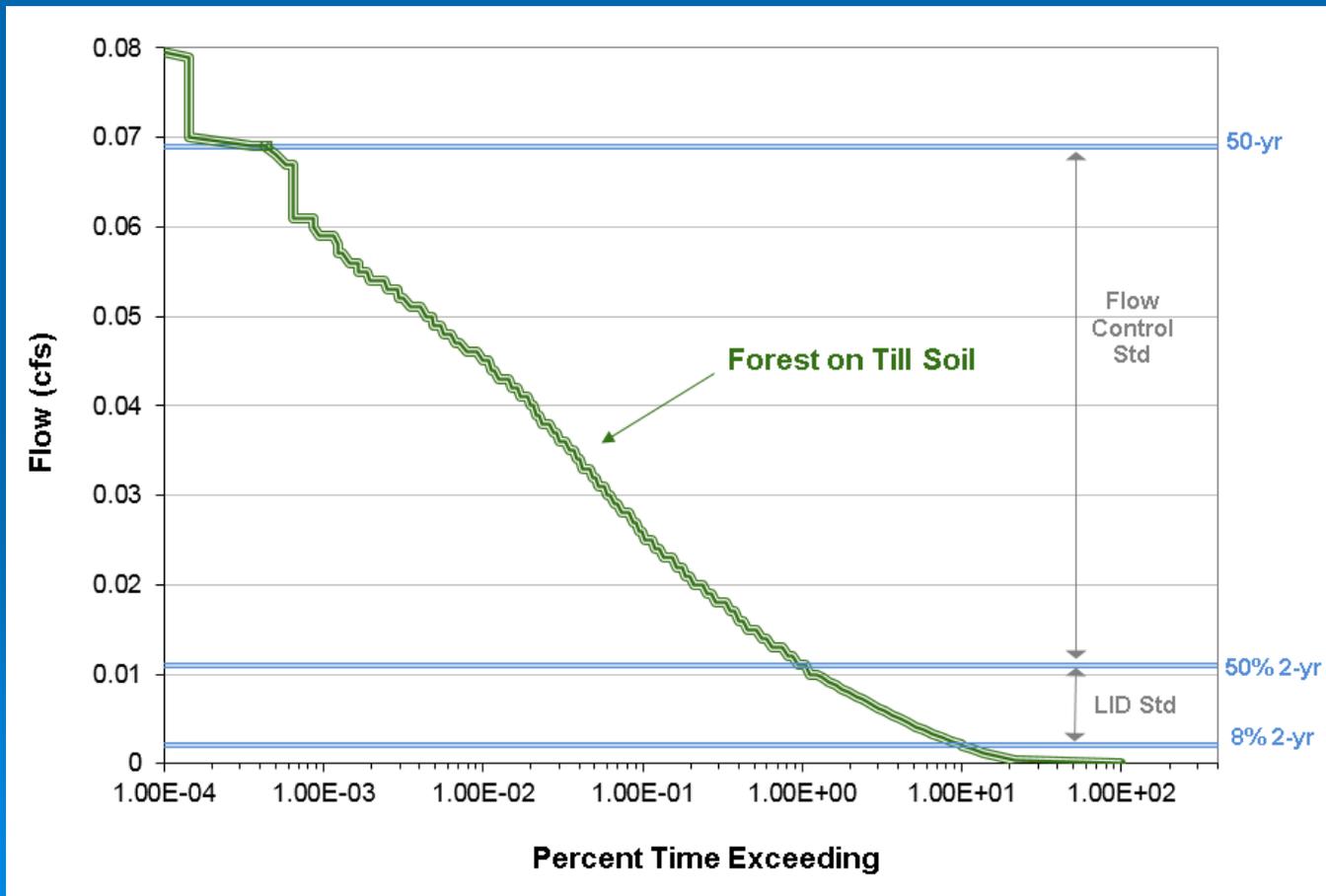
- Q: When does hydrologic modeling enter into your project?
- A: Start to finish
 - preliminary design (sizing)
 - final design (optimization)
 - demonstrate requirements met (permit submittals)

Performance Standards

- On-site Stormwater Management (MR #5) (2013 Permit)
 - Use BMP List
 - 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)
- 

Flow Duration Standards

- LID Performance Standard (MR #5)
- Flow Control (MR #7)



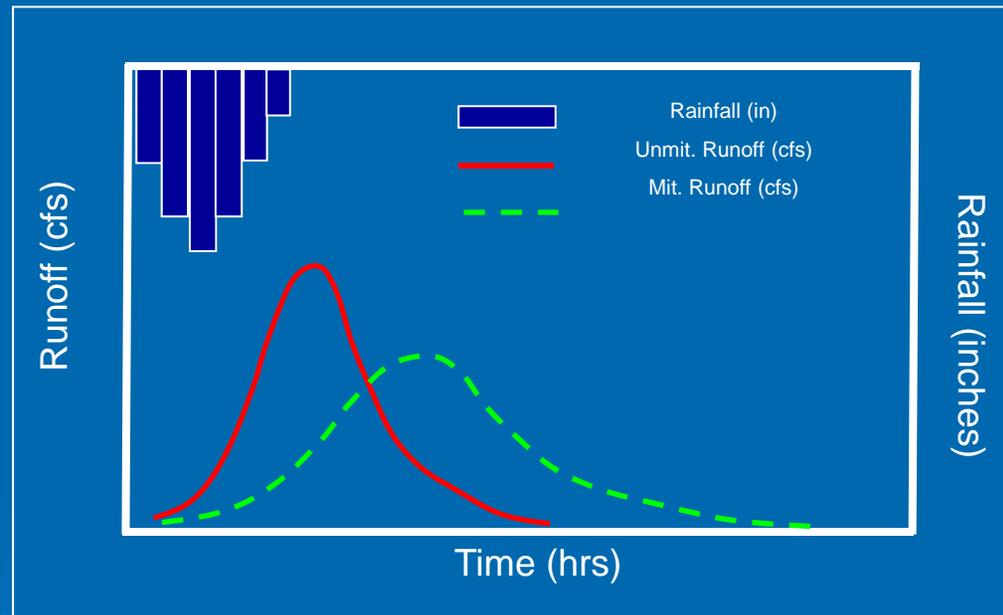
Modeling Methods

- Single-event models
 - May be appropriate for conveyance sizing
- Continuous models
 - Required for sizing facilities to meet the LID performance (MR#5), treatment (MR#6), and flow control (MR#7) standards
- Simplified sizing tools
 - Allow sizing without hydrologic modeling
 - Examples: Flow control credits for green roofs and sizing equations for detention cisterns

Modeling Methods

Single-Event

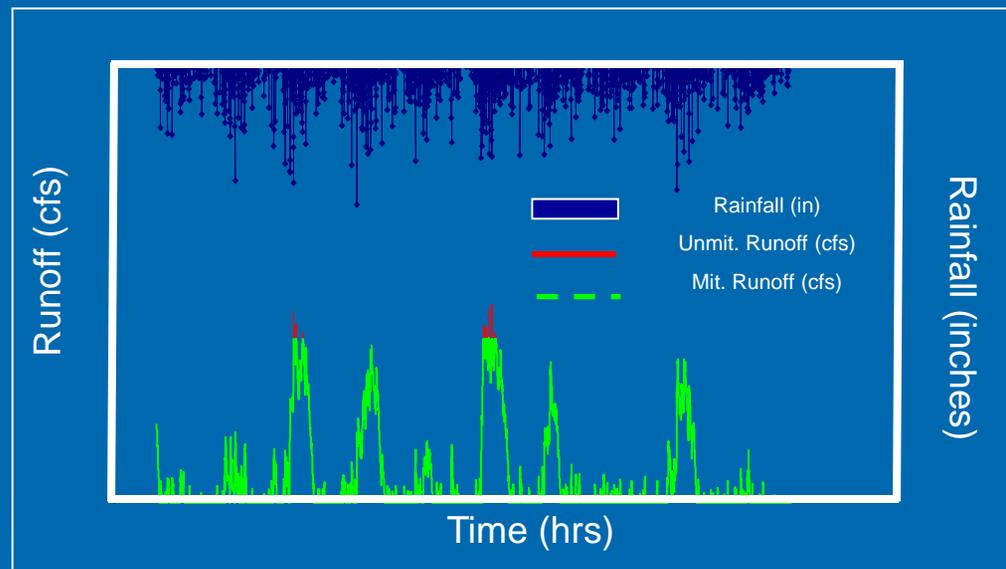
- Input single storm event
- Output peak flow rates
- Typical methods
 - SCS
 - SBUH
 - StormShed
 - SWMM
 - HEC-HMS
 - Sustain



Modeling Methods

Continuous Simulation

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



Modeling Tools

HSPF Basics – Model Inputs

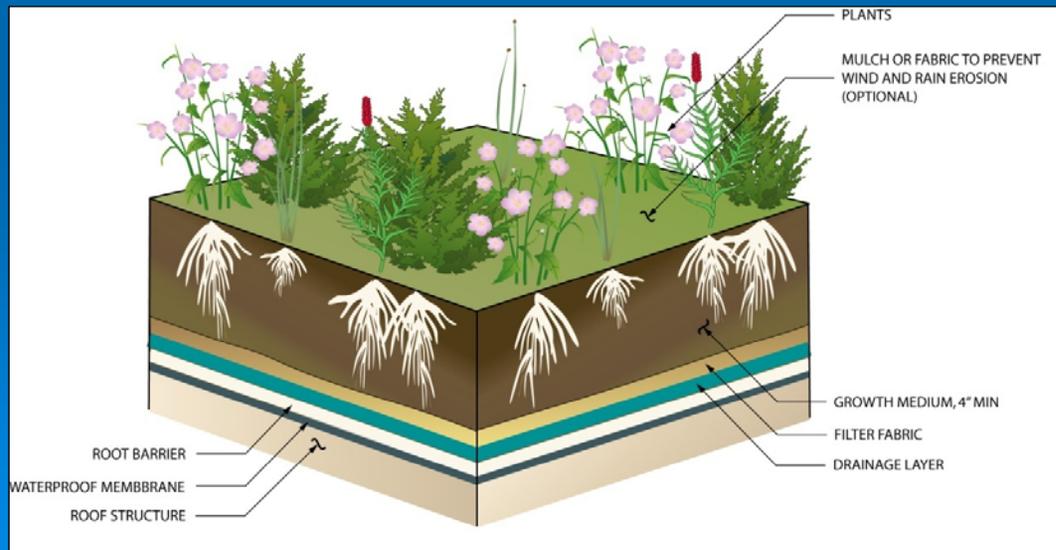
- Meteorological Data
 - Rainfall (5-min, 15-min, hourly)
 - Evaporation (daily)
- Land Cover Types
 - Impervious areas (IMPLNDS)
 - Slope
 - Pervious areas (PERLNDS)
 - Vegetation
 - Soil type (A, B, C/D)
 - Slope
 - Regional calibrated parameters (Dinicola 1990)
- BMP Configurations

Vegetated Roofs

Current Modeling Guidelines

➤ Implicit Method

- 3-8" growing media → model as till lawn
- >8" growing media → model as till pasture

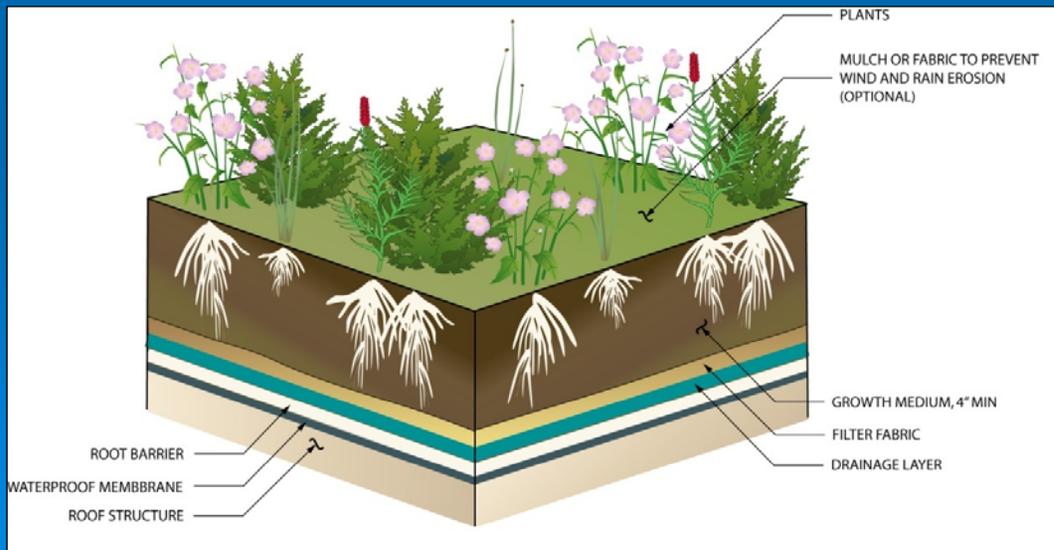


Vegetated Roofs

2013 Permit Modeling Guidelines

➤ Implicit Method

- 3-8" growing media → model as 50% till lawn / 50% impervious area
- >8" growing media → model as 50% till pasture / 50% impervious area



Vegetated Roofs

Current Modeling Guidelines

➤ Explicit Methods

- WWHM2012 and WWHM4
 - Modified PERLND parameters
 - Based on Hamilton Buildings in Portland
 - Considers material depth and vegetated cover
- MGSFlood4
 - Modified PERLND parameters (similar to WWHM)



Vegetated Roofs

Modified PERLND Parameters

Table 1. Eco-Roof HSPF Parameter Values

HSPF Parameter	Eco-Roof Value	Standard WWHM3 Value*
LZSN	0.75/1.25**	4.50
INFILT	0.05	0.03
LSUR	50	400
SLSUR	0.001	0.050
AGWRC	0.100	0.996
AGWETP	0.80	0.00
UZSN	0.075/0.125**	0.250
NSUR	0.55	0.25
INTFW	1.0	6.0
IRC	0.10	0.50
LZETP	0.80	0.25

* Value for till soil, lawn, flat slope

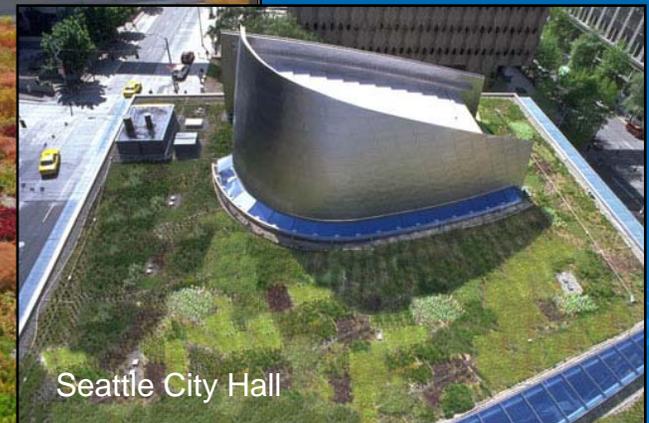
** Values dependent on depth of material (values shown for Portland east and west roofs: 3 inches and 5 inches of material, respectively)

Source: WWHM3 Eco-Roof Documentation, Memorandum prepared by Clear Creek Solutions to Seattle Public Utilities, December 7, 2005.

Vegetated Roof Example

Flow Control (WWHM4)

- 1 acre
Vegetated Roof
- In Seattle
- Performance
relative to Ecology
Flow control
Standard
- Predeveloped
condition is till
forest



Vegetated Roof Example

Select Precipitation

MGSFlood - [Green Roof Example.fld]

File Edit Options Help



Project Information

Project Name: Green Roof Example

Analysis Title:

Comments:

Precipitation Data for Analysis

Select Precipitation Data Set Type to Use in Analysis

- Extended Timeseries (Produces Most Accurate Results)
- Station Data - Uses Ecology Scaling Method

Select Climate Region

26. Seattle 38 in MAP (No Scaling Factor Req'd) 

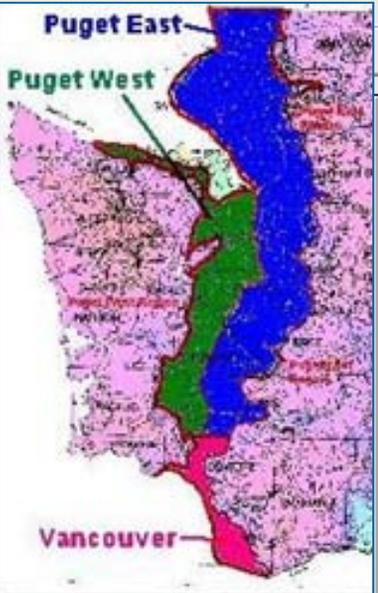
Open Climate Region Map

Mean Annual Precip Ca

Project Latitude (Decimal De

Project Longitude (Decimal D

Compute MAP (inche



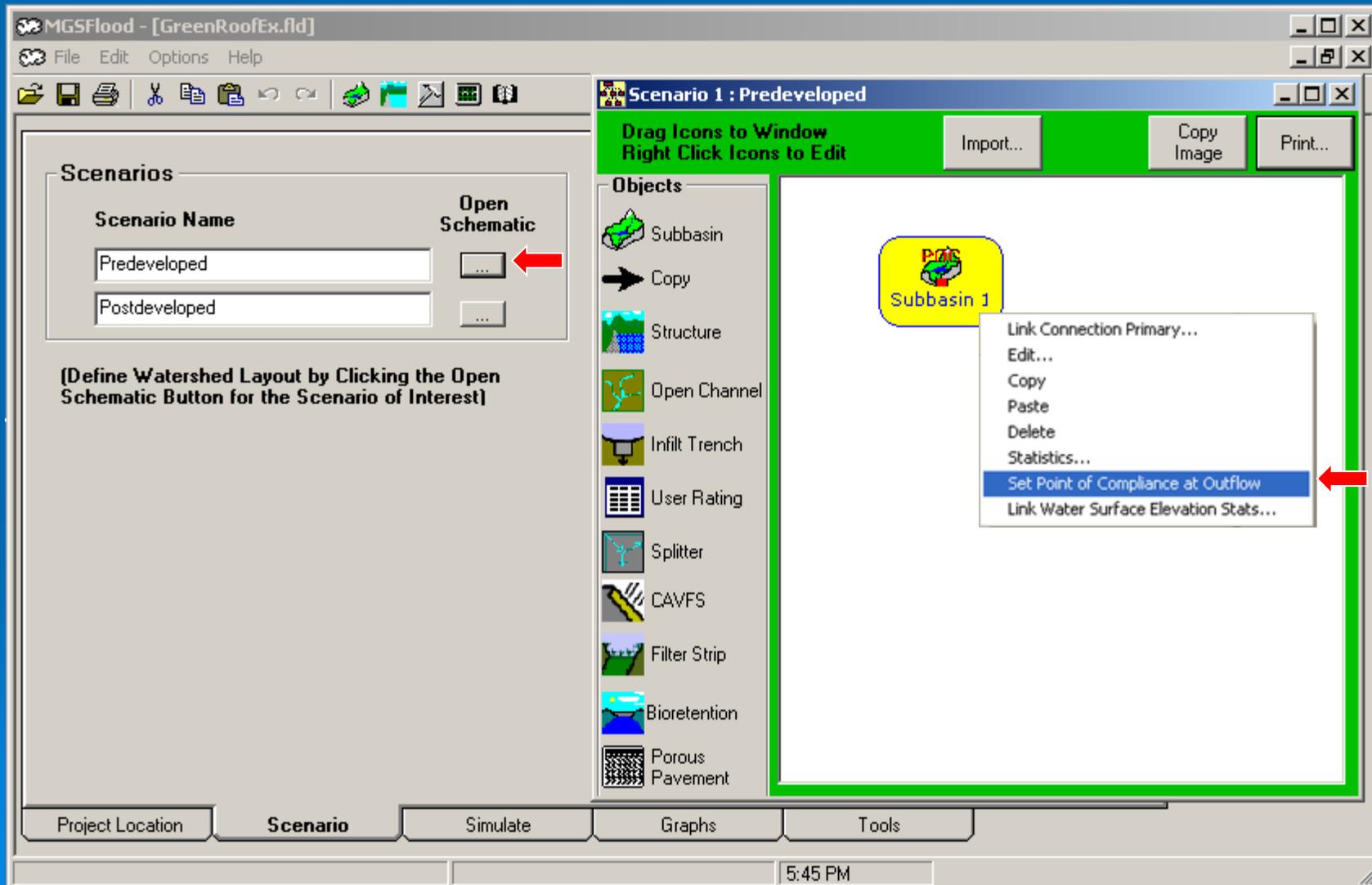
Project Location

Precipitation Station	Period of Record
Seattle 38 in_5min	10/01/1939-10/01/2097
Evaporation Station: Seattle 38 in MAP	10/01/1939-10/01/2097

Scenario Simulate Graphs Tools

Vegetated Roof Example

Define Predeveloped Condition



Vegetated Roof Example

Define Predeveloped Condition

The screenshot shows the MGSFlood software interface. The main window is titled 'Scenario 1 : Predeveloped' and contains a green header with the text 'Drag Icons to Window Right Click Icons to Edit' and buttons for 'Import...', 'Copy Image', and 'Print...'. Below the header is a list of 'Objects' including Subbasin, Copy, Structure, Open Channel, Infiltration Trench, User Rating, Splitter, CAVFS, Filter Strip, Bioretention, and Porous Pavement. A yellow icon labeled 'Subbasin 1' is placed on the main workspace.

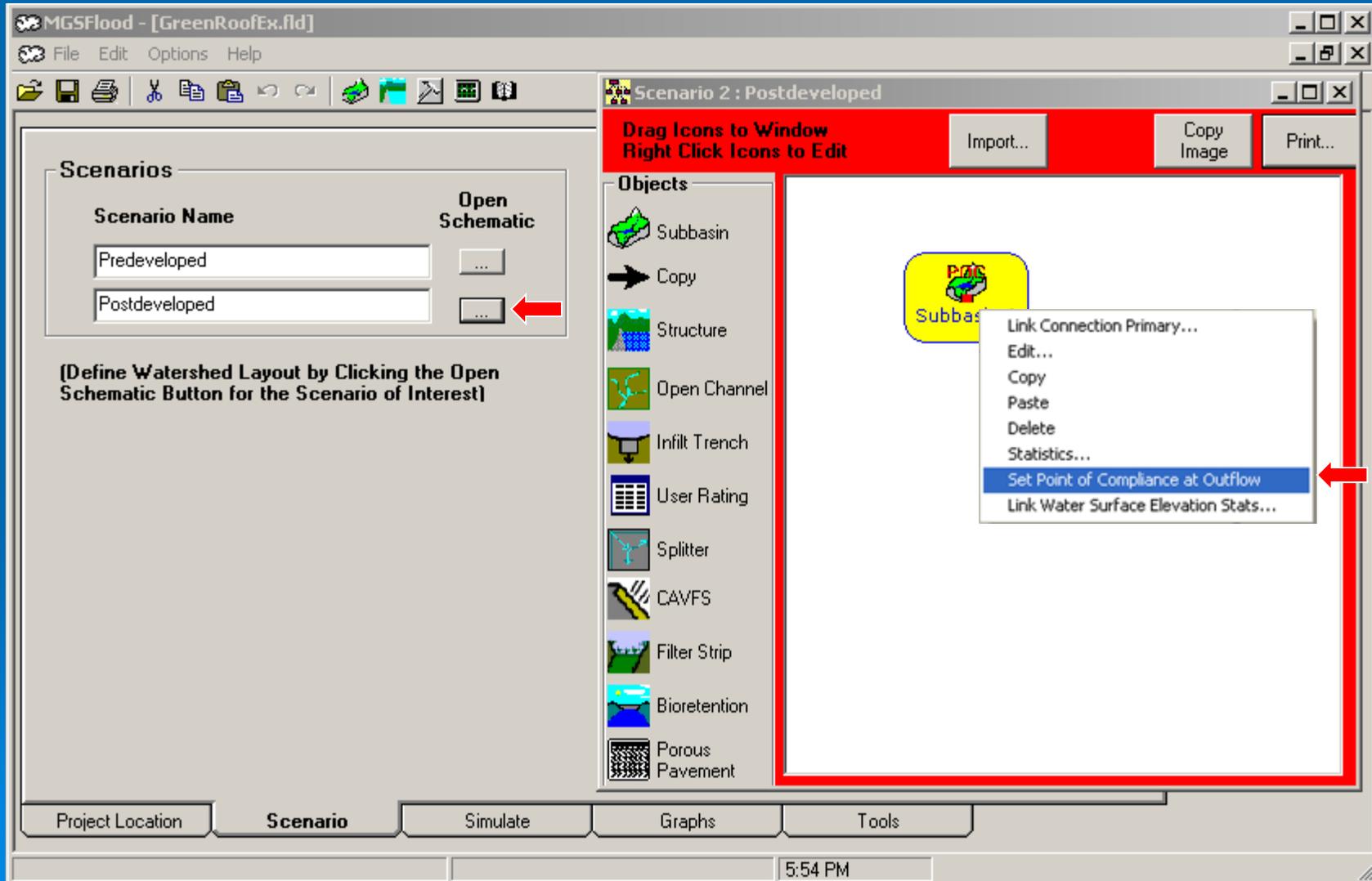
The 'Subbasin Land Use - Forest on Till' dialog box is open, showing the 'Subbasin Area' tab. The 'Edit' field contains 'Forest on Till'. A table lists the area for various land use types:

Cover	Area (ac)
Till Forest	1.000
Till Pasture	0.000
Till Grass	0.000
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Saturated Soil	0.000
Green Roof	0.000
User	0.000
Impervious	0.000
Total (acres)	1.000

Buttons for 'Ok' and 'Cancel' are at the bottom of the dialog box. The software interface also includes a menu bar (File, Edit, Options, Help), a toolbar, and a status bar showing the time as 5:45 PM.

Vegetated Roof Example

Define Developed Mitigated Condition



Vegetated Roof Example

Define Developed Mitigated Condition

The screenshot displays the MGSFlood software interface. The main window is titled "Scenario 2 : Postdeveloped". A red box highlights the main workspace area, and a red arrow points to the "Set Point of Compliance at Outflow" option in the context menu.

The "Subbasin Land Use - GreenRoof" dialog box is open, showing the "Subbasin Area" tab. The "GreenRoof" text field is highlighted with a red arrow. The table below shows the subbasin area breakdown:

Cover	Area (ac)
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.000
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Saturated Soil	0.000
Green Roof	1.000
User	0.000
Impervious	0.000
Total (acres)	1.000

The "Objects" list on the right includes: Subbasin, Copy, Structure, Open Channel, Infiltration Trench, User Rating, Splitter, CAVFS, Filter Strip, Bioretention, and Porous Pavement.

The context menu for the "Subbasin" object is open, showing options: Link Connection Primary..., Edit..., Copy, Paste, Delete, Statistics..., **Set Point of Compliance at Outflow**, and Link Water Surface Elevation Stats....

Vegetated Roof Example

Define Developed Mitigated Condition

Subbasin Land Use - GreenRoof

Edit

GreenRoof

Subbasin Area

Runoff Components

	Check to Enable Runoff Component		
	Surface	Interflow	Groundwater
Till Forest	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Till Pasture	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Till Grass	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Outwash Forest	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Outwash Pasture	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Outwash Grass	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Wetland	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Green Roof	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
User	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

Ok Cancel

Scenario 2 : Postdeveloped

Drag Icons to Window
Right Click Icons to Edit

Import... Copy Image Print...

Objects

- Subbasin
- Copy
- Structure
- Open Channel
- Infiltration Trench
- User Rating
- Splitter
- CAVFS
- Filter Strip
- Bioretention
- Porous Pavement

Subbasin

- Link Connection Primary...
- Edit...
- Copy
- Paste
- Delete
- Statistics...
- Set Point of Compliance at Outflow**
- Link Water Surface Elevation Stats...

Project Location Scenario Simulate Graphs Tools

5:54 PM

Vegetated Roof Example

Run Model

Selected Precipitation and Evaporation for Simulation:
Input: MGSRegions.mdb
Precipitation: Seattle 38 in_5min
Evaporation: Seattle 38 in MAP

Simulation Time Span

	File Limits
Start Date: 10/01/ 1939	10/01/1939 00:00
End Date: 10/01/ 2097 (158 Years)	10/01/2097 00:00

(For Preliminary or Test Runs, Shorten the End Date to Reduce the Computation Time, e.g. 10/1/1996)

Compute Runoff and Route Through Network

Compute Stats for Compliance Subbasin/LinkOnly
 Compute Stats for All Subbasins/Links in Network

Route

Computational Timestep

15 Min

Time Step Guidance

Task	Time Step
Detention Sizing	1-Hour
WQ Wet Pool Volume	15-minutes or 1-hour
WQ Rate Sizing	15-minutes
CAVFS Sizing	15-minutes
Conveyance Sizing	5-minutes to 15-minutes

Predevelopment/Post Development Area Summary

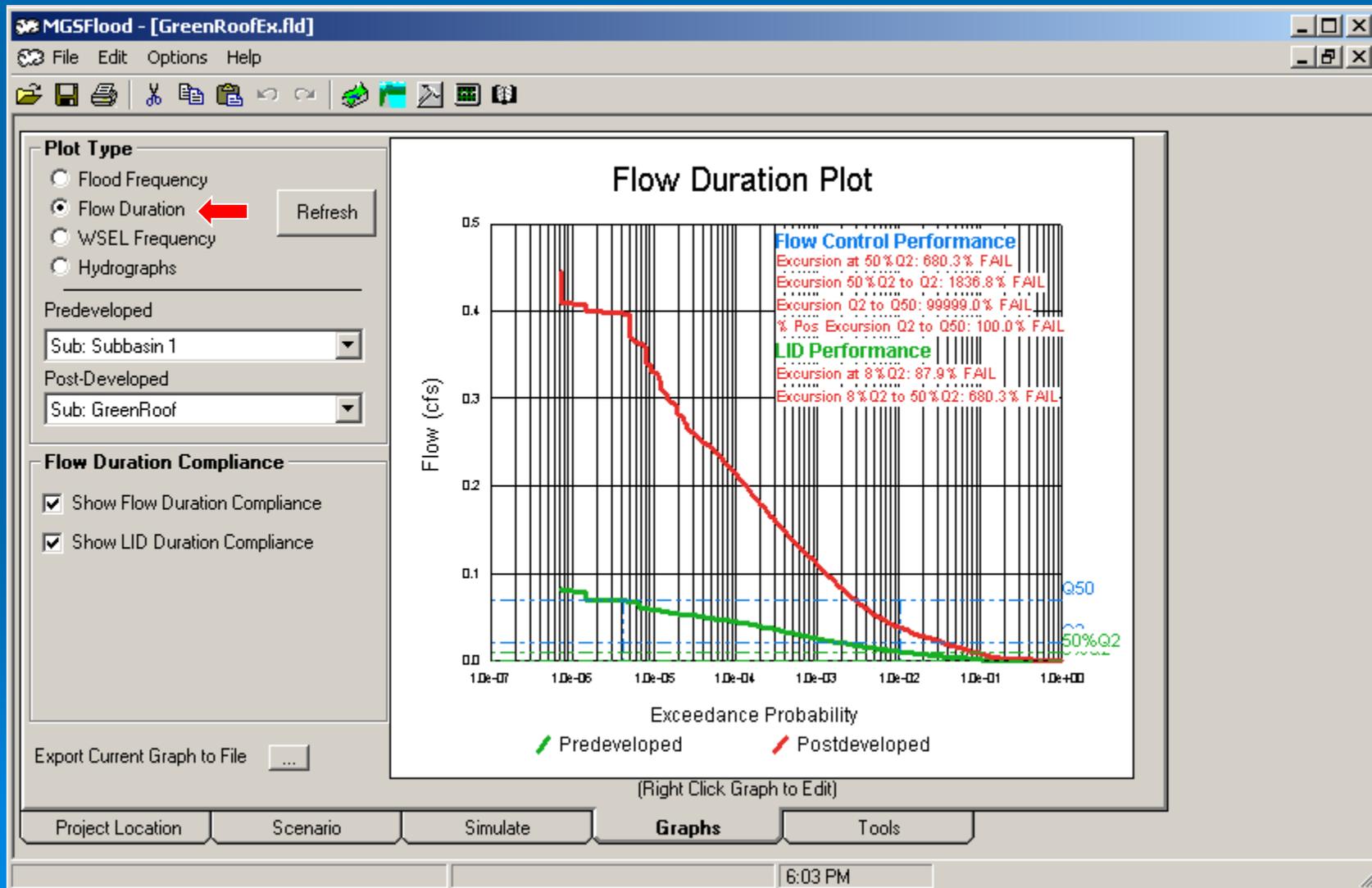
	Predeveloped	Post Developed
Total Subbasin Area (ac)	1.000	1.000
Area of Links That Include Precipitation/Evaporation (ac)	0.000	0.000
Total (ac)	1.000	1.000

Project Location Scenario **Simulate** Graphs Tools

6:04 PM

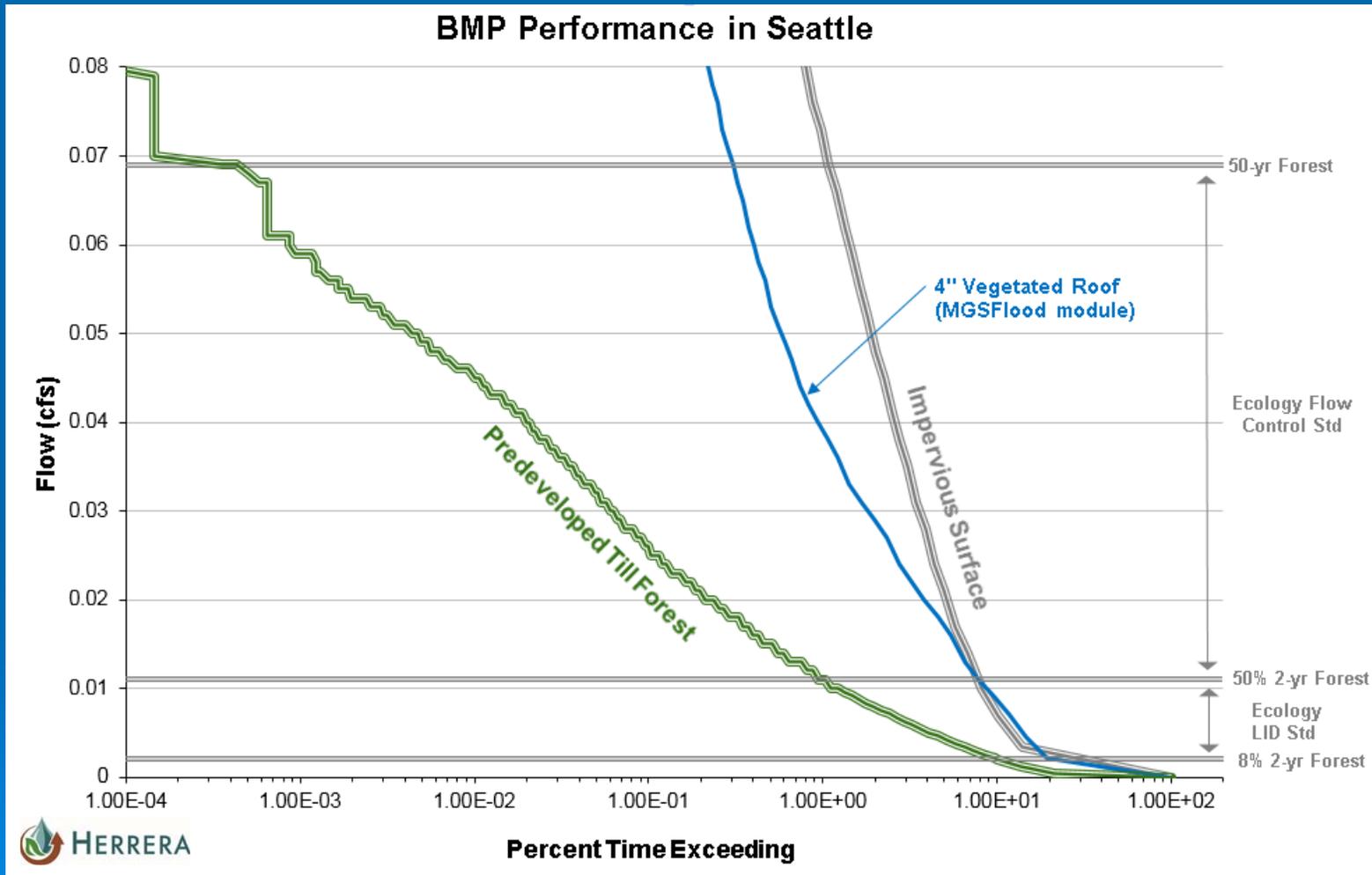
Vegetated Roof Example

Duration Plot



Vegetated Roof Performance

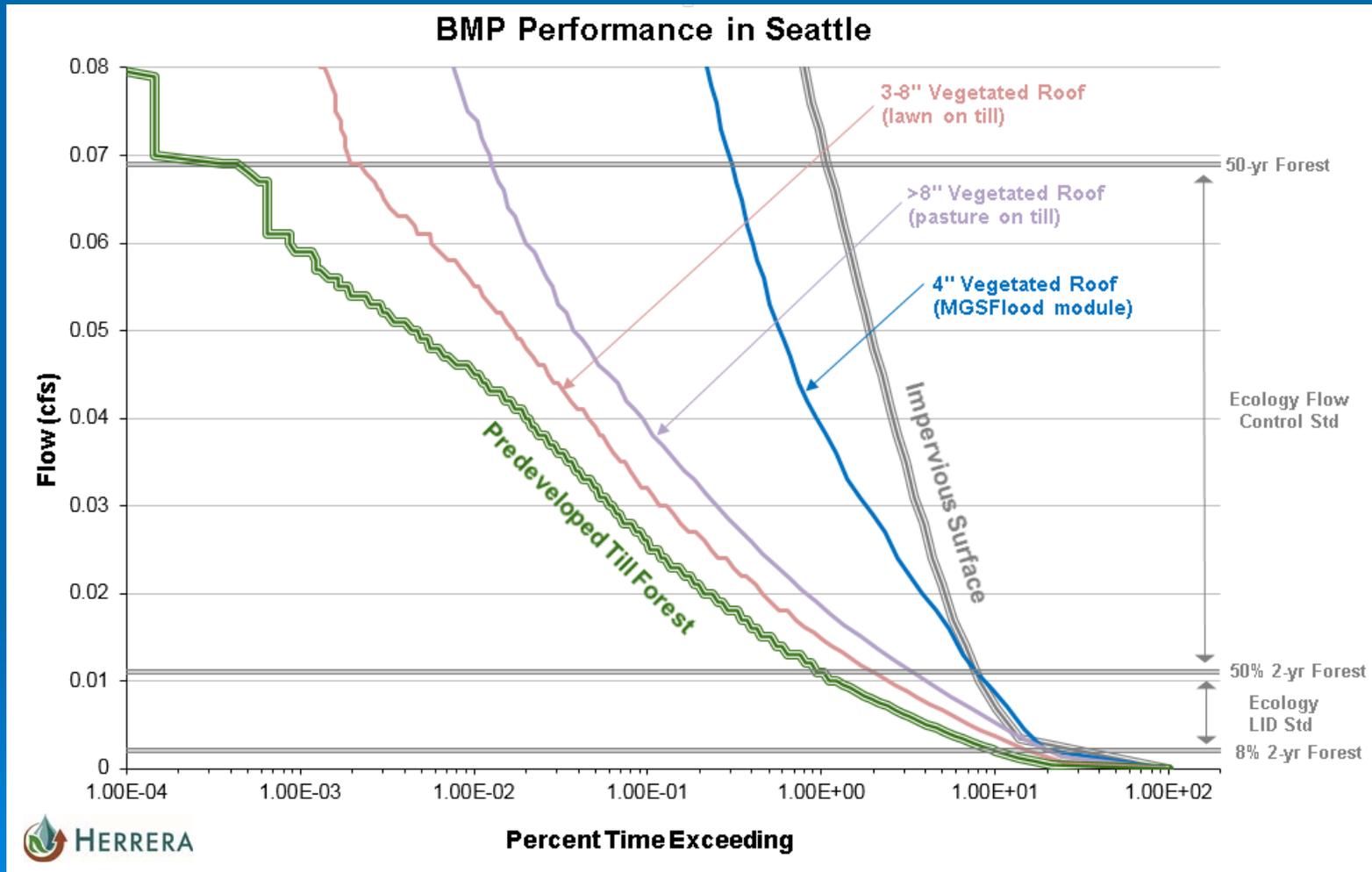
MGSFlood Module



Vegetated roof reduces downstream BMP size

Vegetated Roof Performance

Implicit Methods



Vegetated roof reduces downstream BMP size

Minimal Excavation Foundations

Current* Modeling Guidelines

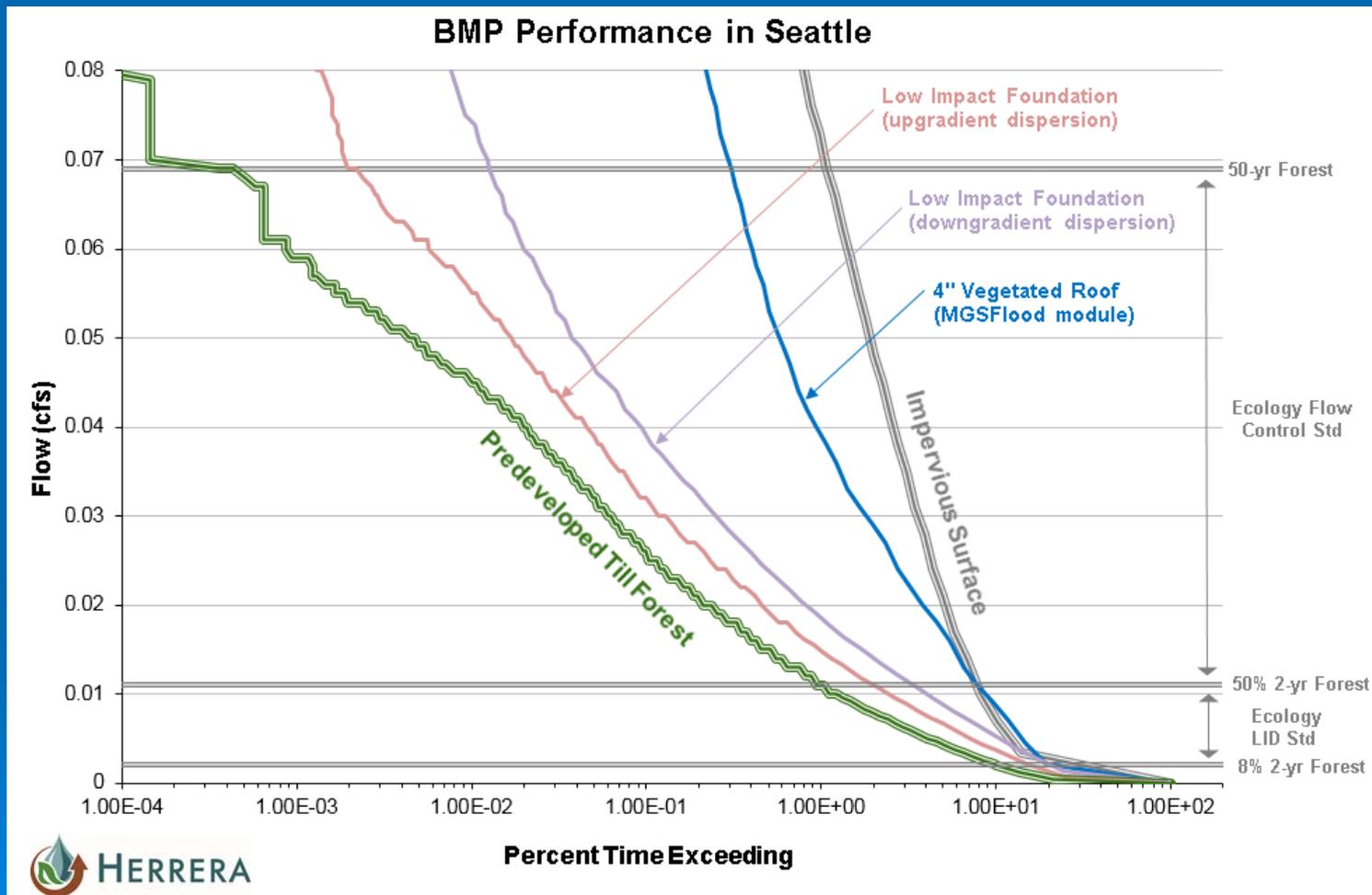
- Roof runoff dispersed on up gradient side of structure
 - Dispersion per BMP T5.10 (downspout dispersion)
 - Model roof as pasture on native soil
 - Highest credit available
 - Note: Area receiving credit reduced when step-forming is used on a slope

- Roof runoff dispersed on down gradient side of structure
 - Dispersion per BMP T5.10 (downspout dispersion) AND at least 50 ft of vegetated flow path that meets BMP T5.13
 - Model roof as lawn/landscape on native soil

* Same as 2013 permit guidelines

LID Foundations Performance

Duration Plot



Modeled as lawn on till- same as implicit representation for vegetated roofs (>8\")

Modeled as lawn on till- same as implicit representation for partial dispersion and vegetated roofs (3-8\")

Detention Cisterns

Current Modeling Guidelines

- Explicitly Model
 - Vault/tank with low flow orifice and overflow
- Orifice Limitations
 - Minimum orifice size typically will not achieve creek protection flow duration standards
 - Useful tool for CSO control



Note: No recommendations in 2005 or 2012 LID Manual

Harvesting Cisterns

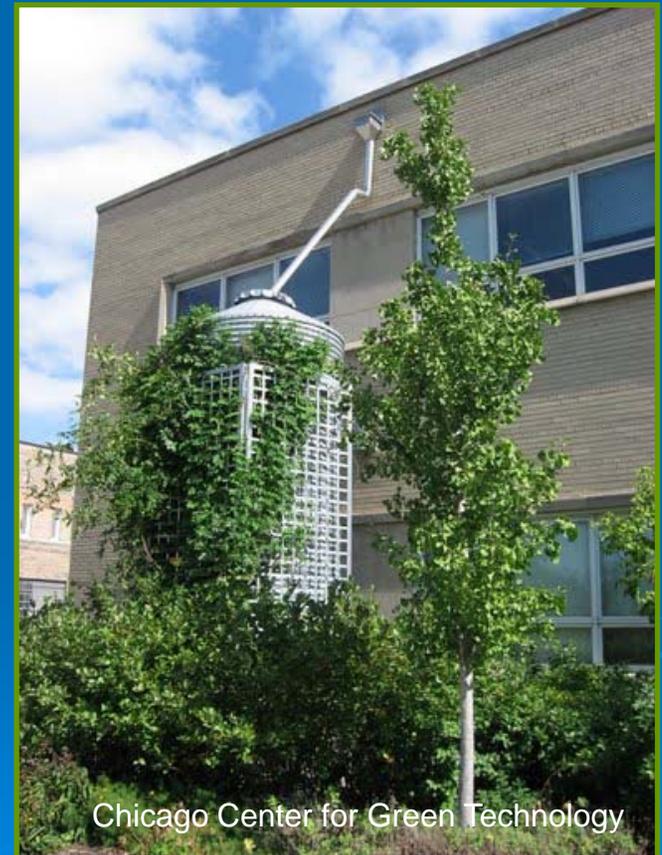
Current* Modeling Guidelines

➤ Explicitly Model

- Estimate average annual runoff volume (V) using continuous model
- Size cisterns to provide storage, V
- For interior reuse, perform monthly water balance
- Subtract roof area from site-wide model if sizing flow control or water quality treatment

➤ Recommendation

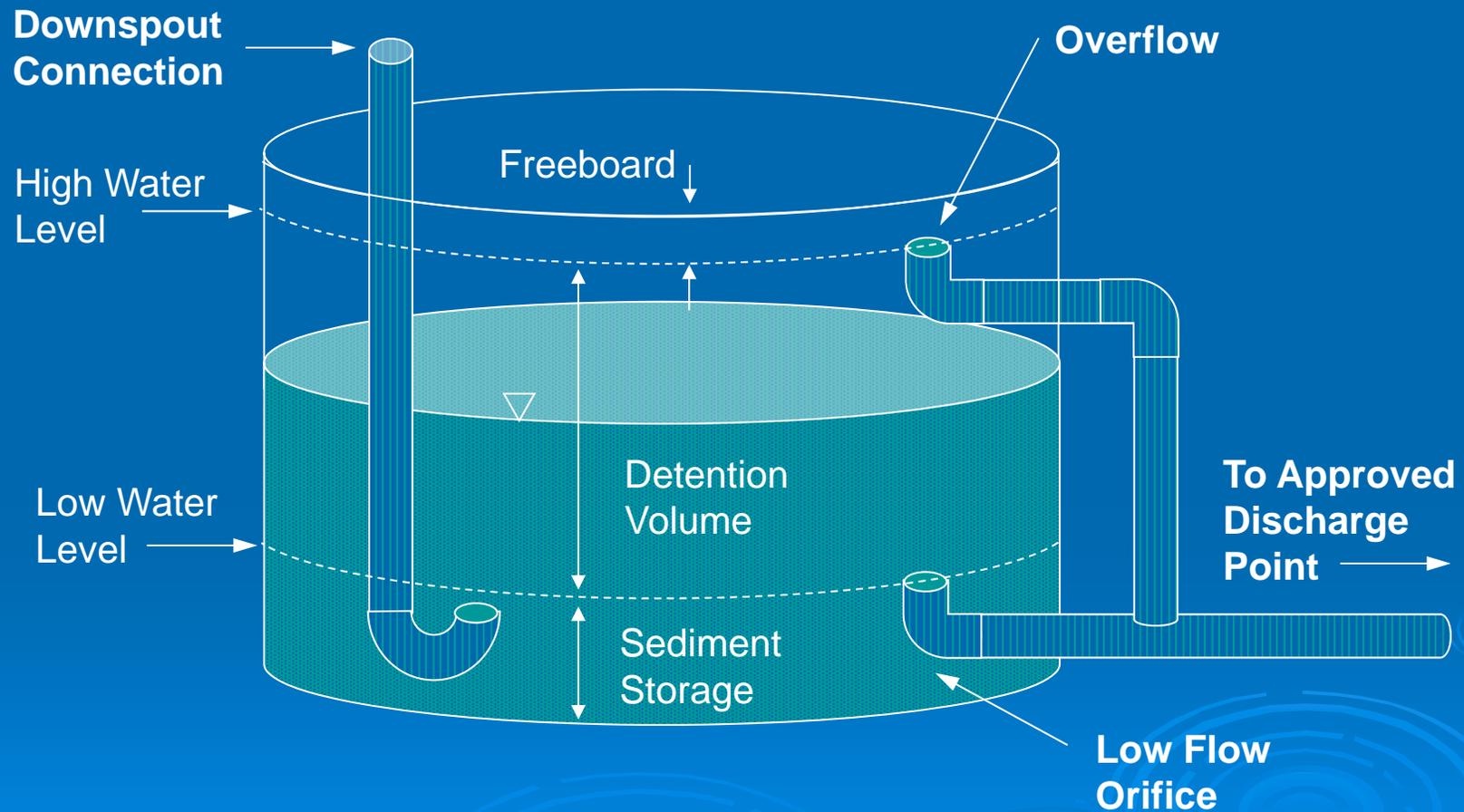
- Perform daily (or sub-daily if rainfall data available) water balance model
- Factor results into site-wide model for flow control sizing



Chicago Center for Green Technology

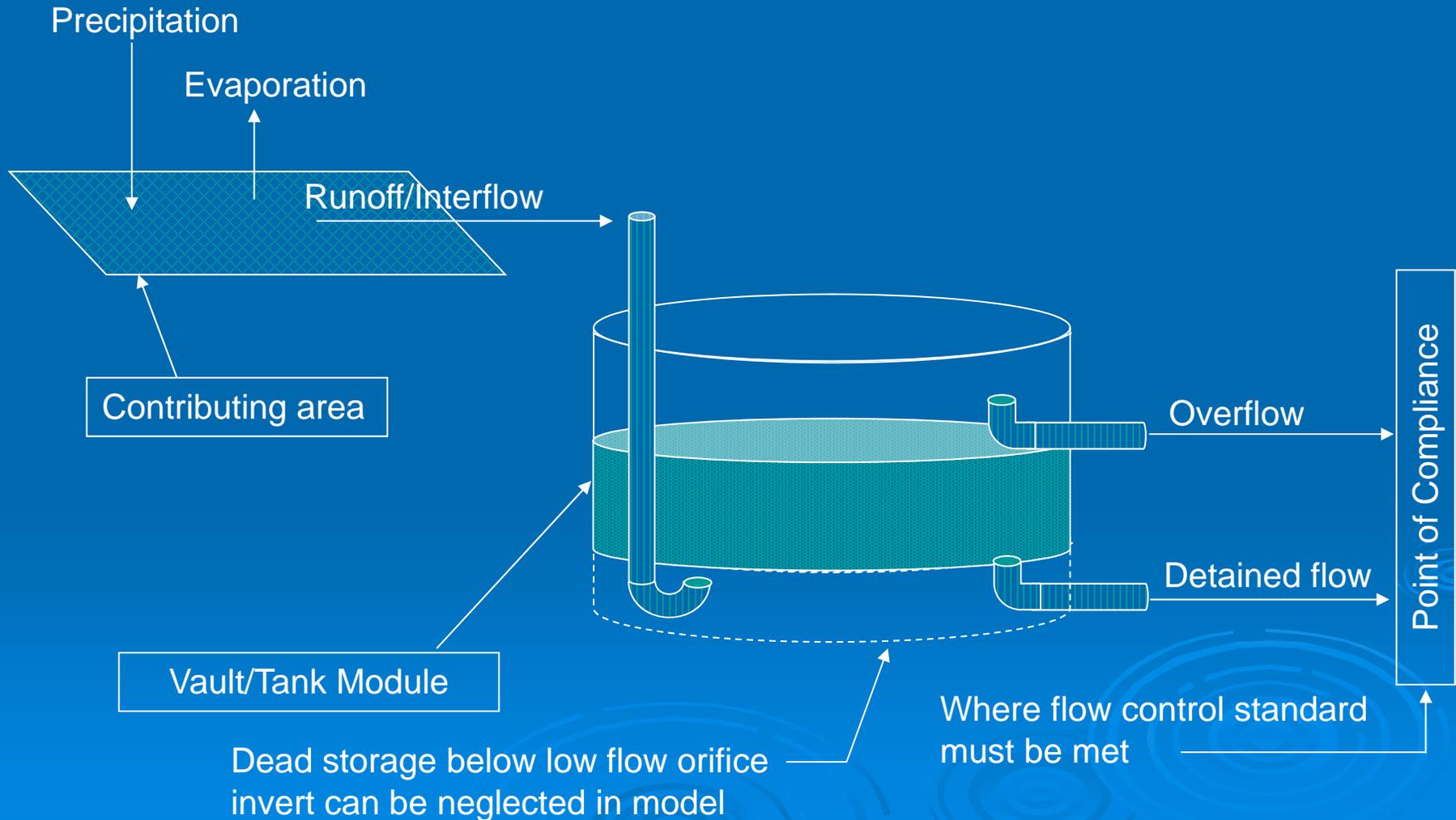
* Same as 2013 permit guidelines

Detention Cisterns Model Representation

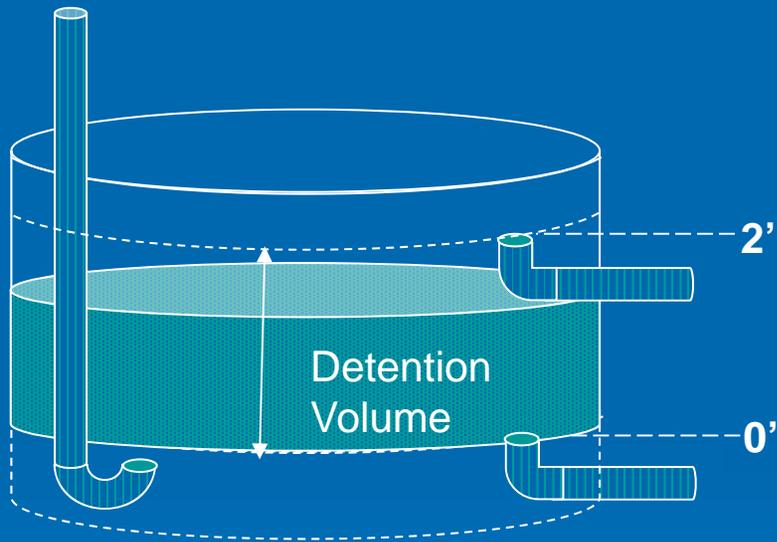


* Can add faucet for rainwater reuse upstream of low flow orifice

Detention Cisterns Model Representation

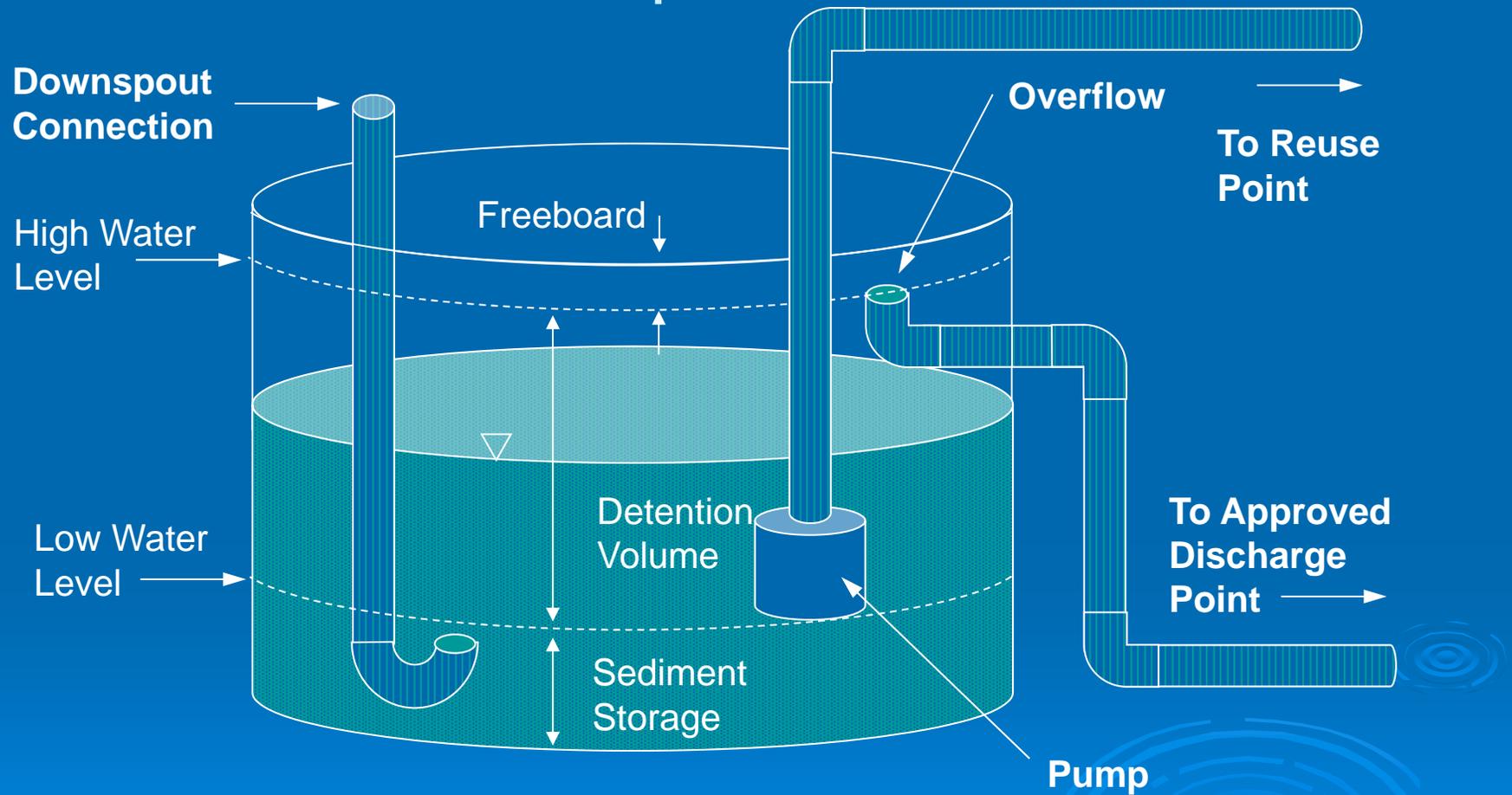


Detention Cisterns Routing



Stage (ft)	Area (sf)	Storage (cf)	Low Flow (cfs)	Overflow (cfs)
0.00	0	0	0	0
0.25	28	7	0.0008	0
0.50	28	14	0.0012	0
0.75	28	21	0.0014	0
1.00	28	28	0.0016	0
1.25	28	35	0.0018	0
1.50	28	42	0.0020	0
1.75	28	49	0.0022	0
2.00	28	56	0.0024	0
2.25	28	63	0.0026	0.4
2.50	28	70	0.0028	1.15

Harvesting Cisterns Model Representation



* Can add faucet for rainwater reuse
and/or low flow orifice

Harvesting Cistern Example

Water Reuse/ Flow Control

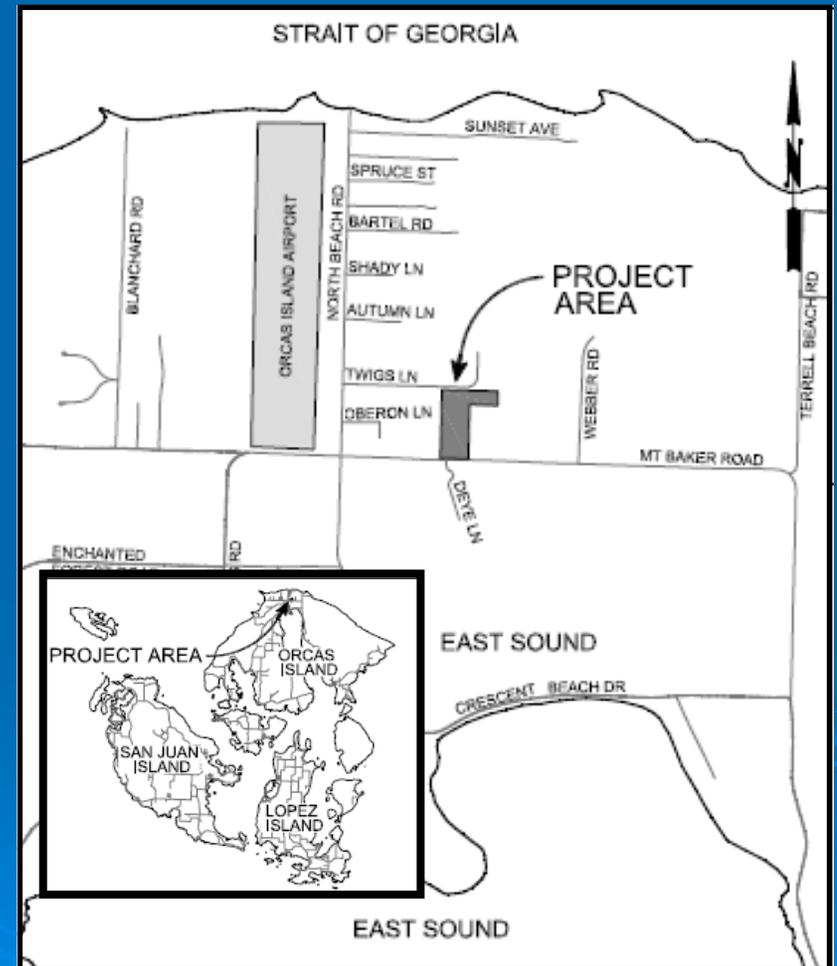
OPAL Community Land Trust, Orcas Island



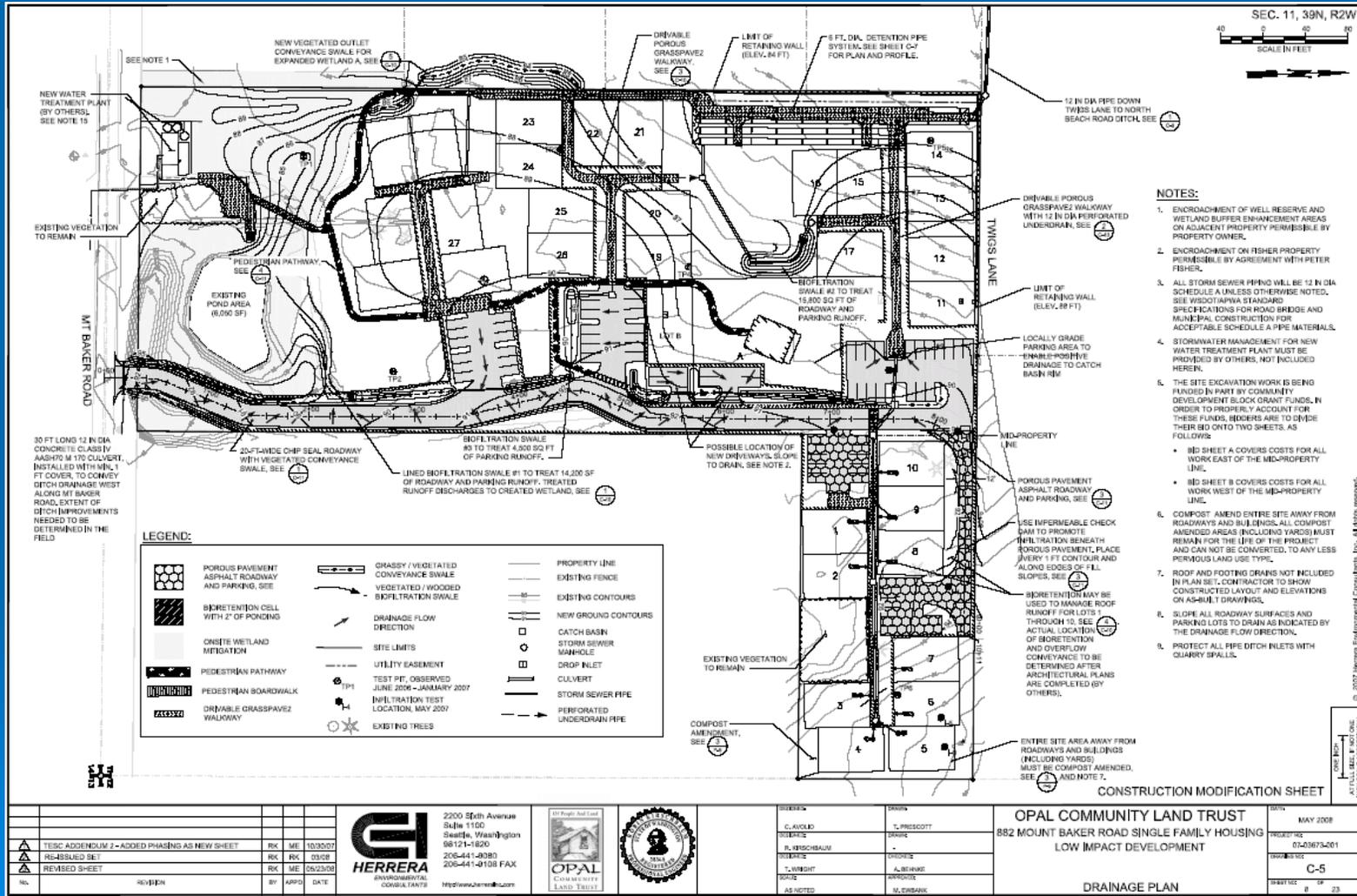
Flow Control

OPAL - Site Location

- Eastsound, WA (Orcas Island)
- 7-acre site, 34 new homes, average roof size = 995 sq. ft.
- 3,000 gallon underground cisterns with indoor reuse
- Daily water balance model in EXCEL
- Size residual detention and WQ for remainder of site (e.g., roadways, driveways, lawns) → 2005 DOE

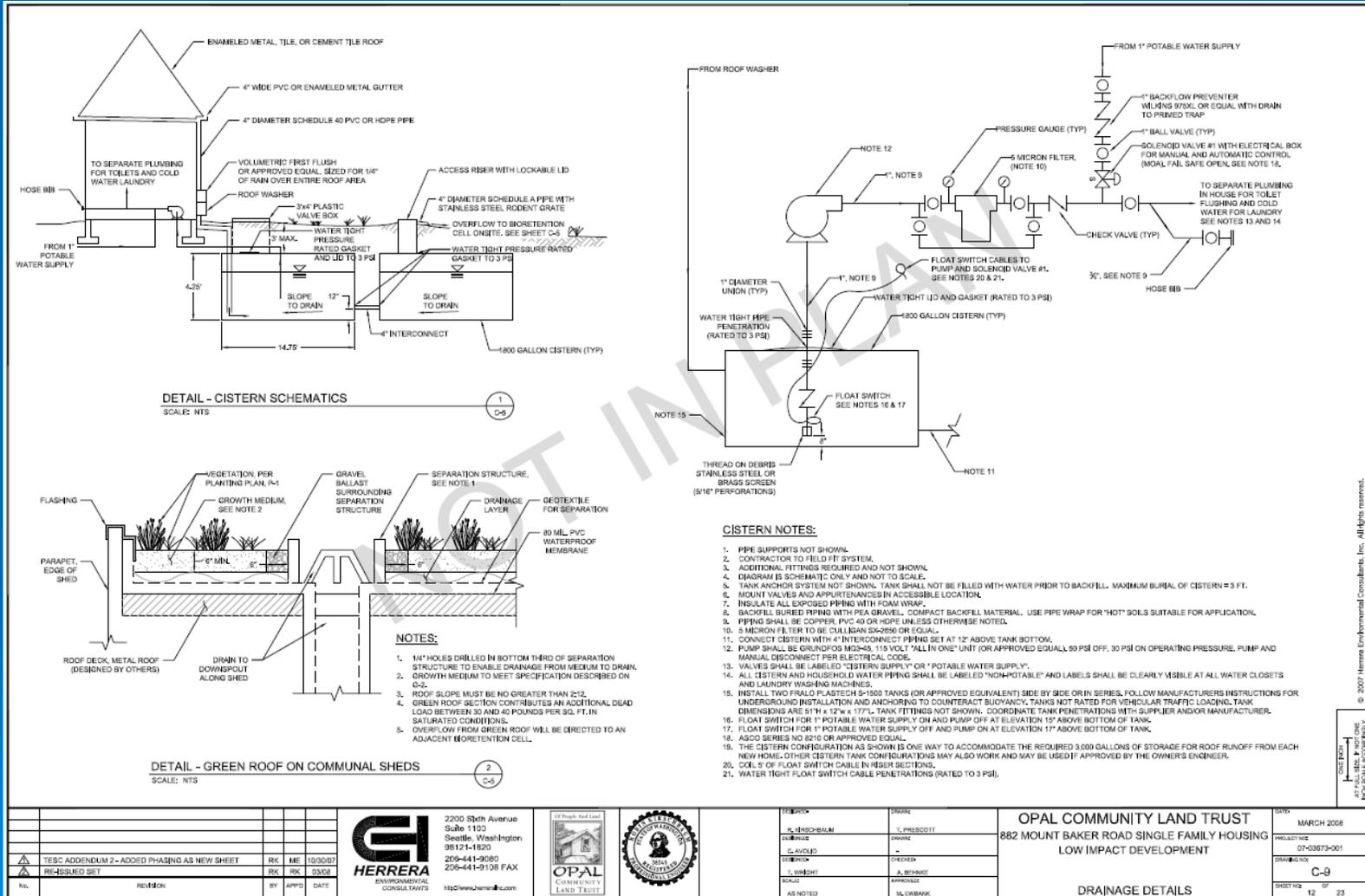


Flow Control OPAL - Site Plan



Flow Control

OPAL – Design of Cisterns for Reuse



© 2007 Herra Environmental Consultants, Inc. All rights reserved.

HERRERA
ENVIRONMENTAL CONSULTANTS

2200 5th Avenue
Suite 1100
Seattle, Washington
98121-1500
206-441-9080
206-441-9108 FAX
http://www.herrera.com



DESIGNED BY	SKR	CHECKED BY	SKR
DRAWN BY	SKR	APPROVED BY	SKR
SCALE	AS NOTED	DATE	

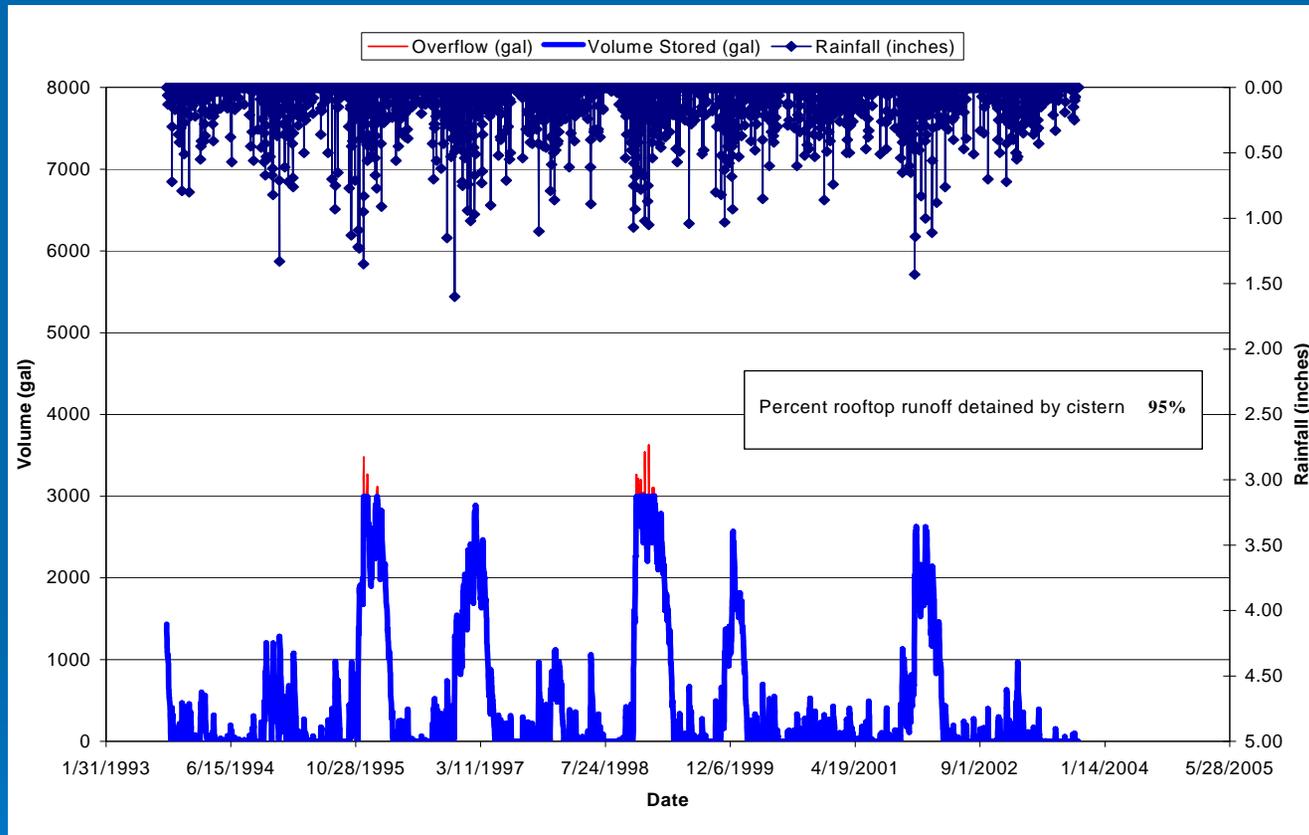
OPAL COMMUNITY LAND TRUST
882 MOUNT BAKER ROAD SINGLE FAMILY HOUSING
LOW IMPACT DEVELOPMENT

DATE	MARCH 2008
PROJECT NO.	07-03873-001
DRAWING NO.	C-9
SHEET NO.	12
OF	23

DRAINAGE DETAILS

Flow Control

OPAL – Evaluation of Cisterns for Reuse

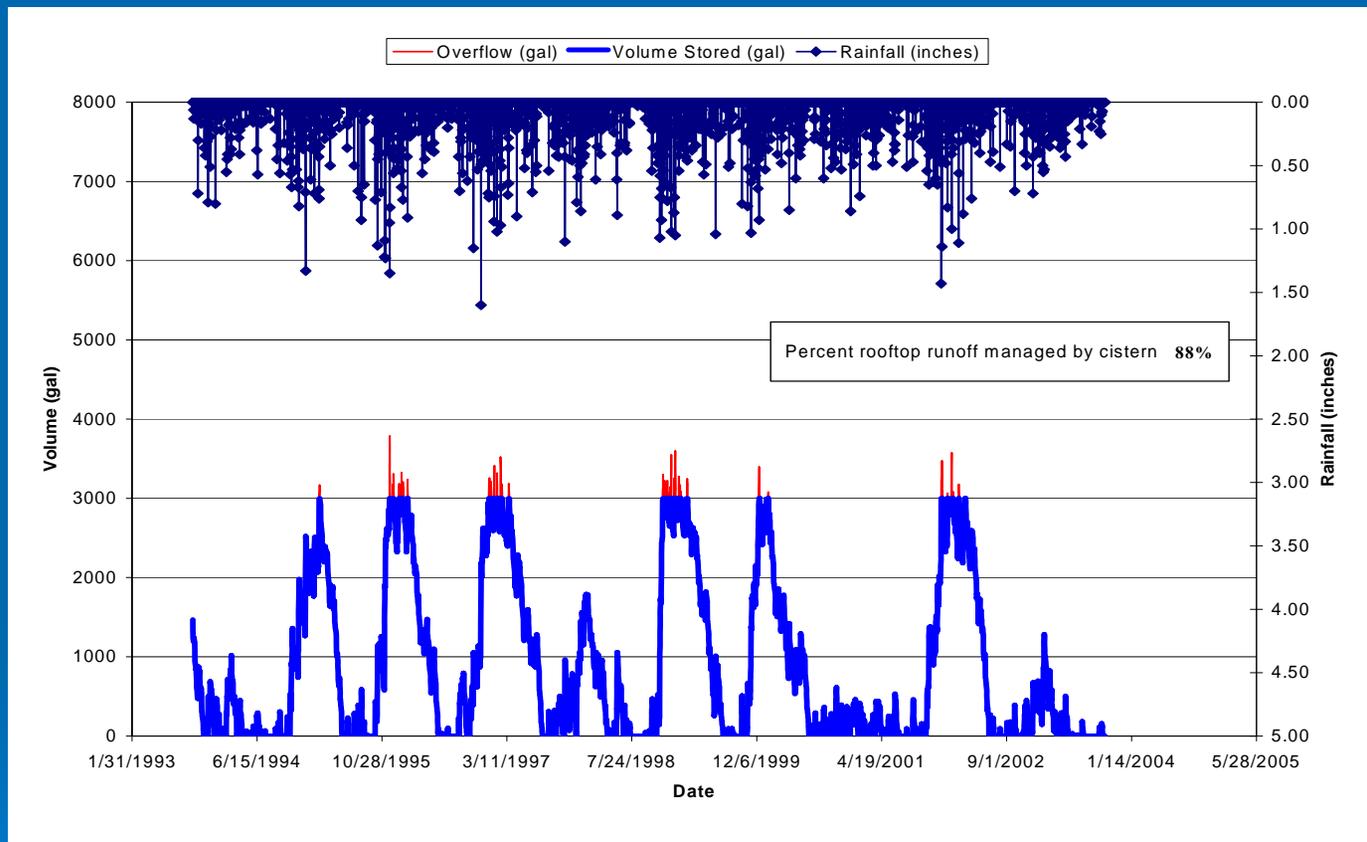


Notes:

1. Large home (1,050 sq. ft. roof)
2. Assume 4 people per house
3. Assume (2) 1,500-gal underground cisterns with indoor plumbing for toilet flushing, cold water for laundry, and irrigation
4. Total daily water demand for reuse assumed to be 90 gal/day
5. Using daily rainfall data from OLGA station (Orcas Island)

Flow Control

OPAL – Evaluation of Cisterns for Reuse

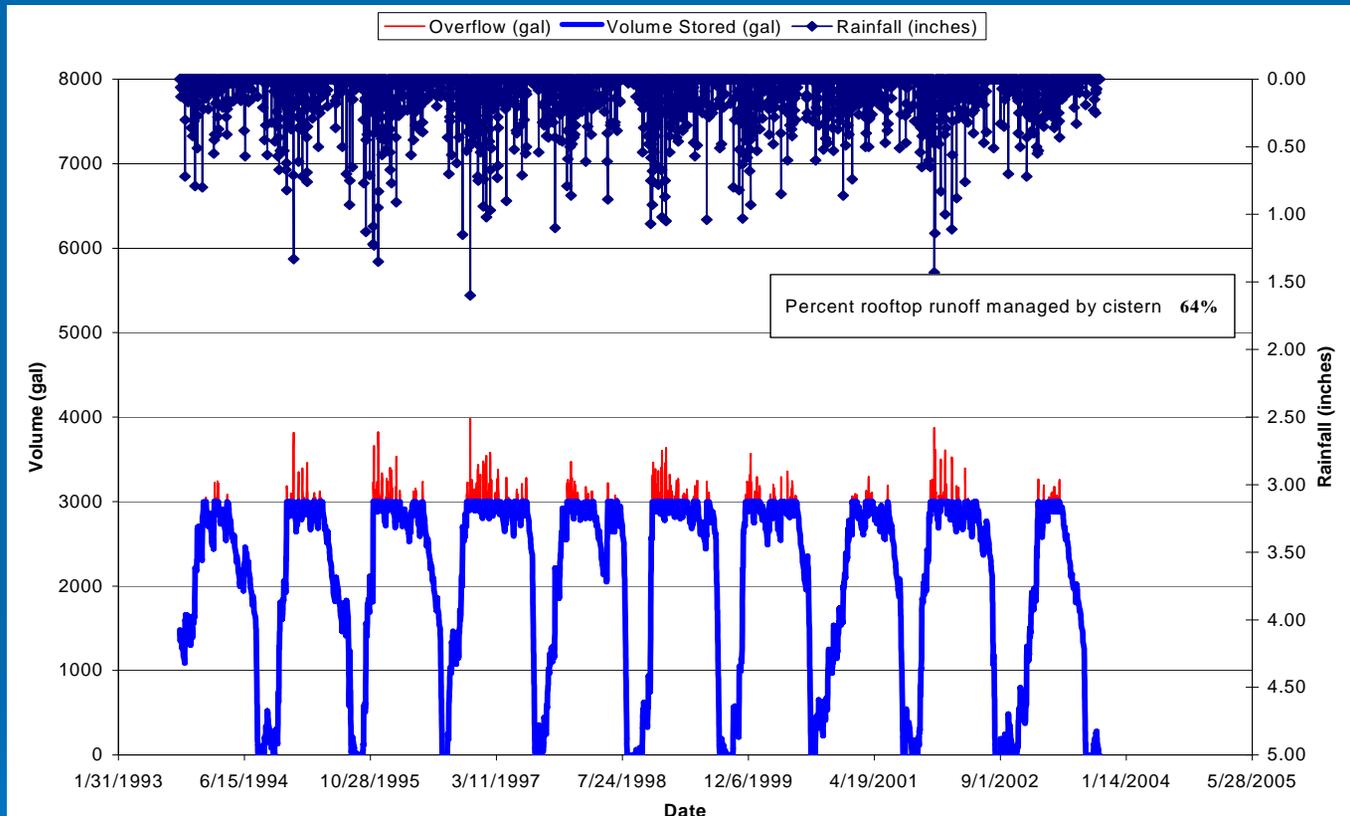


Notes:

1. Average home size (995 sq. ft. roof)
2. Assume 4 people per house
3. Assume (2) 1,500-gal underground cisterns with indoor plumbing for toilet flushing, cold water for laundry, and irrigation
4. Total daily water demand for reuse assumed to be 58 gal/day
5. Using daily rainfall data from OLGA station (Orcas Island)

Flow Control

OPAL – Evaluation of Cisterns for Reuse



Notes:

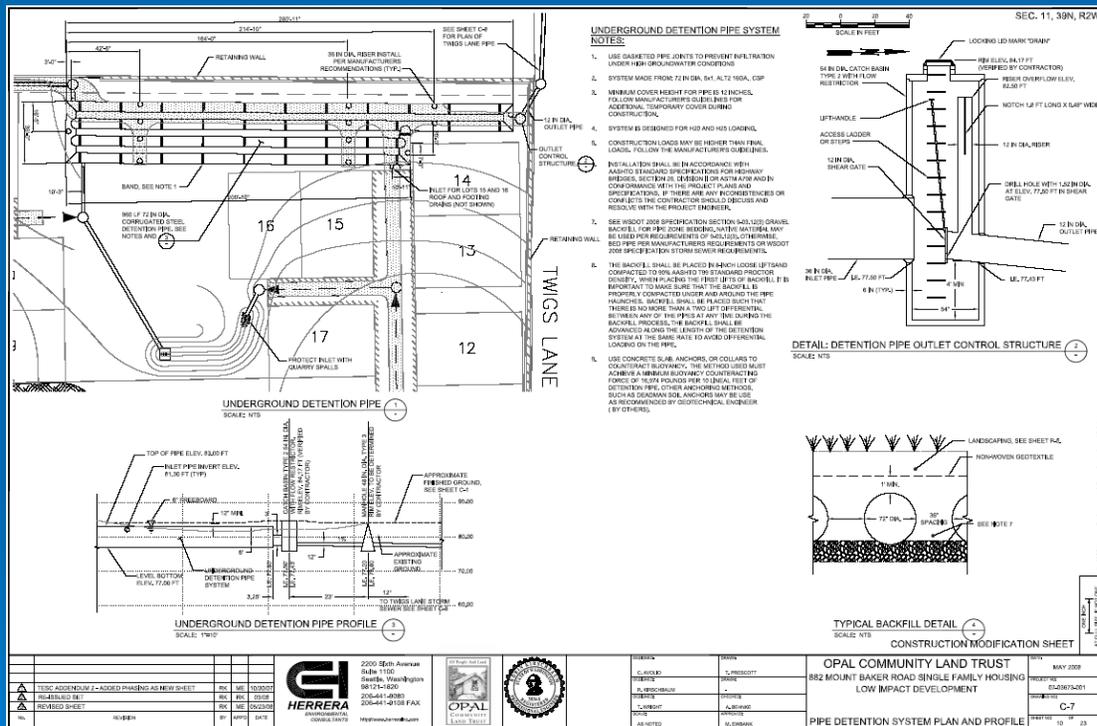
1. Average home size (995 sq. ft. roof)
2. Assume 2 people per house
3. Assume (2) 1,500-gal underground cisterns with indoor plumbing for toilet flushing, cold water for laundry, and irrigation
4. Total daily water demand for reuse assumed to be 29 gal/day
5. Using daily rainfall data from OLGA station (Orcas Island)

Flow Control

OPAL – Residual Flow Control and WQ Treatment

➤ Modeling Approach

- Continuous hydrologic model
- Larger sites → can lump total roof area and route through equivalent lumped cistern
- Smaller sites → can explicitly model individual cistern performance within site-wide model



Detention Cistern Example

Peak Reduction/ Flow Control

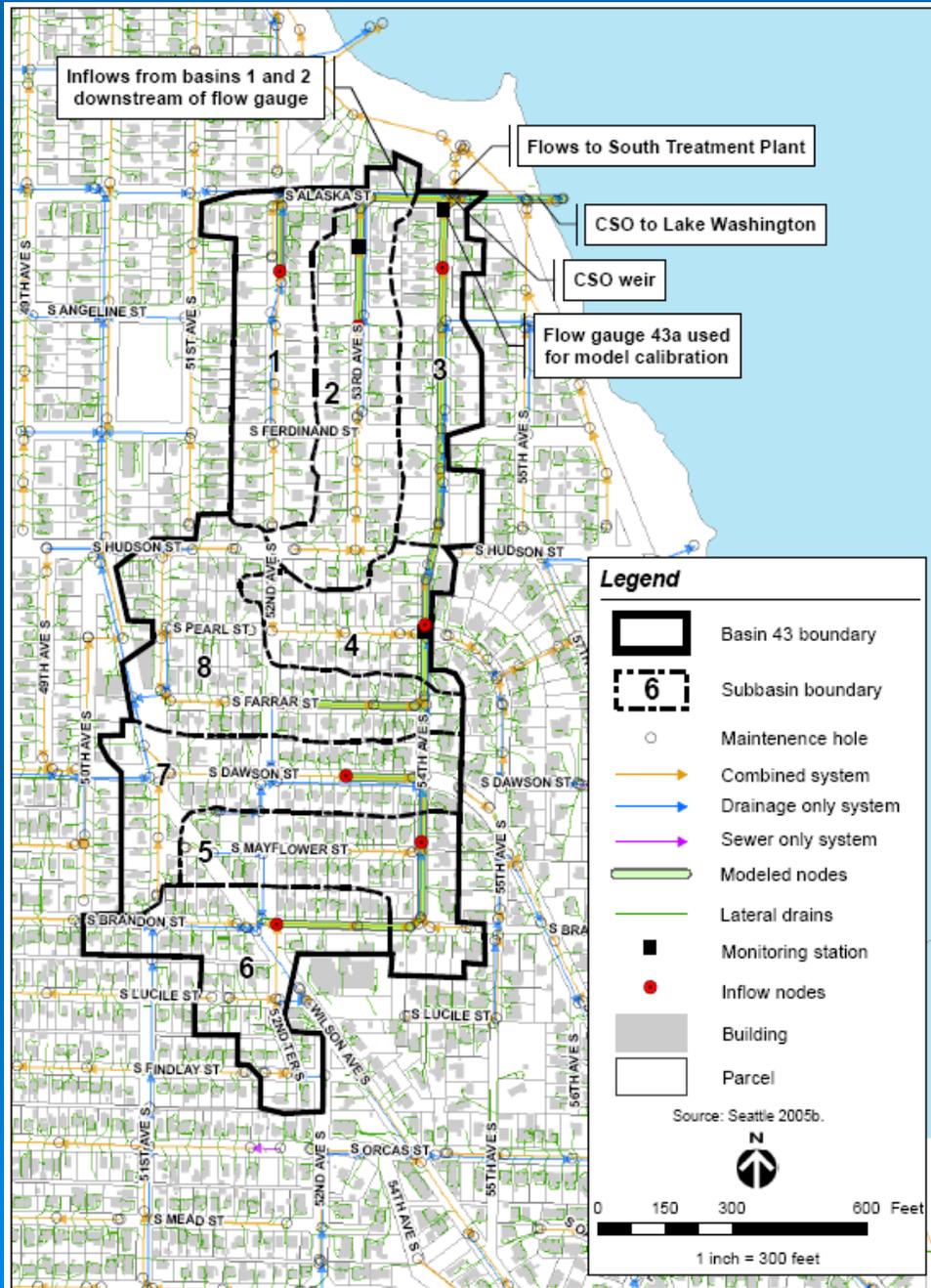
Lakewood RainCatchers, Seattle





Peak Reduction

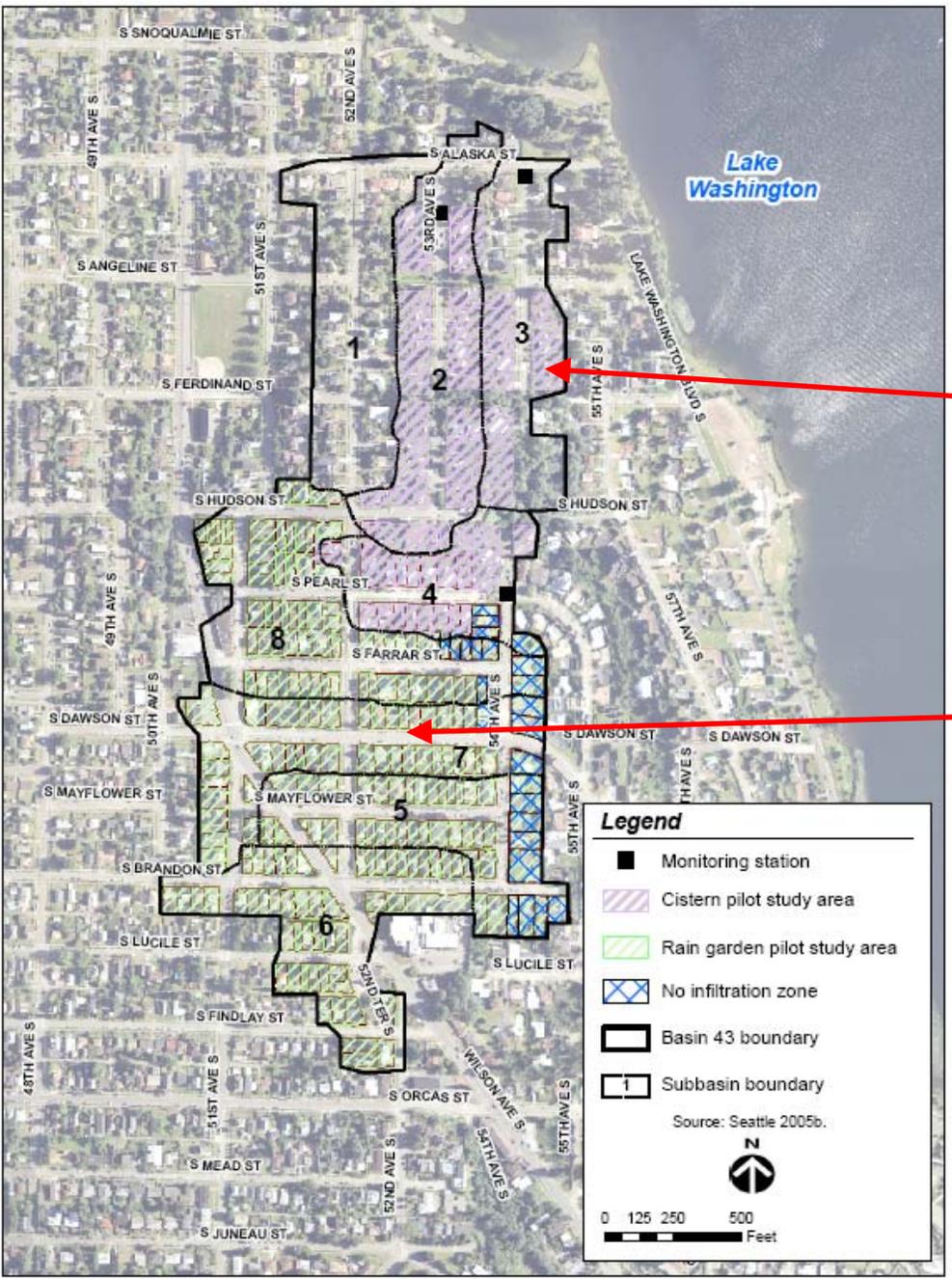
- Lakewood RainCatchers Project
- SPU pilot project to reduce CSOs
- 75-acre residential neighborhood
- 300 homes
- BMPs
 - Cisterns
 - Rain gardens



Peak Reduction

- Partially combined system
 - Roofs to combined
 - Streets to separated
- Combined system modeled in InfoWorks CS

Peak Reduction



Cistern areas

Rain garden areas

Peak Reduction

➤ Cistern modeling method

- Typical rooftop / cistern scenario for individual home modeled in WWHM3
 - Half roof (870 sf) routed to cistern (500 gallon)
- Detained runoff timeseries exported and multiplied by the number of homes in the basin
- Imported into InfoWorks CS to evaluate performance

Peak Reduction

➤ Precipitation/Evap. Data → Import timeseries from InfoWorks model

➤ Computational Time Step → 15 minutes, 5 minutes preferred

The screenshot displays the WWHM3 Pro software interface. The main window title is "WWHM3 Pro RC-cistern0.25in". The menu bar includes "File", "Edit", "View", and "Help". The "View" menu is circled in red, with a red arrow pointing to the "Option Menu" label. Below the menu bar is a toolbar with several icons, including a globe, a tree, a bar chart, a document, a circled icon of a hand holding a pencil, and a house with "+LID".

The "Options" dialog is open, showing the "Timestep" tab. The "Timestep" section has radio buttons for "5-Minute", "15-Minute", "30-Minute", "Hourly", and "Daily". The "15-Minute" option is selected and circled in red, with a red arrow pointing to the "Computational Time Step" text. The "Options" dialog also has "Restore Defaults" and "Update" buttons.

The "Load Alternate Precip" dialog is open, showing the "Precip Time Series" section. The "Copy To:" section has radio buttons for "Precip" (selected) and "Evap". The "Start Date" is "01/10/2001" and the "End Date" is "11/30/2005". The "Use Alternate Precip/evap" checkbox is checked. The "Choose Input Dataset" section lists three datasets: "1 15min prec (in/hr)", "2 15min evap", and "3 15min prec (in)". The "ALTERNATE PRECIP" button in the "Standard Import Features" section is circled in red, with a red arrow pointing to the "Option Menu" label.

Peak Reduction

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

The screenshot displays the WWHM3 Pro software interface. The main window is titled "Basin 1 Predeveloped". On the left, the "SCENARIOS" panel shows "Predeveloped" selected. Below it, the "ELEMENTS" panel shows a grid of land cover options, with one element highlighted. The right-hand panel contains configuration options for the basin, including "Subbasin Name" (Basin 1), "Flows To" (Surface, Interflow, Groundwater), and "Show Only Selected" (unchecked). The "Available Pervious" and "Available Impervious" lists are shown. In the "Available Impervious" list, "ROADS MOD" is selected with a value of 0.02. The "Pervious Total" is 0 Acres, and the "Impervious Total" is 0.02 Acres. The "Basin Total" is 0.02 Acres. The "Select By" dropdown is set to "GO".

Available Pervious	
<input type="checkbox"/> A/B, Forest, Flat	0
<input type="checkbox"/> A/B, Forest, Mod	0
<input type="checkbox"/> A/B, Forest, Steep	0
<input type="checkbox"/> A/B, Pasture, Flat	0
<input type="checkbox"/> A/B, Pasture, Mod	0
<input type="checkbox"/> A/B, Pasture, Steep	0
<input type="checkbox"/> A/B, Lawn, Flat	0
<input type="checkbox"/> A/B, Lawn, Mod	0
<input type="checkbox"/> A/B, Lawn, Steep	0
<input type="checkbox"/> C, Forest, Flat	0
<input type="checkbox"/> C, Forest, Mod	0
<input type="checkbox"/> C, Forest, Steep	0
<input type="checkbox"/> C, Pasture, Flat	0
<input type="checkbox"/> C, Pasture, Mod	0
<input type="checkbox"/> C, Pasture, Steep	0
<input type="checkbox"/> C, Lawn, Flat	0
<input type="checkbox"/> C, Lawn, Mod	0
<input type="checkbox"/> C, Lawn, Steep	0

Available Impervious	
<input type="checkbox"/> ROADS/FLAT	0
<input checked="" type="checkbox"/> ROADS MOD	0.02
<input type="checkbox"/> ROADS/STEEP	0
<input type="checkbox"/> ROOF TOPS/FLAT	0
<input type="checkbox"/> DRIVEWAYS/FLAT	0
<input type="checkbox"/> DRIVEWAYS/MOD	0
<input type="checkbox"/> DRIVEWAYS/STEEP	0
<input type="checkbox"/> SIDEWALKS/FLAT	0
<input type="checkbox"/> SIDEWALKS/MOD	0
<input type="checkbox"/> SIDEWALKS/STEEP	0
<input type="checkbox"/> PARKING/FLAT	0
<input type="checkbox"/> PARKING/MOD	0
<input type="checkbox"/> PARKING/STEEP	0
<input type="checkbox"/> POND	0

Pervious Total: 0 Acres
Impervious Total: 0.02 Acres
Basin Total: 0.02 Acres

Peak Reduction

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

The screenshot displays the WWHM3 Pro software interface for configuring a basin. The main window is titled "Basin 1 Mitigated".

SCENARIOS: The "Mitigated" scenario is selected, indicated by a red circle around the checkbox.

ELEMENTS: A red circle highlights a specific element icon in the left-hand menu.

Basin 1 Mitigated Properties:

- Subbasin Name: Basin 1
- Flows To: Surface (Vault 1), Interflow (Vault 1), Groundwater (Vault 1)
- Area in Basin: 0.02 Acres
- Available Pervious: A/B. Forest, Flat (0), A/B. Forest, Mod (0), A/B. Forest, Steep (0), A/B. Pasture, Flat (0), A/B. Pasture, Mod (0), A/B. Pasture, Steep (0), A/B. Lawn, Flat (0), A/B. Lawn, Mod (0), A/B. Lawn, Steep (0), C. Forest, Flat (0), C. Forest, Mod (0), C. Forest, Steep (0), C. Pasture, Flat (0), C. Pasture, Mod (0), C. Pasture, Steep (0), C. Lawn, Flat (0), C. Lawn, Mod (0), C. Lawn, Steep (0)
- Available Impervious: ROADS/FLAT (0), **ROADS MOD (.02)** (circled in red), ROADS/STEEP (0), ROOF TOPS/FLAT (0), DRIVEWAYS/FLAT (0), DRIVEWAYS/MOD (0), DRIVEWAYS/STEEP (0), SIDEWALKS/FLAT (0), SIDEWALKS/MOD (0), SIDEWALKS/STEEP (0), PARKING/FLAT (0), PARKING/MOD (0), PARKING/STEEP (0), POND (0)
- Pervious Total: 0 Acres
- Impervious Total: 0.02 Acres
- Basin Total: 0.02 Acres
- Select By: 60

Peak Reduction

Developed Mitigated Basin Continued: Route to vault module

The screenshot displays the WWHM3 Pro software interface for configuring a vault module. The main window is titled "Vault 1 Mitigated".

SCHEMATIC

The schematic shows a grid with a rain icon and a vault icon labeled "A1". The vault icon is highlighted with a green box. The "Mitigated" scenario is selected in the "SCENARIOS" list, and a vault icon is also highlighted in the "ELEMENTS" list.

Vault 1 Mitigated Configuration

Facility Name: Vault 1

Outlet 1: 0, **Outlet 2:** 0, **Outlet 3:** 0

Downstream Connection: 0

Facility Type: Vault

Precipitation Applied to Facility

Evaporation Applied to Facility

Fixed Width For Auto Vault

Facility Bottom Elevation (ft): 0

Facility Dimensions:

Length	7
Width	4
Effective Depth	2.5

Outlet Structure:

Riser Height (ft)	2
Riser Diameter(in)	4
Riser Type	Flat
Notch Type	

Infiltration: NO

Orifice Table:

Orifice Number	Diameter (In)	Height (Ft)	QMax (cfs)
1	0.25	0	0.00232
2	0	0	0
3	0	0	0

Pond Volume at Riser Head (acre-ft): .001

Pond Increment: 0.10

Show Pond Table: Open Table

Peak Reduction

Stage Storage Discharge Table

Stage (ft)	Area (acres)	Storage (acre-ft)	Dschrge (cfs)
0.000000	0.000643	0.000000	0.000000
0.027778	0.000643	0.000018	0.000000
0.055556	0.000643	0.000036	0.000000
0.083333	0.000643	0.000054	0.000000
0.111111	0.000643	0.000071	0.000000
0.138889	0.000643	0.000089	0.000000
0.166667	0.000643	0.000107	0.000000
0.194444	0.000643	0.000125	0.000000
0.222222	0.000643	0.000143	0.000000
0.250000	0.000643	0.000161	0.000000
0.277778	0.000643	0.000179	0.000000
0.305556	0.000643	0.000196	0.000000
0.333333	0.000643	0.000214	0.000000
0.361111	0.000643	0.000232	0.000000
0.388889	0.000643	0.000250	0.000000
0.416667	0.000643	0.000268	0.000000
0.444444	0.000643	0.000286	0.000000
0.472222	0.000643	0.000304	0.000000
0.500000	0.000643	0.000321	0.000000
0.527778	0.000643	0.000339	0.000274
0.555556	0.000643	0.000357	0.000387
0.583333	0.000643	0.000375	0.000474
0.611111	0.000643	0.000393	0.000547
0.638889	0.000643	0.000411	0.000612
0.666667	0.000643	0.000429	0.000670
0.694444	0.000643	0.000446	0.000724
0.722222	0.000643	0.000464	0.000774
0.750000	0.000643	0.000482	0.000821
0.777778	0.000643	0.000500	0.000865
0.805556	0.000643	0.000518	0.000907
0.833333	0.000643	0.000536	0.000948

Stage (ft)	Area (acres)	Storage (acre-ft)	Dschrge (cfs)
1.694444	0.000643	0.001089	0.001794
1.722222	0.000643	0.001107	0.001815
1.750000	0.000643	0.001125	0.001835
1.777778	0.000643	0.001143	0.001856
1.805556	0.000643	0.001161	0.001876
1.833333	0.000643	0.001178	0.001895
1.861111	0.000643	0.001196	0.001915
1.888889	0.000643	0.001214	0.001935
1.916667	0.000643	0.001232	0.001954
1.944444	0.000643	0.001250	0.001973
1.972222	0.000643	0.001268	0.001992
2.000000	0.000643	0.001286	0.002010
2.027778	0.000643	0.001303	0.017058
2.055556	0.000643	0.001321	0.044557
2.083333	0.000643	0.001339	0.080160
2.111111	0.000643	0.001357	0.122318
2.138889	0.000643	0.001375	0.170134
2.166667	0.000643	0.001393	0.223004
2.194444	0.000643	0.001411	0.280484
2.222222	0.000643	0.001428	0.342229
2.250000	0.000643	0.001446	0.407963
2.277778	0.000643	0.001464	0.477458
2.305556	0.000643	0.001482	0.550518
2.333333	0.000643	0.001500	0.626980
2.361111	0.000643	0.001518	0.706696
2.388889	0.000643	0.001536	0.789540
2.416667	0.000643	0.001553	0.875397
2.444444	0.000643	0.001571	0.964165
2.472222	0.000643	0.001589	1.055752
2.500000	0.000643	0.001607	1.150074

← Overflow

Peak Reduction

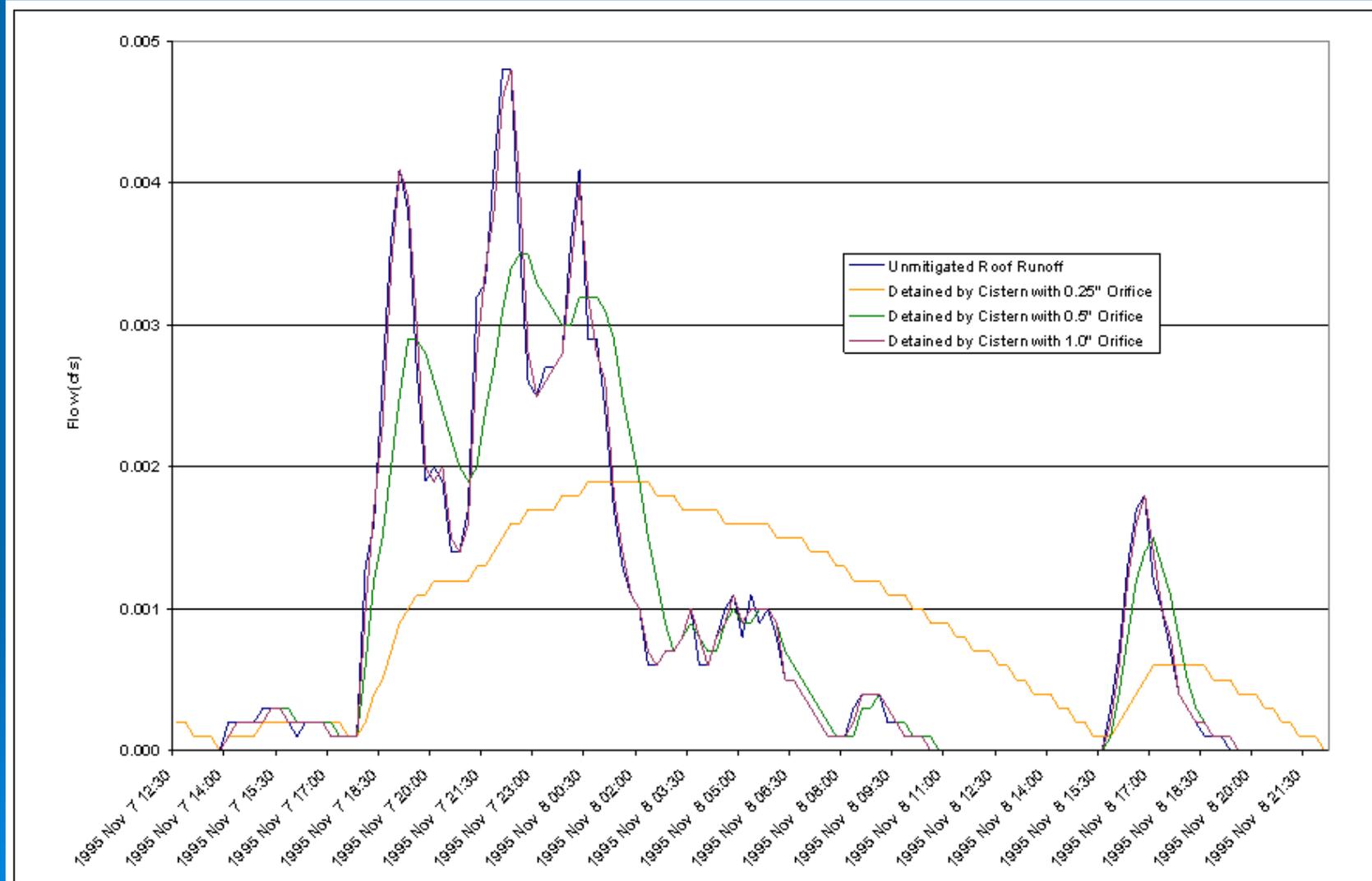
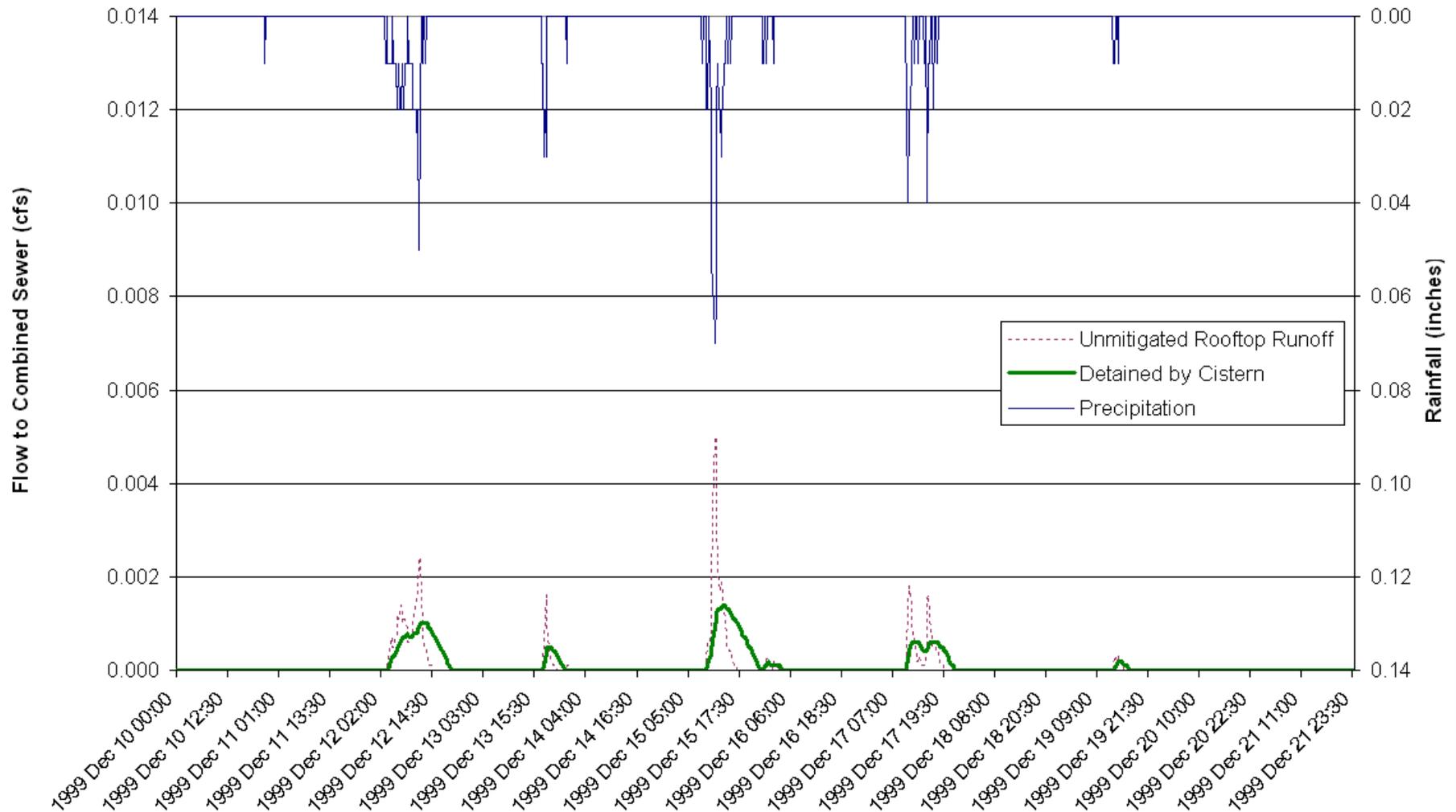


Figure 17. Comparison of roof runoff detention benefits for cisterns with varying orifice sizes.

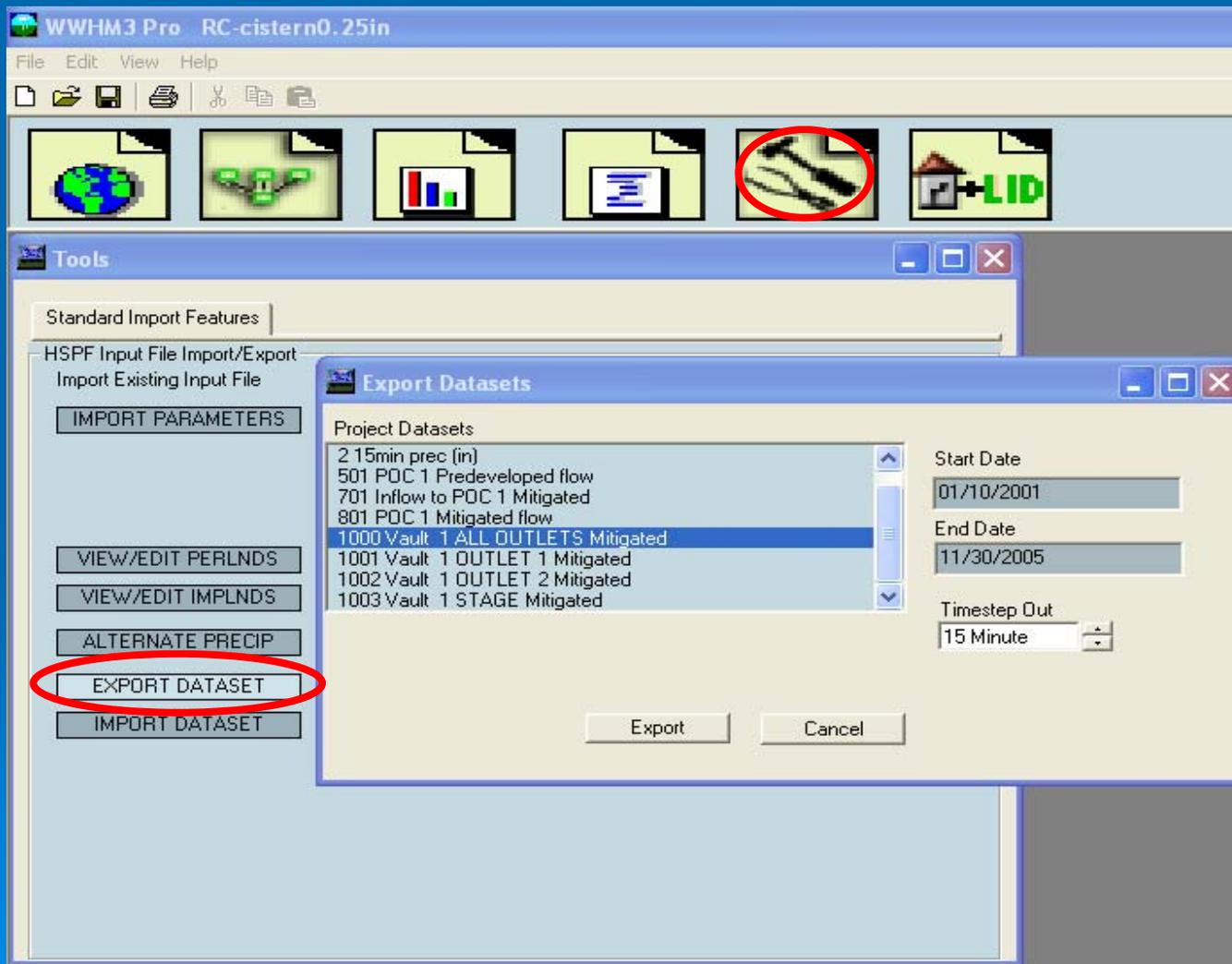
Peak Reduction

Figure 10. Performance of a cistern for a typical parcel



Peak Reduction

Time Series Export



Peak Reduction

Time Series Import to InfoWorks

The screenshot displays the InfoWorks CS [4.50] interface. The title bar reads "InfoWorks CS [4.50] - [GeoPlan - Existing Conditions - 100% Rooftop to Cisterns]". The menu bar includes File, Edit, Network, Selection, Geo, Results, Tools, Window, and Help. The toolbar contains various icons for navigation and editing. The left pane shows a project tree with the following items:

- Group C Basins 39,40,41,42,43,165
- Group C Networks
 - Existing Conditions
 - Existing Conditions - existing
 - 100% disconnect
 - Existing Conditions-New Areas
 - Group C Flow Data
 - Group C Rainfall
 - Oct-Dec 2000 Graph Templates and Flow Surveys
 - Overflows - Graph Templates and Flow Survey
 - ADS data
 - Group C Networks!
 - Engineering Validation
 - GW Infiltration** (circled in red)
 - Test
 - Cistern Effluent Flow0.5in-Opt1
 - Cistern Effluent Flow0.5in-Opt2
 - Cistern Effluent Flow0.5in-Opt3
 - Cistern Effluent Flow0.25in-Opt1
 - Cistern Effluent Flow0.25in-Opt2
 - Cistern Effluent Flow0.25in-Opt3
 - 20% Cistern Effluent Flow0.25in
 - 100% Cistern Effluent Flow0.25in
- Lake Washington Levels
- Overflow Simulations
- New Calibration Runs
- 5-year
- Theoretical Curves
- Corrected Basin 43 Areas
- Selection Lists
- Statistics Template Group
- Trade Flow
- Group C Waste Water Group - 60 gal/cap/day

The right pane shows a map with a red hatched area representing a catchment or network. The map contains numerous numbered points, including 066-441, 066-402, 066-403, 066-404, 066-406, 066-408, 066-409, 066-416, 066-413, 066-414, 066-415, 066-416, 066-417, 066-418, 066-419, 066-420, 066-421, 066-422, 066-423, 066-424, 066-425, 066-426, 066-427, 066-428, 066-429, 066-430, 066-431, 066-432, 066-433, 066-434, 066-435, 066-436, 066-437, 066-438, 066-439, 066-440, 066-441, 066-442, 066-443, 066-444, 066-445, 066-446, 066-447, 066-448, 066-449, 066-450, 066-451, 066-452, 066-453, 066-454, 066-455, 066-456, 066-457, 066-458, 066-459, 066-460, 066-461, 066-462, 066-463, 066-464, 066-465, 066-466, 066-467, 066-468, 066-469, 066-470, 066-471, 066-472, 066-473, 066-474, 066-475, 066-476, 066-477, 066-478, 066-479, 066-480, 066-481, 066-482, 066-483, 066-484, 066-485, 066-486, 066-487, 066-488, 066-489, 066-490, 066-491, 066-492, 066-493, 066-494, 066-495, 066-496, 066-497, 066-498, 066-499, 066-500, 066-501, 066-502, 066-503, 066-504, 066-505, 066-506, 066-507, 066-508, 066-509, 066-510, 066-511, 066-512, 066-513, 066-514, 066-515, 066-516, 066-517, 066-518, 066-519, 066-520, 066-521, 066-522, 066-523, 066-524, 066-525, 066-526, 066-527, 066-528, 066-529, 066-530, 066-531, 066-532, 066-533, 066-534, 066-535, 066-536, 066-537, 066-538, 066-539, 066-540, 066-541, 066-542, 066-543, 066-544, 066-545, 066-546, 066-547, 066-548, 066-549, 066-550, 066-551, 066-552, 066-553, 066-554, 066-555, 066-556, 066-557, 066-558, 066-559, 066-560, 066-561, 066-562, 066-563, 066-564, 066-565, 066-566, 066-567, 066-568, 066-569, 066-570, 066-571, 066-572, 066-573, 066-574, 066-575, 066-576, 066-577, 066-578, 066-579, 066-580, 066-581, 066-582, 066-583, 066-584, 066-585, 066-586, 066-587, 066-588, 066-589, 066-590, 066-591, 066-592, 066-593, 066-594, 066-595, 066-596, 066-597, 066-598, 066-599, 066-600, 066-601, 066-602, 066-603, 066-604, 066-605, 066-606, 066-607, 066-608, 066-609, 066-610, 066-611, 066-612, 066-613, 066-614, 066-615, 066-616, 066-617, 066-618, 066-619, 066-620, 066-621, 066-622, 066-623, 066-624, 066-625, 066-626, 066-627, 066-628, 066-629, 066-630, 066-631, 066-632, 066-633, 066-634, 066-635, 066-636, 066-637, 066-638, 066-639, 066-640, 066-641, 066-642, 066-643, 066-644, 066-645, 066-646, 066-647, 066-648, 066-649, 066-650, 066-651, 066-652, 066-653, 066-654, 066-655, 066-656, 066-657, 066-658, 066-659, 066-660, 066-661, 066-662, 066-663, 066-664, 066-665, 066-666, 066-667, 066-668, 066-669, 066-670, 066-671, 066-672, 066-673, 066-674, 066-675, 066-676, 066-677, 066-678, 066-679, 066-680, 066-681, 066-682, 066-683, 066-684, 066-685, 066-686, 066-687, 066-688, 066-689, 066-690, 066-691, 066-692, 066-693, 066-694, 066-695, 066-696, 066-697, 066-698, 066-699, 066-700, 066-701, 066-702, 066-703, 066-704, 066-705, 066-706, 066-707, 066-708, 066-709, 066-710, 066-711, 066-712, 066-713, 066-714, 066-715, 066-716, 066-717, 066-718, 066-719, 066-720, 066-721, 066-722, 066-723, 066-724, 066-725, 066-726, 066-727, 066-728, 066-729, 066-730, 066-731, 066-732, 066-733, 066-734, 066-735, 066-736, 066-737, 066-738, 066-739, 066-740, 066-741, 066-742, 066-743, 066-744, 066-745, 066-746, 066-747, 066-748, 066-749, 066-750, 066-751, 066-752, 066-753, 066-754, 066-755, 066-756, 066-757, 066-758, 066-759, 066-760, 066-761, 066-762, 066-763, 066-764, 066-765, 066-766, 066-767, 066-768, 066-769, 066-770, 066-771, 066-772, 066-773, 066-774, 066-775, 066-776, 066-777, 066-778, 066-779, 066-780, 066-781, 066-782, 066-783, 066-784, 066-785, 066-786, 066-787, 066-788, 066-789, 066-790, 066-791, 066-792, 066-793, 066-794, 066-795, 066-796, 066-797, 066-798, 066-799, 066-800, 066-801, 066-802, 066-803, 066-804, 066-805, 066-806, 066-807, 066-808, 066-809, 066-810, 066-811, 066-812, 066-813, 066-814, 066-815, 066-816, 066-817, 066-818, 066-819, 066-820, 066-821, 066-822, 066-823, 066-824, 066-825, 066-826, 066-827, 066-828, 066-829, 066-830, 066-831, 066-832, 066-833, 066-834, 066-835, 066-836, 066-837, 066-838, 066-839, 066-840, 066-841, 066-842, 066-843, 066-844, 066-845, 066-846, 066-847, 066-848, 066-849, 066-850, 066-851, 066-852, 066-853, 066-854, 066-855, 066-856, 066-857, 066-858, 066-859, 066-860, 066-861, 066-862, 066-863, 066-864, 066-865, 066-866, 066-867, 066-868, 066-869, 066-870, 066-871, 066-872, 066-873, 066-874, 066-875, 066-876, 066-877, 066-878, 066-879, 066-880, 066-881, 066-882, 066-883, 066-884, 066-885, 066-886, 066-887, 066-888, 066-889, 066-890, 066-891, 066-892, 066-893, 066-894, 066-895, 066-896, 066-897, 066-898, 066-899, 066-900, 066-901, 066-902, 066-903, 066-904, 066-905, 066-906, 066-907, 066-908, 066-909, 066-910, 066-911, 066-912, 066-913, 066-914, 066-915, 066-916, 066-917, 066-918, 066-919, 066-920, 066-921, 066-922, 066-923, 066-924, 066-925, 066-926, 066-927, 066-928, 066-929, 066-930, 066-931, 066-932, 066-933, 066-934, 066-935, 066-936, 066-937, 066-938, 066-939, 066-940, 066-941, 066-942, 066-943, 066-944, 066-945, 066-946, 066-947, 066-948, 066-949, 066-950, 066-951, 066-952, 066-953, 066-954, 066-955, 066-956, 066-957, 066-958, 066-959, 066-960, 066-961, 066-962, 066-963, 066-964, 066-965, 066-966, 066-967, 066-968, 066-969, 066-970, 066-971, 066-972, 066-973, 066-974, 066-975, 066-976, 066-977, 066-978, 066-979, 066-980, 066-981, 066-982, 066-983, 066-984, 066-985, 066-986, 066-987, 066-988, 066-989, 066-990, 066-991, 066-992, 066-993, 066-994, 066-995, 066-996, 066-997, 066-998, 066-999, 066-1000.

Peak Reduction

Time Series Import to InfoWorks

InfoWorks CS [4.50] - [Inflow (Time Varying Data) - 100% Cistern Effluent Flow0.25in (Read Only)]

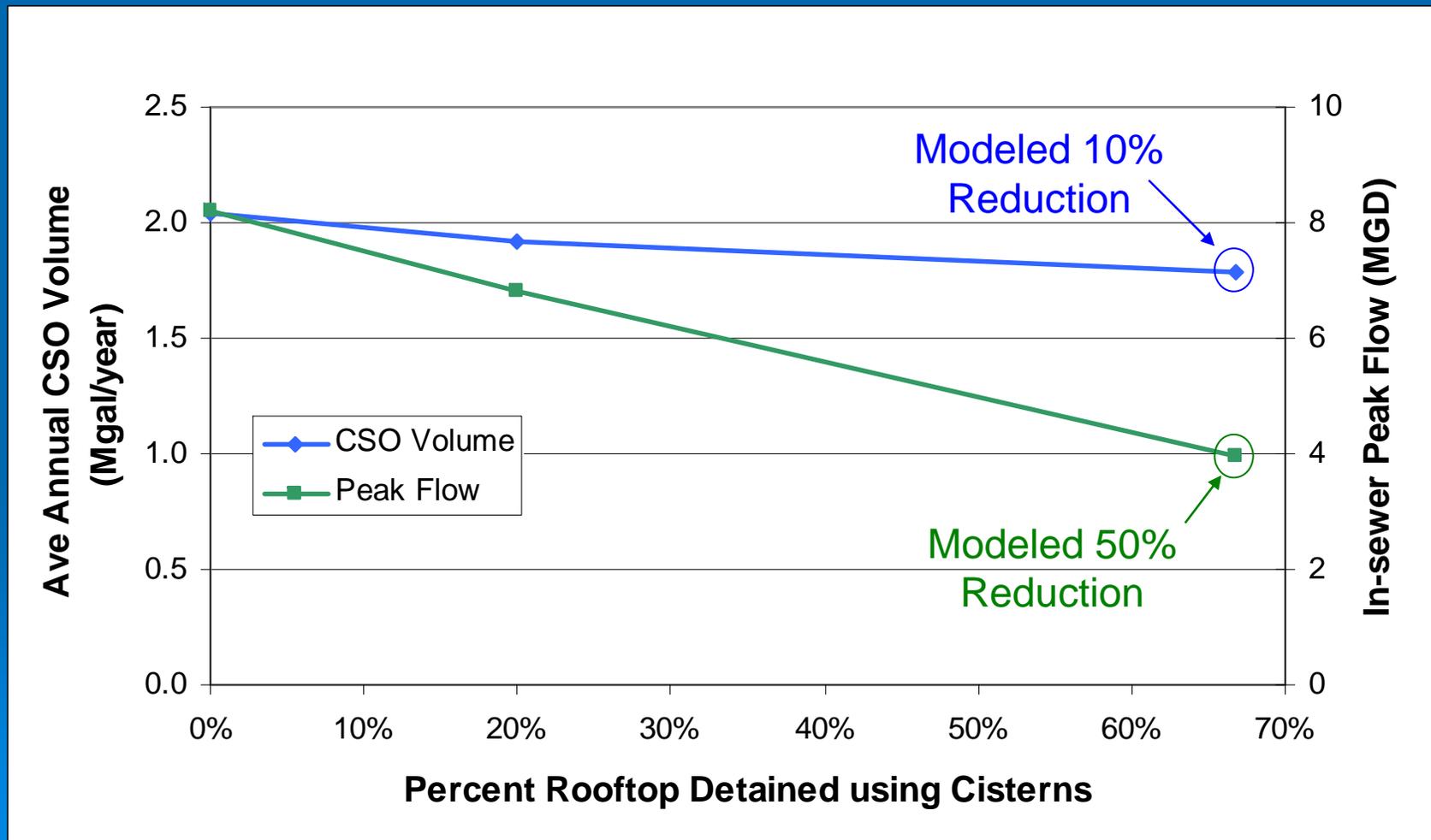
File Edit Event Results Tools Window Help

Item Type User Description

Time	067-008 (MGD)	067-015 (MGD)	067-023 (MGD)	067-029 (MGD)	067-032 (MGD)	067-038 (MGD)	067-045 (MGD)
01-10-95 at 21:15	0.000205	0.000205	0.000091	0.000091	0.000205	0.000205	0.000205
01-10-95 at 21:30	0.000205	0.000205	0.000091	0.000091	0.000205	0.000205	0.000205
01-10-95 at 21:45	0.000205	0.000205	0.000091	0.000091	0.000205	0.000205	0.000205
01-10-95 at 22:00	0.000091	0.000205	0.000091	0.000091	0.000205	0.000091	0.000091
01-10-95 at 22:15	0.000091	0.000091	0.000091	0.000091	0.000205	0.000091	0.000091
01-10-95 at 22:30	0.000091	0.000091	0.000000	0.000000	0.000091	0.000091	0.000091
01-10-95 at 22:45	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
01-10-95 at 23:00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
01-10-95 at 23:15	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
01-10-95 at 23:30	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
01-10-95 at 23:45	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
01-11-95 at 00:00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
01-11-95 at 00:15	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
01-11-95 at 00:30	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
01-11-95 at 00:45	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
01-11-95 at 01:00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
01-11-95 at 01:15	0.000890	0.000890	0.000593	0.000593	0.000890	0.000799	0.000890
01-11-95 at 01:30	0.003310	0.003492	0.002305	0.002305	0.003606	0.003195	0.003310
01-11-95 at 01:45	0.006094	0.006391	0.004200	0.004200	0.006596	0.005797	0.006094
01-11-95 at 02:00	0.008308	0.008696	0.005706	0.005797	0.008993	0.007897	0.008308
01-11-95 at 02:15	0.010294	0.010796	0.007098	0.007098	0.011207	0.009792	0.010294
01-11-95 at 02:30	0.012896	0.013489	0.008810	0.008993	0.013991	0.012302	0.012896
01-11-95 at 02:45	0.016000	0.016799	0.011001	0.011093	0.017392	0.015292	0.016000
01-11-95 at 03:00	0.018100	0.018990	0.012394	0.012599	0.019606	0.017301	0.018100
01-11-95 at 03:15	0.018990	0.019994	0.013101	0.013193	0.020702	0.018191	0.018990
01-11-95 at 03:30	0.019492	0.020496	0.013398	0.013603	0.021204	0.018693	0.019492
01-11-95 at 03:45	0.019310	0.020291	0.013307	0.013398	0.020999	0.018511	0.019310
01-11-95 at 04:00	0.018807	0.019698	0.012896	0.013101	0.020405	0.018009	0.018807
01-11-95 at 04:15	0.018009	0.018899	0.012394	0.012508	0.019492	0.017210	0.018009
01-11-95 at 04:30	0.017004	0.017803	0.011709	0.011800	0.018397	0.016297	0.017004
01-11-95 at 04:45	0.015909	0.016708	0.010910	0.011093	0.017301	0.015201	0.015909
01-11-95 at 05:00	0.014790	0.015498	0.010111	0.010294	0.016000	0.014106	0.014790
01-11-95 at 05:15	0.013489	0.014197	0.009290	0.009404	0.014608	0.012896	0.013489
01-11-95 at 05:30	0.012211	0.012805	0.008399	0.008491	0.013193	0.011709	0.012211
01-11-95 at 05:45	0.011001	0.011504	0.007509	0.007601	0.011892	0.010498	0.011001

Peak Reduction

Preliminary Results, Basin-Wide InfoWorks Model



Resources

- LID Technical Guidance Manual
http://www.pierce.wsu.edu/Water_Quality/LID/LID_manual2005.pdf
(Draft 2012 Manual does not yet have modeling section developed)
- 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

???



Contact Information

- Alice Lancaster, PE
alancaster@herrerainc.com



- Robin Kirschbaum, PE, LEED
robin.kirschbaum@hdrinc.com

