

Hydrologic Modeling for Vegetated Roofs, Rainwater Harvesting and LID Foundations

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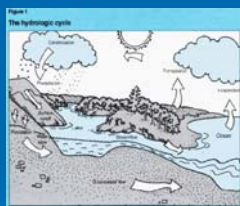
October 9, 2014

Presentation Outline

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



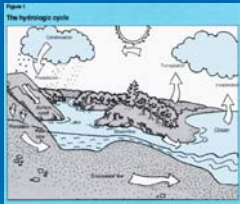
Hydrologic Modeling



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?

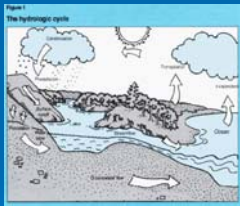
➤ A1: Characterize hydrologic conditions

- 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)

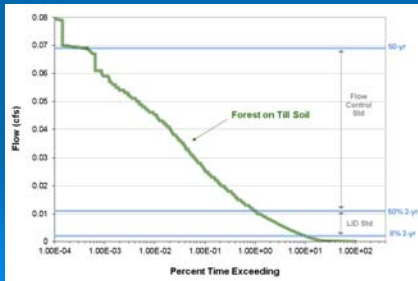
- Match flow durations to pre-developed condition from 50% of the 2-year to the 50-year peak flow

➤ 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)

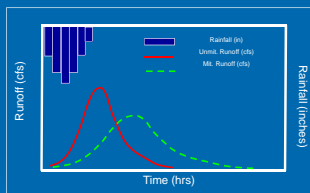


Modeling Methods

- 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

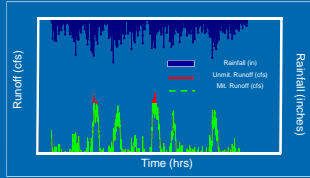
Modeling Methods Single-Event

- 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
AGWIETP	0.80	0.50
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

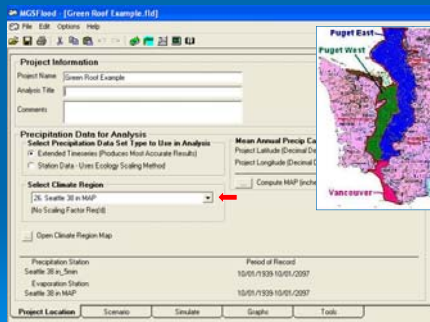
Flow Control (WVHM4)

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



Vegetated Roof Example

Select Precipitation



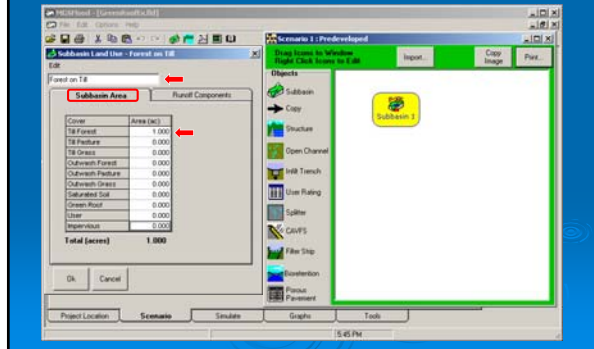
Vegetated Roof Example

Define Predeveloped Condition



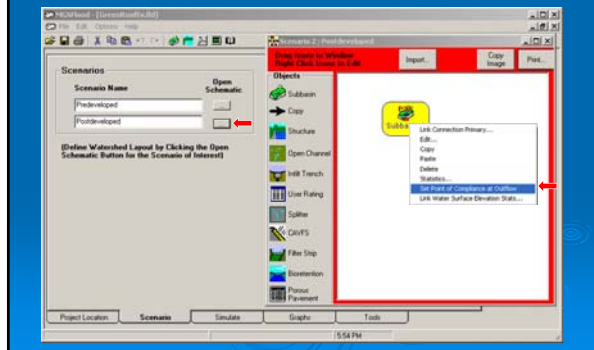
Vegetated Roof Example

Define Predeveloped Condition



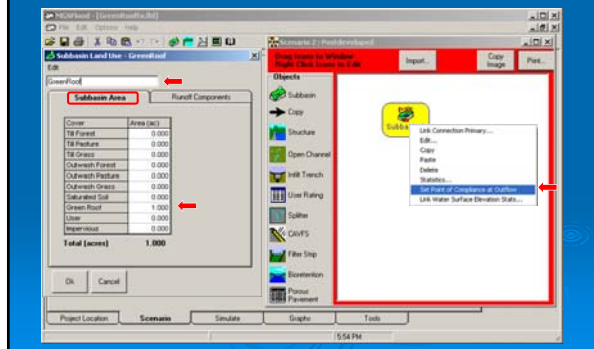
Vegetated Roof Example

Define Developed Mitigated Condition



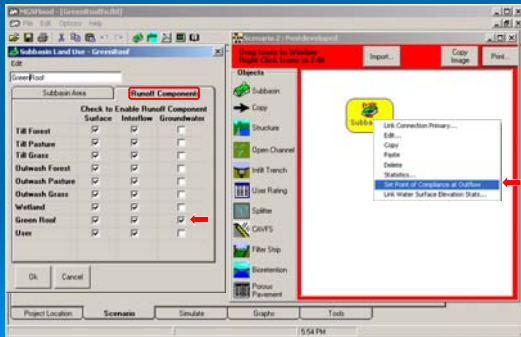
Vegetated Roof Example

Define Developed Mitigated Condition



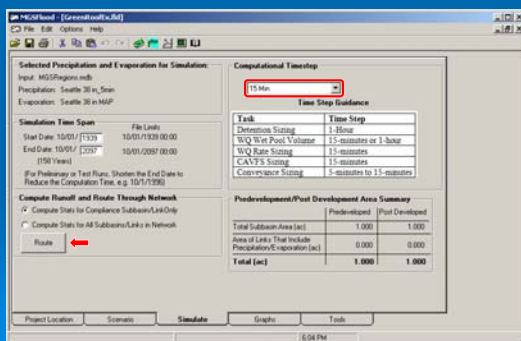
Vegetated Roof Example

Define Developed Mitigated Condition

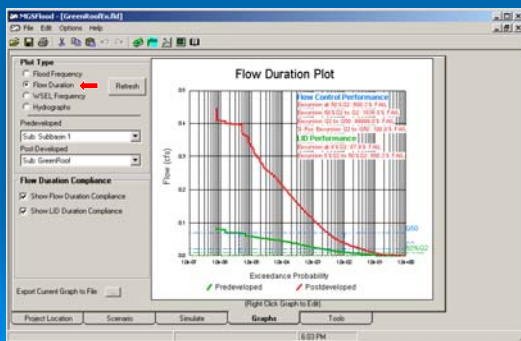


Vegetated Roof Example

Run Model

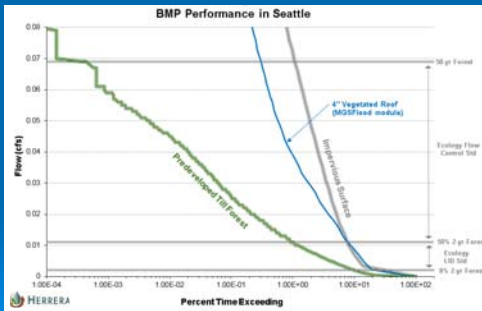


Vegetated Roof Example



Vegetated Roof Performance

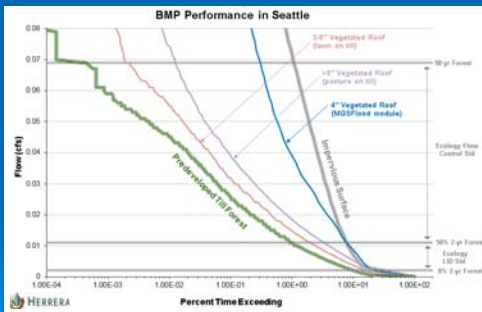
MGSFlood Module



Vegetated roof reduces downstream BMP size

Vegetated Roof Performance

Implicit Methods



Vegetated roof reduces downstream BMP size

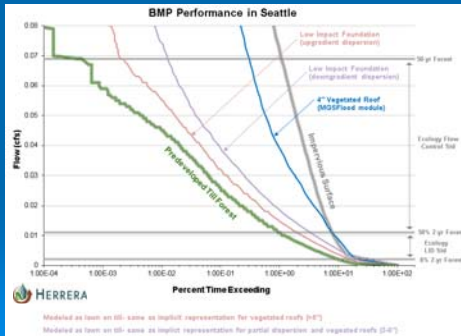
Minimal Excavation Foundations

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

Duration Plot



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

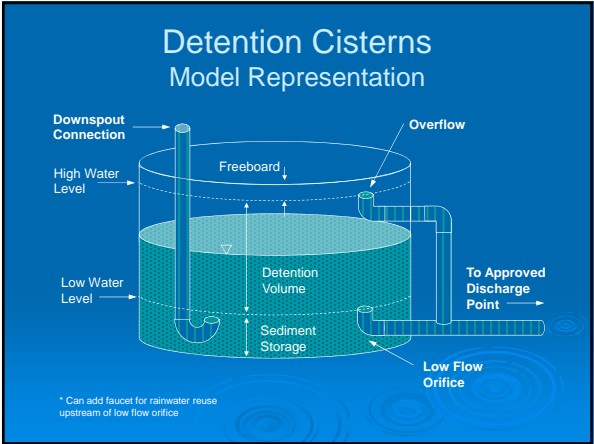
Harvesting Cisterns

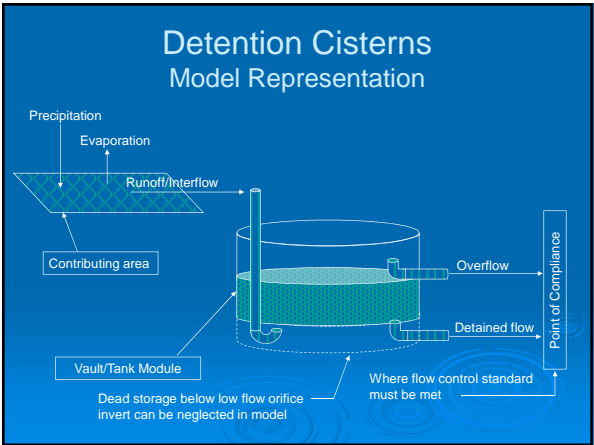
Current* Modeling Guidelines

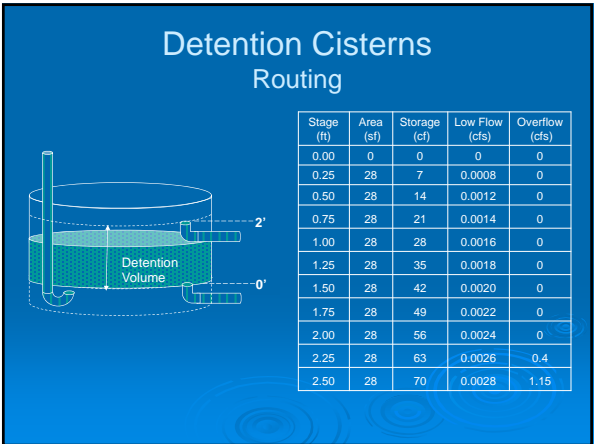
- ## ➤ Explicitly Model
- Estimate average annual runoff volume (V) using continuous model
 - Size cisterns to provide storage, V
 - For interior reuse, perform monthly water balance
 - Subtract roof area from site-wide model if sizing flow control or water quality treatment
- ## ➤ Recommendation
- Perform daily (or sub-daily if rainfall data available) water balance model
 - Factor results into site-wide model for flow control sizing

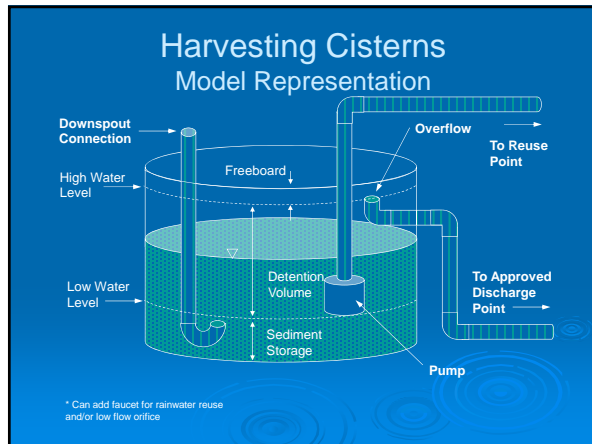


* Same as 2013 permit guidelines









Harvesting Cistern Example Water Reuse/ Flow Control

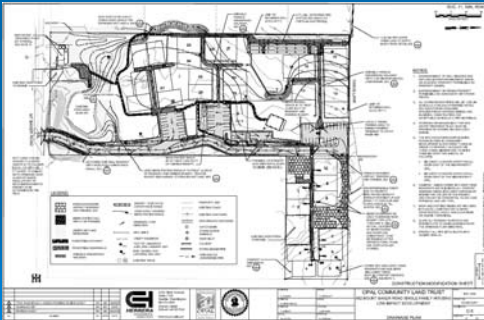
OPAL Community Land Trust, Orcas Island

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

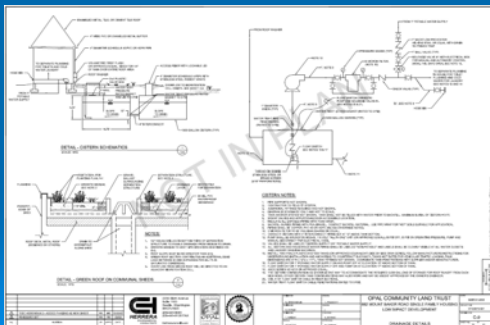
Flow Control

OPAL - Site Plan



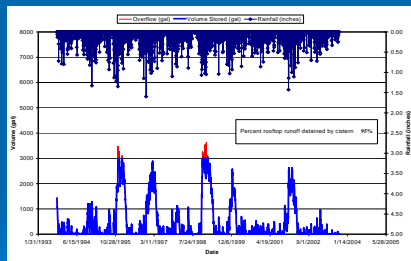
Flow Control

OPAL – Design of Cisterns for Reuse



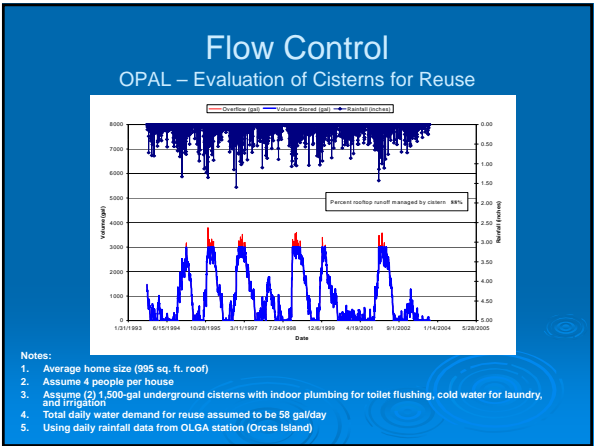
Flow Control

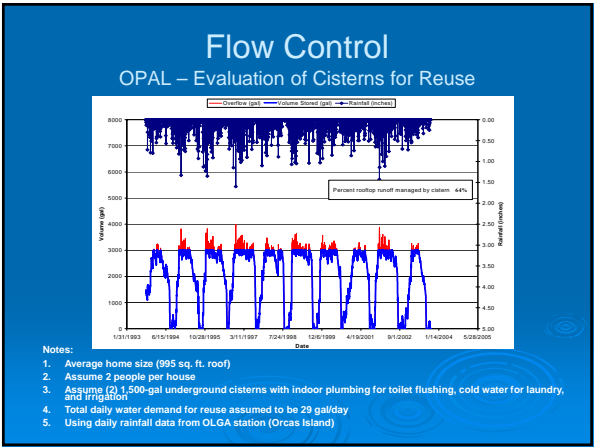
OPAL – Evaluation of Cisterns for Reuse

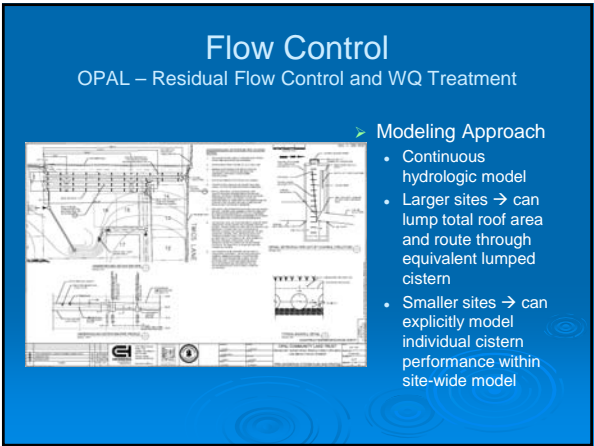


Notes:

1. Large home (1,050 sq. ft. roof)
2. Assume 4 people per house
3. Assume (2) 7,500-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)









Detention Cistern Example Peak Reduction/ Flow Control

Lakewood RainCatchers, Seattle



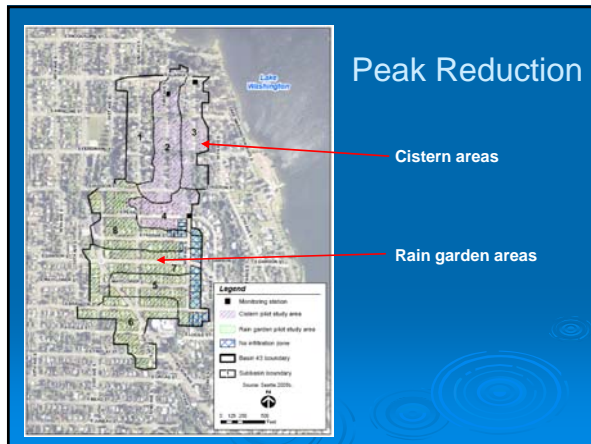
Peak Reduction

- 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 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

Option Menu

PRECIPITATION/EVAPORATION

PRECIPITATION

EVAPORATION

TIME STEP

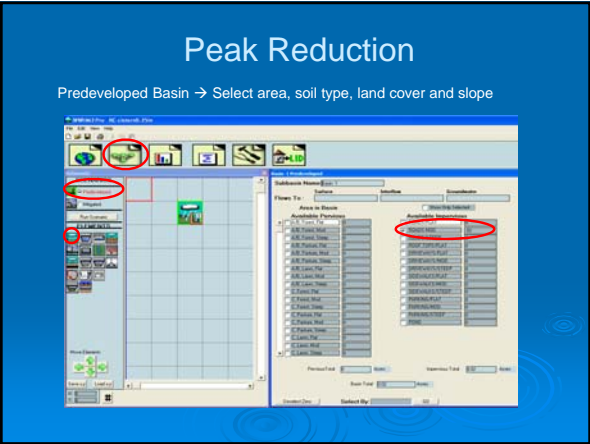
15 MIN

[illegible]

Peak Reduction

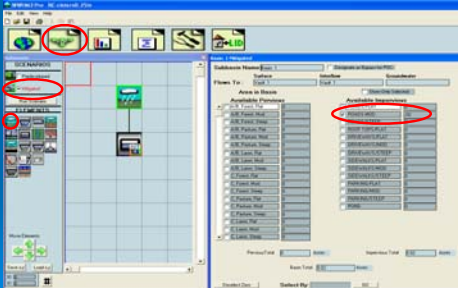
Predeveloped Basin → Select area, soil type, land cover and slope

The screenshot displays the US2 software interface for setting up a Predeveloped Basin. The main workspace is a grid where a red rectangle indicates the selected area. The left sidebar contains various tool icons, with the 'Predeveloped Basin' icon highlighted. The right sidebar shows the 'Subbasin Name' and 'Flows To' fields, both set to 'Basin'. The 'Basin' tab is active, showing a list of 'Predeveloped Basins' and a list of 'Predeveloped Land Uses'. The 'Predeveloped Land Uses' list includes 'Predeveloped Land Use' and 'Predeveloped Land Use'.

[illegible]

Peak Reduction

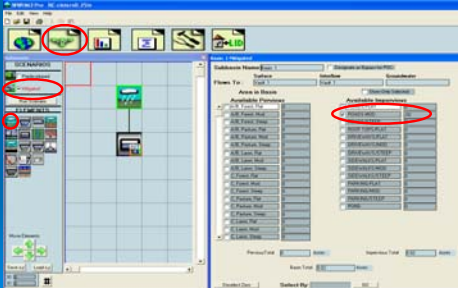
Developed Mitigated Basin → Impervious with same area and slope....



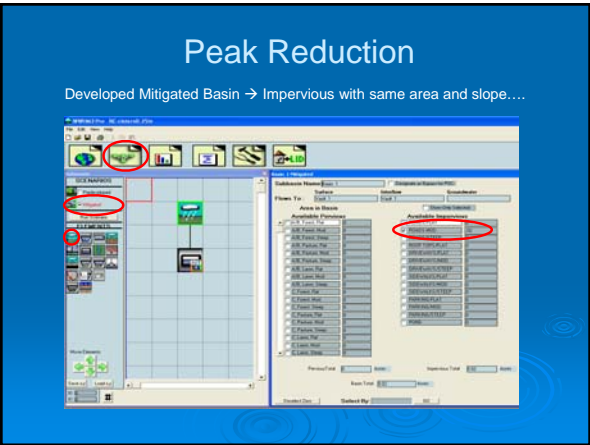
The screenshot shows the ArcSWAT software interface. The 'SWAT Parameters' tab is active, displaying various parameters for the watershed. The 'Impervious' parameter is highlighted with a red circle, indicating its role in peak reduction. The 'SWAT Parameters' tab is also highlighted with a red circle. The 'SWAT Parameters' tab is also highlighted with a red circle.

Peak Reduction

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

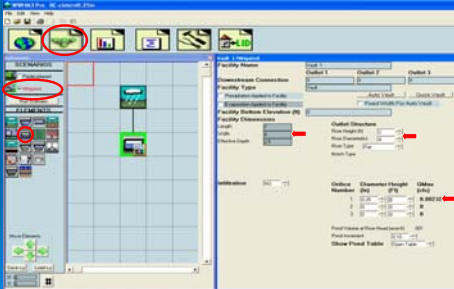


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Peak Reduction

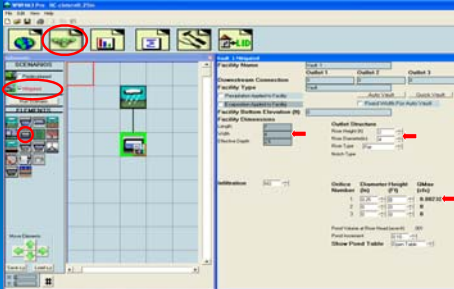
Developed Mitigated Basin Continued: Route to vault module



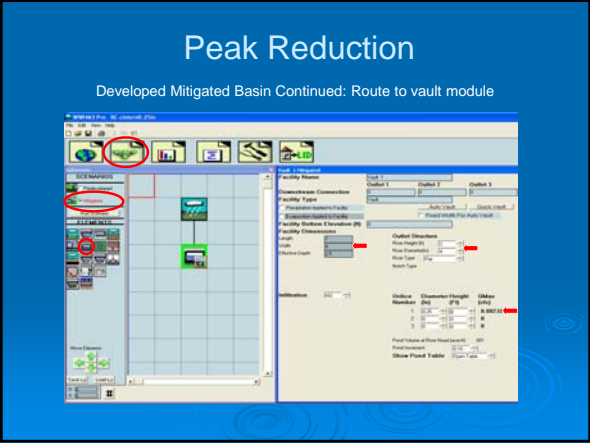
The screenshot displays the StormCAD software interface. The left-hand pane shows the project tree with the 'Route to Vault' module highlighted. The central workspace shows a grid with a 'Route to Vault' module placed. The right-hand pane shows the configuration options for the 'Route to Vault' module, including 'Facility Name', 'Facility Type', 'Facility Description', 'Facility Elevation', 'Facility Dimensions', 'Facility Cost', 'Facility Weight', 'Facility Volume', 'Facility Area', 'Facility Perimeter', 'Facility Length', 'Facility Width', 'Facility Height', 'Facility Depth', 'Facility Thickness', 'Facility Material', 'Facility Color', 'Facility Texture', 'Facility Sound', 'Facility Smell', 'Facility Taste', 'Facility Feel', 'Facility Look', 'Facility Sound', 'Facility Smell', 'Facility Taste', 'Facility Feel', 'Facility Look'. The 'Route to Vault' module is highlighted in the project tree, and the 'Route to Vault' module is highlighted in the workspace. The 'Route to Vault' module is highlighted in the configuration panel.

Peak Reduction

Developed Mitigated Basin Continued: Route to vault module



The screenshot displays the StormCAD software interface. The left-hand pane shows the project tree with the 'Route to Vault' module highlighted. The central workspace shows a grid with a 'Route to Vault' module placed. The right-hand pane shows the configuration options for the 'Route to Vault' module, including 'Facility Name', 'Facility Type', 'Facility Description', 'Facility Elevation', 'Facility Dimensions', 'Facility Cost', 'Facility Weight', 'Facility Volume', 'Facility Area', 'Facility Perimeter', 'Facility Length', 'Facility Width', 'Facility Height', 'Facility Depth', 'Facility Thickness', 'Facility Material', 'Facility Color', 'Facility Texture', 'Facility Sound', 'Facility Smell', 'Facility Taste', 'Facility Feel', 'Facility Look', 'Facility Sound', 'Facility Smell', 'Facility Taste', 'Facility Feel', 'Facility Look'. The 'Route to Vault' module is highlighted in the project tree, and the 'Route to Vault' module is highlighted in the workspace. The 'Route to Vault' module is highlighted in the configuration panel.

[illegible]

Peak Reduction

Stage Storage Discharge Table

Sheet 1				Sheet 2			
Stage (ft)	Area (acres)	Storage (acre-ft)	Discharge (cfs)	Stage (ft)	Area (acres)	Storage (acre-ft)	Discharge (cfs)
0.000000	0.000643	0.000000	0.000000	1.000000	0.000643	0.000000	0.000000
0.027778	0.000643	0.000019	0.000000	1.122222	0.000643	0.001107	0.001835
0.055556	0.000643	0.000036	0.000000	1.244444	0.000643	0.002214	0.003670
0.083333	0.000643	0.000054	0.000000	1.366667	0.000643	0.003321	0.005505
0.111111	0.000643	0.000071	0.000000	1.488889	0.000643	0.004428	0.007340
0.138889	0.000643	0.000089	0.000000	1.611111	0.000643	0.005535	0.009175
0.166667	0.000643	0.000107	0.000000	1.733333	0.000643	0.006642	0.011010
0.194444	0.000643	0.000125	0.000000	1.855556	0.000643	0.007749	0.012845
0.222222	0.000643	0.000143	0.000000	1.977778	0.000643	0.008856	0.014680
0.250000	0.000643	0.000161	0.000000	2.099999	0.000643	0.009963	0.016515
0.277778	0.000643	0.000179	0.000000	2.222222	0.000643	0.011070	0.018350
0.305556	0.000643	0.000196	0.000000	2.344444	0.000643	0.012177	0.020185
0.333333	0.000643	0.000214	0.000000	2.466667	0.000643	0.013284	0.022020
0.361111	0.000643	0.000232	0.000000	2.588889	0.000643	0.014391	0.023855
0.388889	0.000643	0.000250	0.000000	2.711111	0.000643	0.015498	0.025690
0.416667	0.000643	0.000268	0.000000	2.833333	0.000643	0.016605	0.027525
0.444444	0.000643	0.000286	0.000000	2.955556	0.000643	0.017712	0.029360
0.472222	0.000643	0.000304	0.000000	3.077778	0.000643	0.018819	0.031195
0.500000	0.000643	0.000321	0.000000	3.199999	0.000643	0.019926	0.033030
0.527778	0.000643	0.000339	0.000000	3.322222	0.000643	0.021033	0.034865
0.555556	0.000643	0.000357	0.000000	3.444444	0.000643	0.022140	0.036700
0.583333	0.000643	0.000375	0.000000	3.566667	0.000643	0.023247	0.038535
0.611111	0.000643	0.000393	0.000000	3.688889	0.000643	0.024354	0.040370
0.638889	0.000643	0.000411	0.000000	3.811111	0.000643	0.025461	0.042205
0.666667	0.000643	0.000429	0.000000	3.933333	0.000643	0.026568	0.044040
0.694444	0.000643	0.000446	0.000000	4.055556	0.000643	0.027675	0.045875
0.722222	0.000643	0.000464	0.000000	4.177778	0.000643	0.028782	0.047710
0.750000	0.000643	0.000482	0.000000	4.299999	0.000643	0.029889	0.049545
0.777778	0.000643	0.000500	0.000000	4.422222	0.000643	0.030996	0.051380
0.805556	0.000643	0.000518	0.000000	4.544444	0.000643	0.032103	0.053215
0.833333	0.000643	0.000536	0.000000	4.666667	0.000643	0.033210	0.055050

Overflow

Peak Reduction

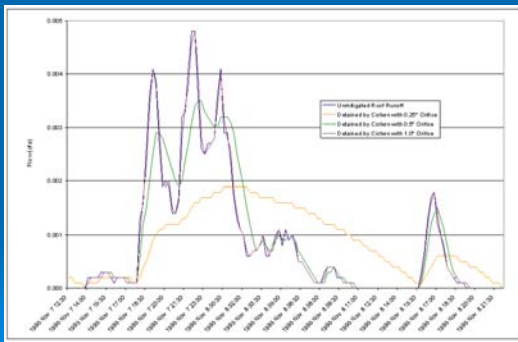


Figure 17. Comparison of roof runoff detention benefits for cisterns with varying cistern sizes.

Peak Reduction

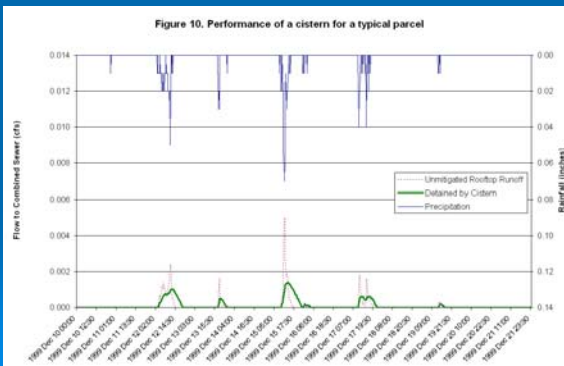
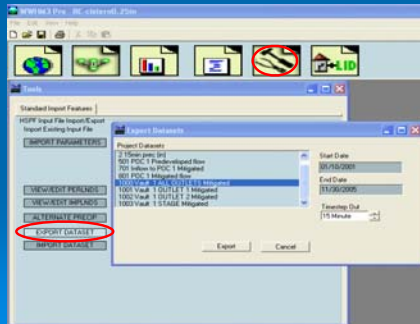


Figure 10. Performance of a cistern for a typical parcel

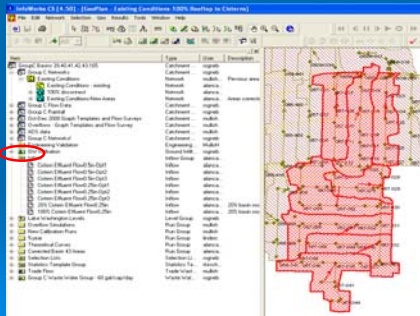
Peak Reduction

Time Series Export



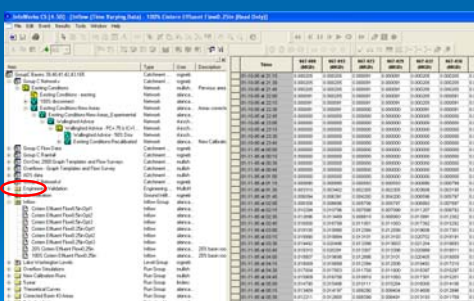
Peak Reduction

Time Series Import to InfoWorks



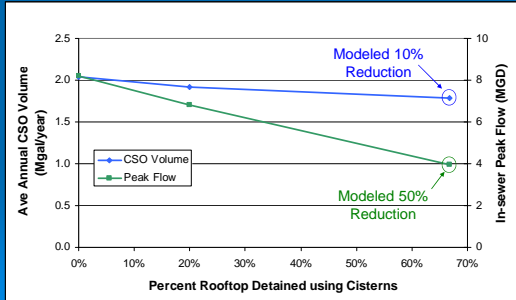
Peak Reduction

Time Series Import to InfoWorks



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

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