



Modelling LIDs using PCSWMM and EPA SWMM5

March 28, 2012

Presented by: Rob James (CHI)

Credit to: Lewis Rossman (US EPA)

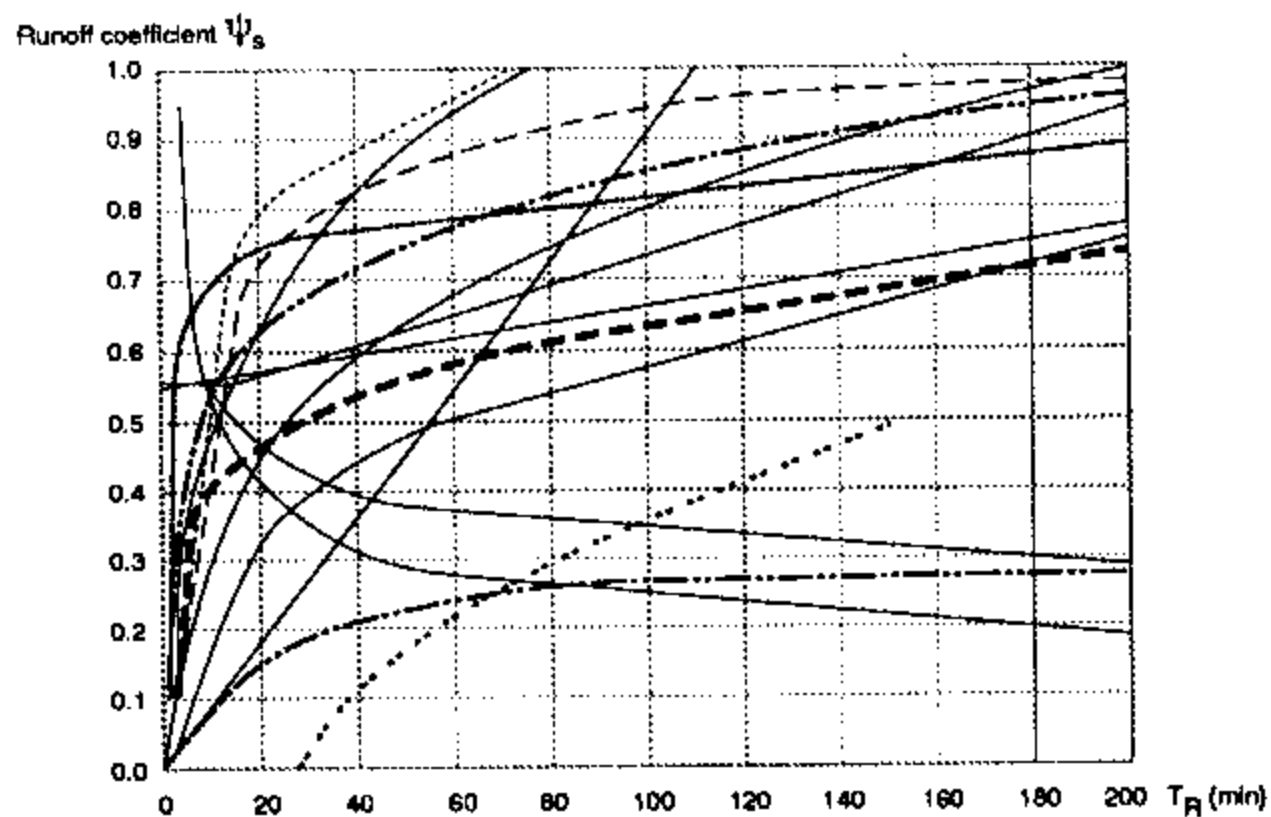
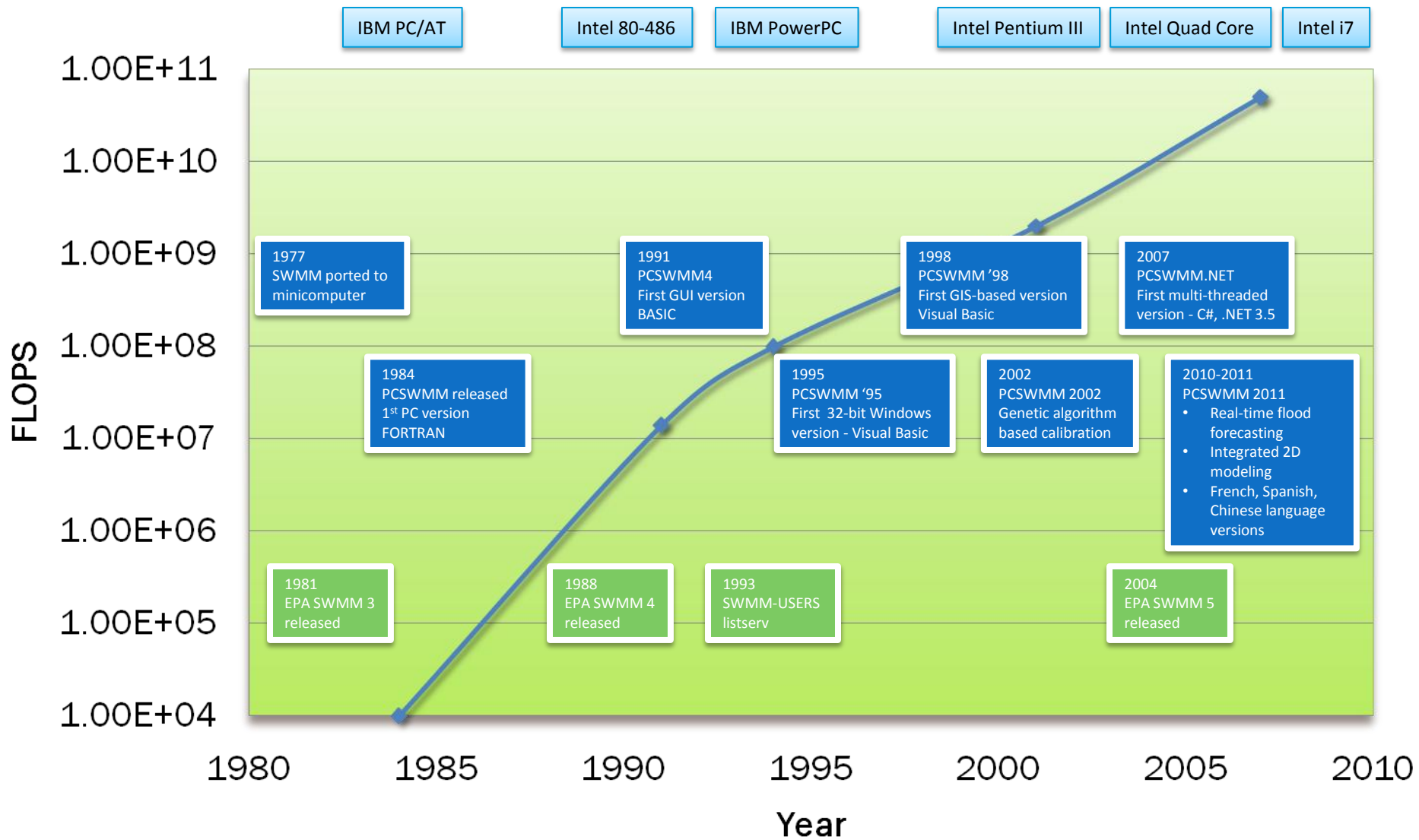


FIGURE 2.1
Runoff coefficient as function of the duration of rain, according to a study by Pecher.



Processing power increase over the
history of PCSWMM

100,000,000

100'000'000

TIMES

PCSWMM's computational grid at CHI

1,000,000,000,000

↓ '000'000'000'000

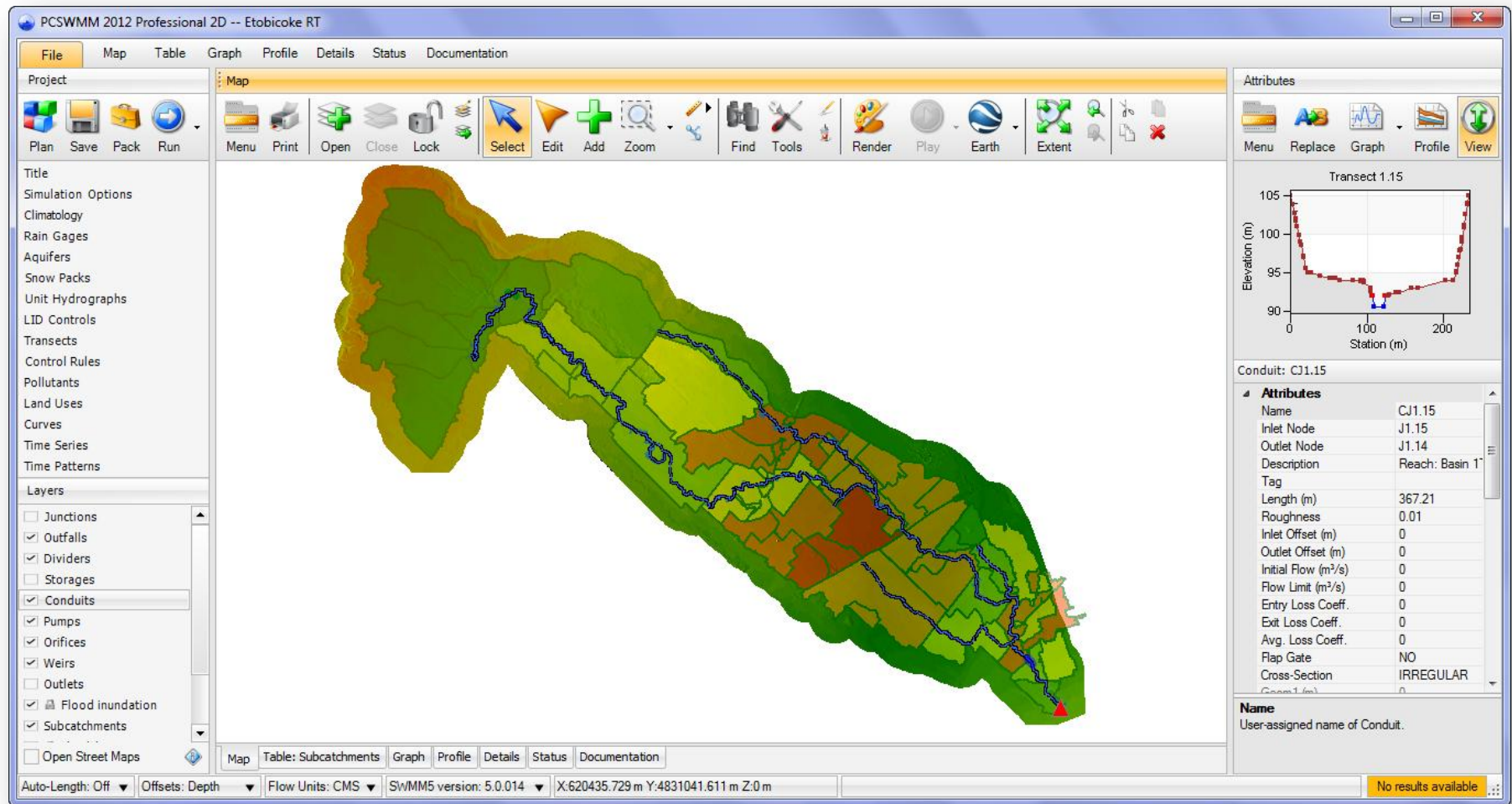
FLOPS

So how much is 1 trillion floating point operations?

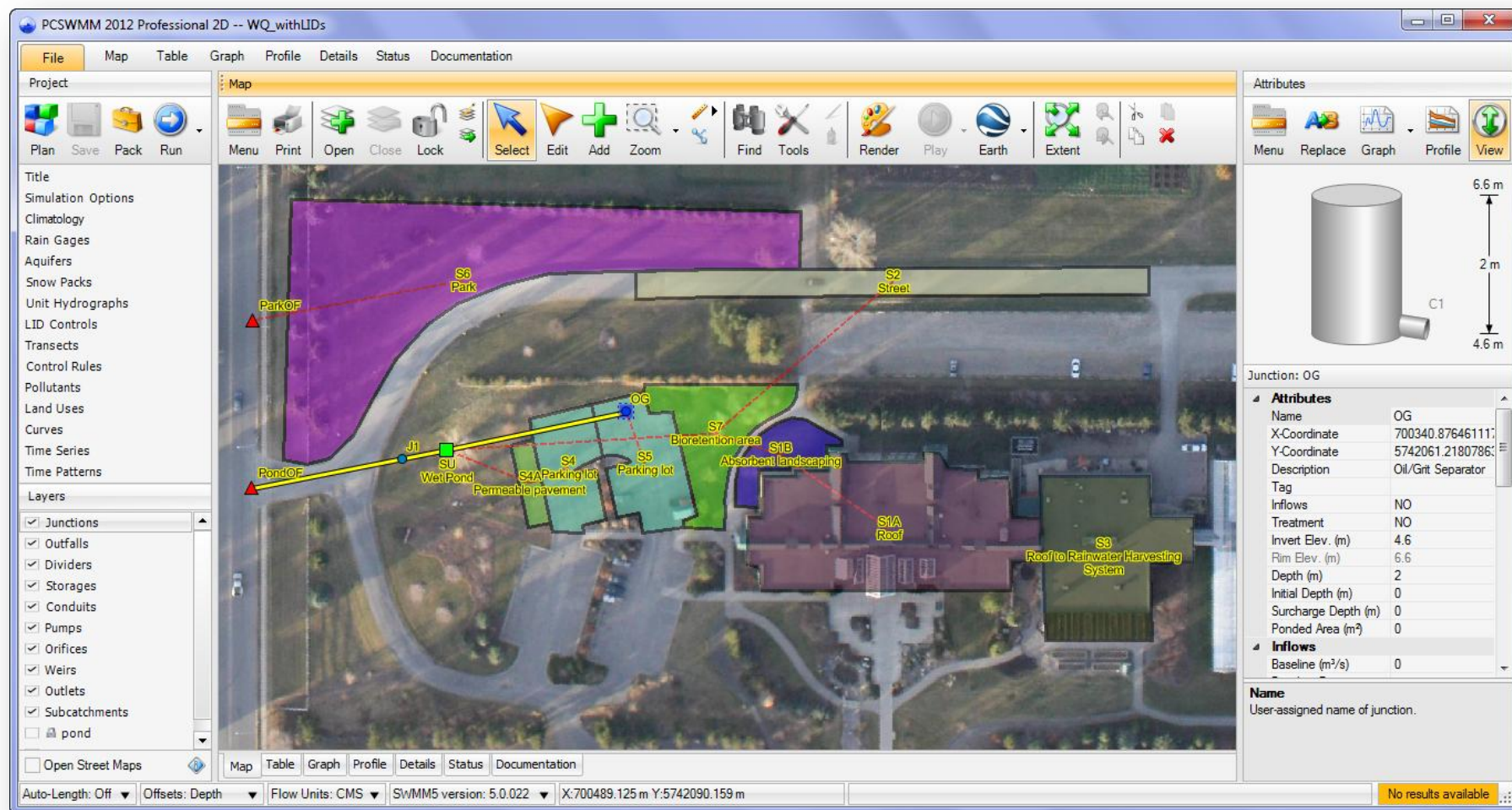
1 x 60s x 60m x 2100h x 40y

$$\frac{302,400,000}{1,000,000,000,000} = 0.03\%$$

PCSWMM: Spatial DSS for EPA SWMM5



PCSWMM: Spatial DSS for EPA SWMM5



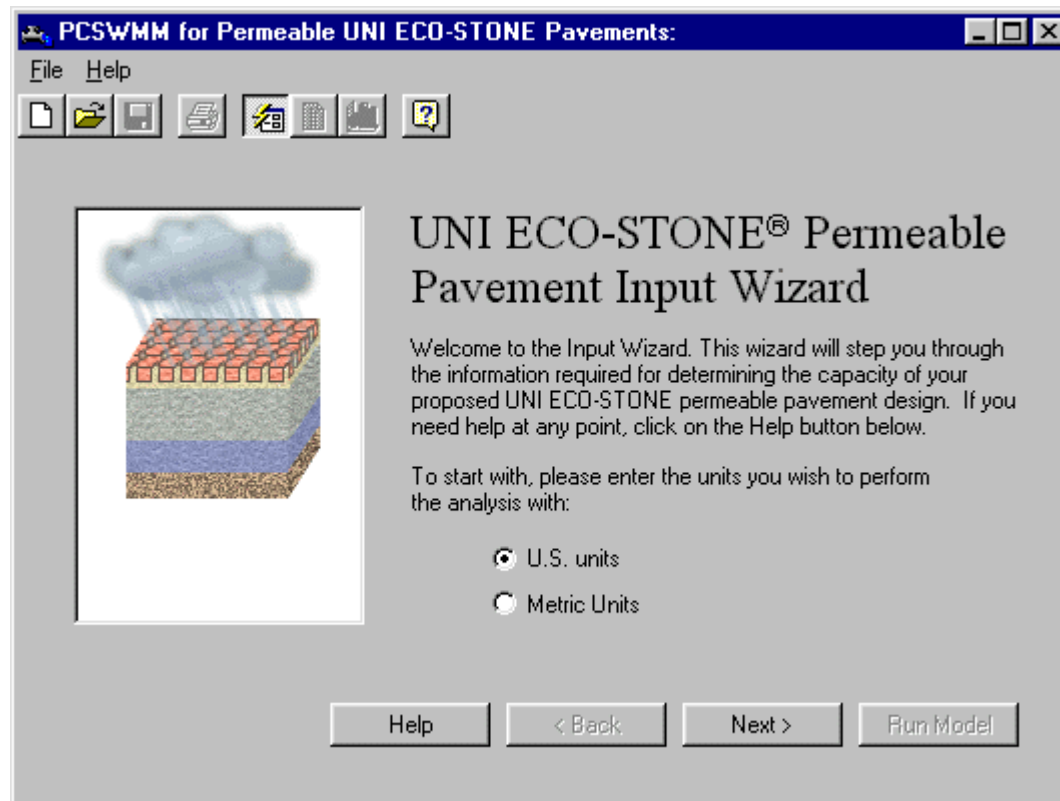
PCSWMM/SWMM5 LID toolbox

- Physically-based processes
- Flexible components
- SWMM Version 5.0.022
- Simplifies the modeling of:
 - Lot level implementations
 - Watershed scale or city master planning
 - Single event
 - Continuous
 - Performance degradation

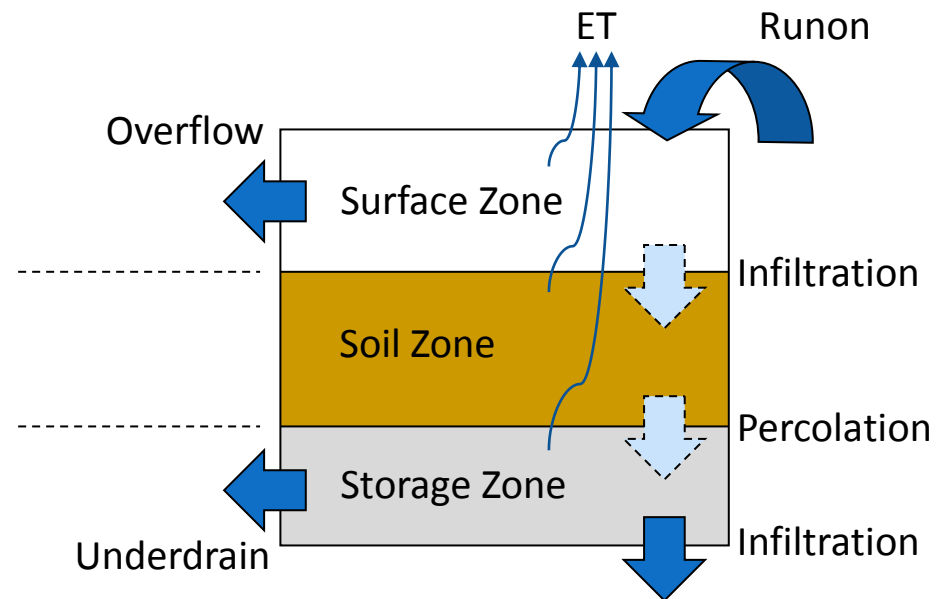
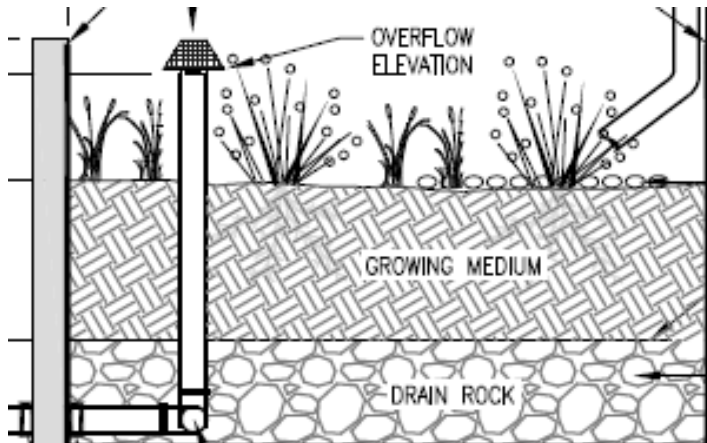
Examples of SWMM5 LID controls



EPA SWMM5 LID toolkit: follows the methodology of PCSWMM for PP



Conceptual Model of an LID Process

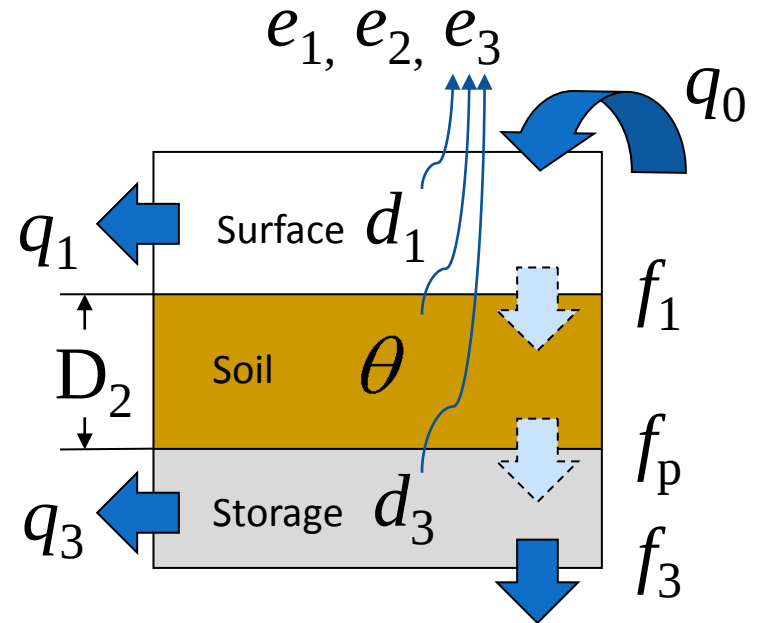


Flow Balance Equations

$$\frac{\partial d_1}{\partial t} = q_0 - e_1 - f_1 - q_1$$

$$D_2 \frac{\partial \theta}{\partial t} = f_1 - e_2 - f_p$$

$$\phi \frac{\partial d_3}{\partial t} = f_p - e_3 - f_3 - q_3$$

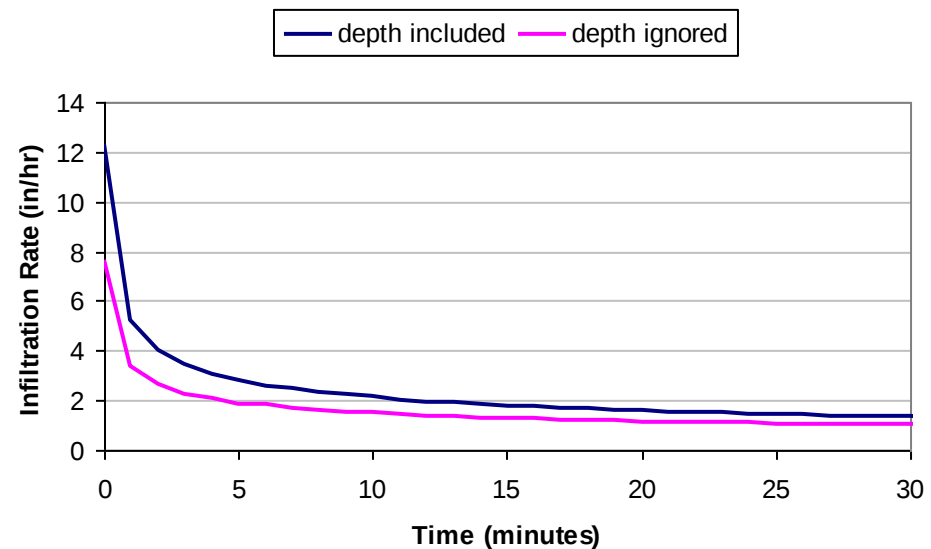
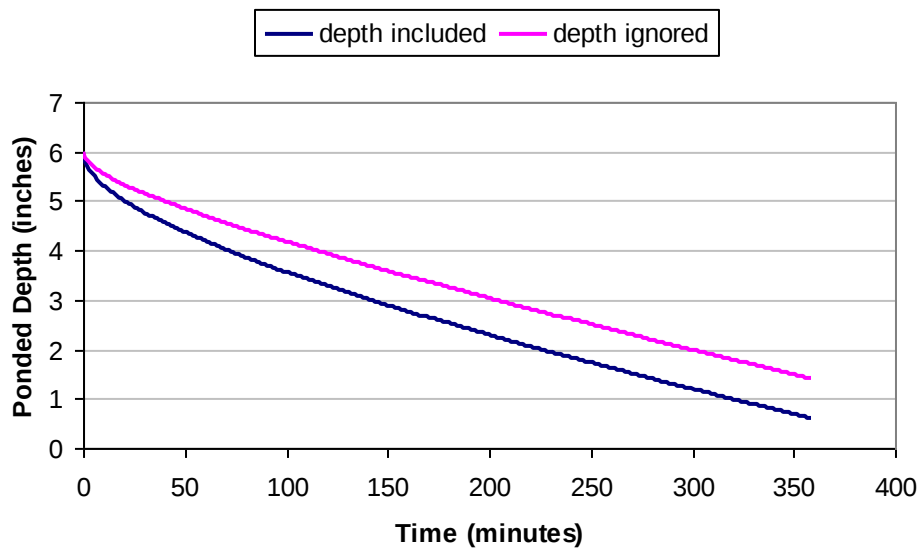


Infiltration Flux

Classical Green-Ampt Eqn:
(depth d is normally ignored)

$$f = K_{sat} \left(1 + \frac{(\phi - \theta)(d + \psi)}{F} \right)$$

Effect of ponded depth (d) on infiltration rate ($K_{sat} = 0.5$ in/hr)



Percolation Flux

Rate of percolation (f_p) through the unsaturated soil zone as a function of moisture content (θ) is described by Darcy's Law:

$$f_p = K(\theta) \left(1 + \frac{\psi(\theta)}{D} \right)$$

$$K = K_{sat} \exp(-(\phi - \theta)HCO)$$

$$\psi = 135 \exp(-(\theta - \theta_{FC})PCO)$$

K = hydraulic conductivity, ψ = capillary tension, ϕ = porosity, θ_{FC} = field capacity, and HCO and PCO are coefficients.

Outflow Fluxes

- Flux rates are functions of zone's water depth (d)

- Surface zone

- Overland flow using Manning's formula

$$Q = (1.49/n)AR^{2/3}S^{1/2} \text{ where } A \text{ and } R \text{ depend on } d$$

- Overflow using the weir equation

$$Q = C_w L(d)^{1.5}$$

- Storage zone underdrain flow

$$Q = C_D(d)^\eta$$

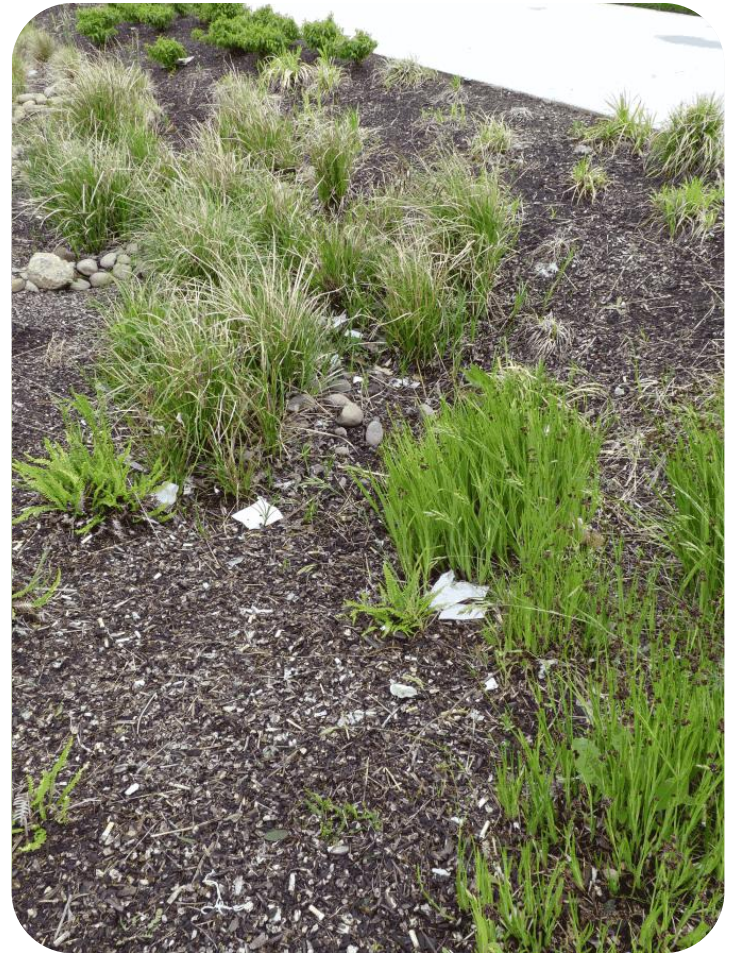
n = Manning's roughness, A = flow area, R = hyd. radius, S = surface slope, L = length of weir crest, and C_w , C_D , and η are coefficients.

Representing Different LID Alternatives

LID Alternative	Zones	Processes (besides ET)
Rain Barrel	Surface, Storage	Surface Overflow Storage Underdrain Flow
Porous Pavement	Surface, Storage	Surface Overland Flow Storage Infiltration*
Infiltration Trench	Surface, Storage	Surface Overflow Storage Infiltration
Vegetative Swale	Surface	Surface Overland Flow Surface Infiltration
Bioretention Cell	Surface, Soil, Storage	Surface Overflow Soil Infiltration Soil Percolation Storage Infiltration*

*May also include storage underdrain flow

Bio-retention cell – ‘Street Planter’



LID example: Valleyfield, PQ



- New residential development to include 22 boulevard planters
- Reduce minor system inflow
- Reduce pollutant loading

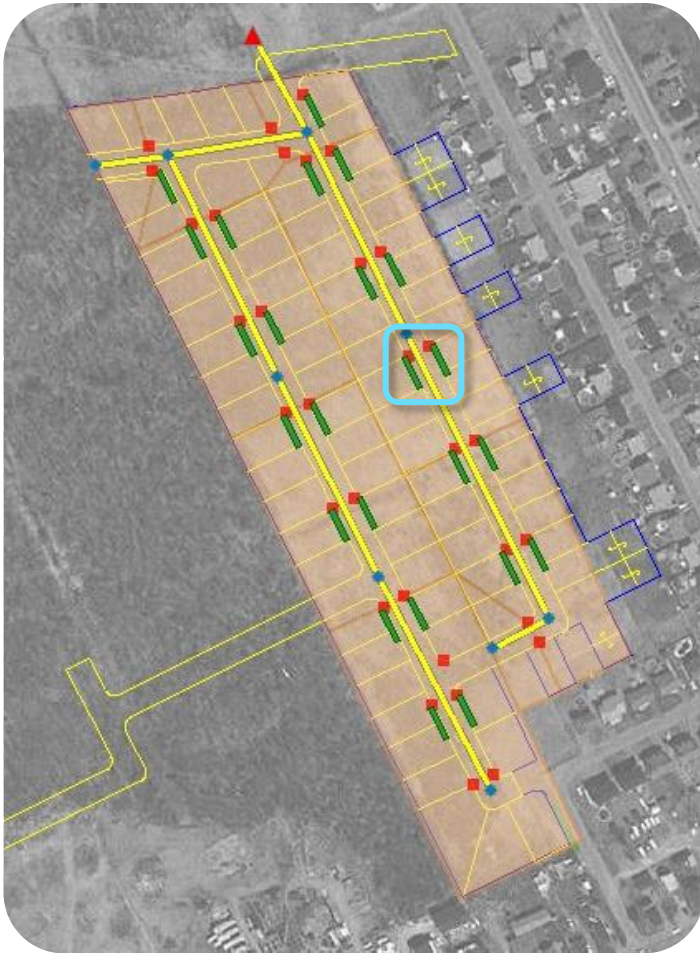
Boulevard Planters



Alternate designs

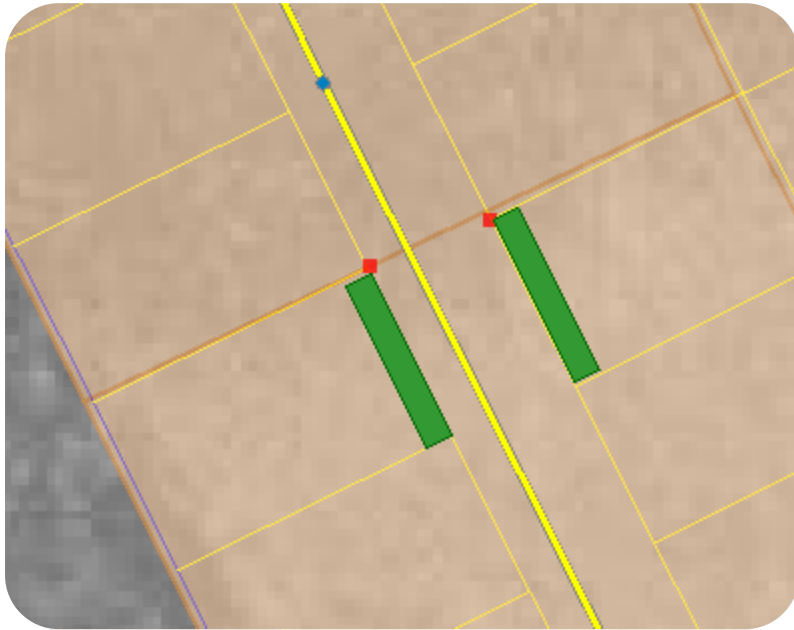


Valleyfield, Quebec – LID retrofit example



Bio-retention cell to be installed in typical residential neighbourhood

PCSWMM LID representation



LID Usage Editor: S1

LID usages:

Street_Planter

LID control name:

Street_Planter

Number of replicate units: 4

☐ LID occupies full subcatchment

Area of each unit (m²): 100

% of subcatchment occupied: 2.878

Top width of overland flow surface of each unit (m): 3.3

% initially saturated: 0

% of impervious area treated: 100

☐ Send outflow to pervious area

Detailed report file (optional): C:\Users\Rob James\Documents\CHI Presentations\1

Add Del OK Cancel

PCSWMM LID representation: surface

The screenshot shows the 'LID Control Editor' dialog box. On the left, under 'LID controls:', a list contains 'Street_Planter'. To the right, the 'Name:' field is 'Street_Planter' and the 'LID type:' dropdown is 'Bio-Retention Cell'. Below these are four tabs: 'Surface' (selected), 'Soil', 'Storage', and 'Underdrain'. The 'Surface' tab contains four input fields: 'Storage depth (mm)' with value 100, 'Vegetative cover (fraction)' with value 0.99, 'Surface roughness (Mannings n)' with value 0.3, and 'Surface slope (percent)' with value 0.25. At the bottom are 'Add', 'Del', 'OK', and 'Cancel' buttons.

Field	Value
Name	Street_Planter
LID type	Bio-Retention Cell
Storage depth (mm)	100
Vegetative cover (fraction)	0.99
Surface roughness (Mannings n)	0.3
Surface slope (percent)	0.25

PCSWMM LID representation: surface storage

LID Control Editor

LID controls:
Street_Planter

Name:
Street_Planter

LID type:
Bio-Retention Cell

Surface Soil Storage Underdrain

Storage depth (mm) 100

Vegetative cover (fraction) 0.99

Surface roughness (Mannings n) 0.3

Surface slope (percent) 0.25

Add Del OK Cancel



PCSWMM LID representation: soil

The screenshot shows the 'LID Control Editor' dialog box. On the left, under 'LID controls:', 'Street_Planter' is listed. On the right, the 'Name:' field contains 'Street_Planter' and the 'LID type:' dropdown is set to 'Bio-Retention Cell'. Below these are four tabs: 'Surface', 'Soil' (which is selected), 'Storage', and 'Underdrain'. The 'Soil' tab contains the following parameters and values:

Parameter	Value
Thickness (mm)	900
Porosity (volume fraction)	0.44
Field capacity (volume fraction)	0.11
Wilting point (volume fraction)	0.05
Conductivity (mm/hr)	25
Conductivity slope	7.5
Suction head (mm)	88.9

At the bottom of the dialog are buttons for 'Add', 'Del', 'OK', and 'Cancel'.

PCSWMM LID representation: storage

The screenshot shows the 'LID Control Editor' dialog box. On the left, a list titled 'LID controls:' contains 'Street_Planter'. On the right, the 'Name' field is 'Street_Planter' and the 'LID type' dropdown is 'Bio-Retention Cell'. Below these are four tabs: 'Surface', 'Soil', 'Storage' (which is selected), and 'Underdrain'. The 'Storage' tab contains four input fields: 'Height (mm)' with value 450, 'Void ratio (voids/solids)' with value 0.75, 'Conductivity (mm/hr)' with value 6, and 'Clogging factor' with value 0. A note at the bottom of the tab states: 'Note: use a conductivity of 0 if the LID unit has an impermeable bottom.' At the bottom of the dialog are 'Add', 'Del', 'OK', and 'Cancel' buttons.

Field	Value
Name	Street_Planter
LID type	Bio-Retention Cell
Height (mm)	450
Void ratio (voids/solids)	0.75
Conductivity (mm/hr)	6
Clogging factor	0

Note: use a conductivity of 0 if the LID unit has an impermeable bottom.

PCSWMM LID representation: tile drain

The screenshot shows the 'LID Control Editor' dialog box. On the left, under 'LID controls:', a list contains 'Street_Planter'. To the right, the 'Name:' field is 'Street_Planter' and the 'LID type:' dropdown is 'Bio-Retention Cell'. Below these are four tabs: 'Surface', 'Soil', 'Storage', and 'Underdrain'. The 'Underdrain' tab is active, showing three input fields: 'Drain coefficient (mm/hr)' with value 0, 'Drain exponent' with value 0, and 'Drain offset height (mm)' with value 0. A note at the bottom of the tab states: 'Note: use a drain coefficient of 0 if the LID unit has no underdrain.' At the bottom of the dialog are 'Add', 'Del', 'OK', and 'Cancel' buttons.

LID Control Editor

LID controls:

Street_Planter

Name: Street_Planter

LID type: Bio-Retention Cell

Surface Soil Storage Underdrain

Drain coefficient (mm/hr) 0

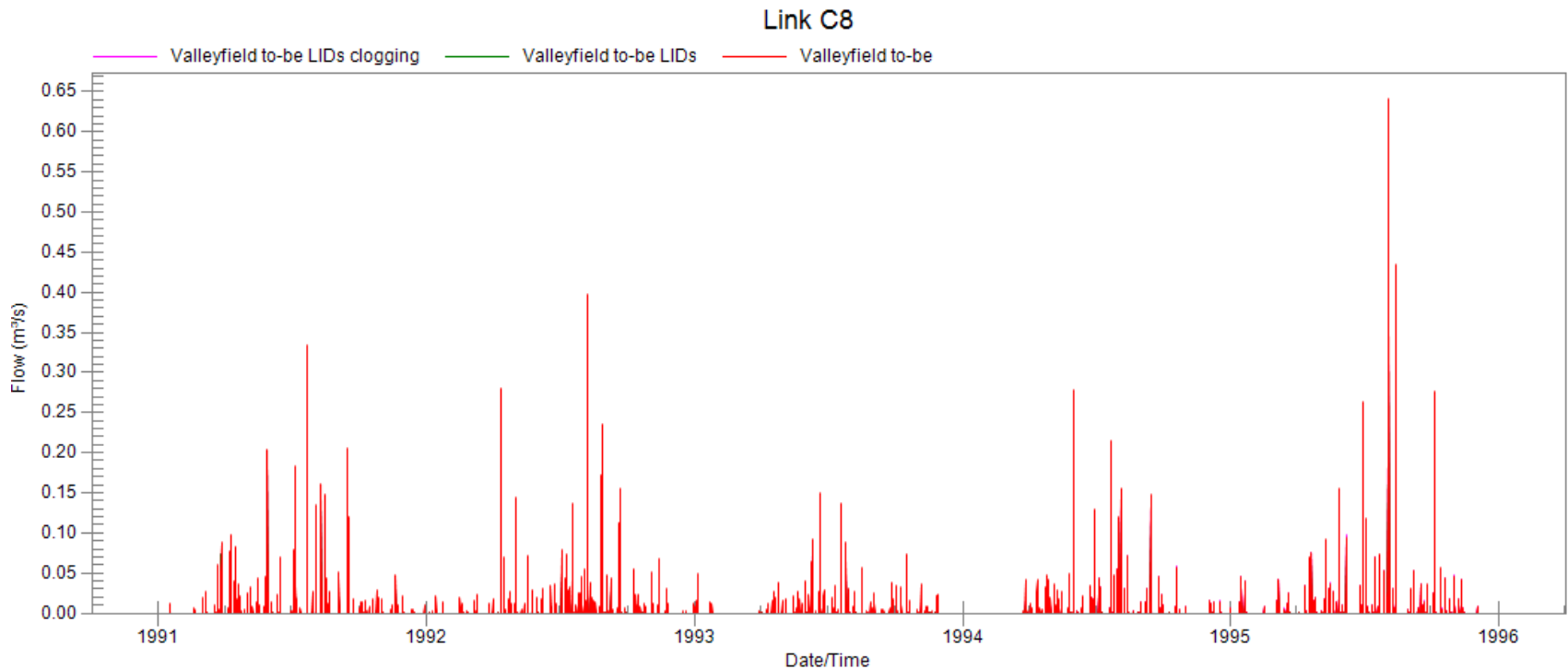
Drain exponent 0

Drain offset height (mm) 0

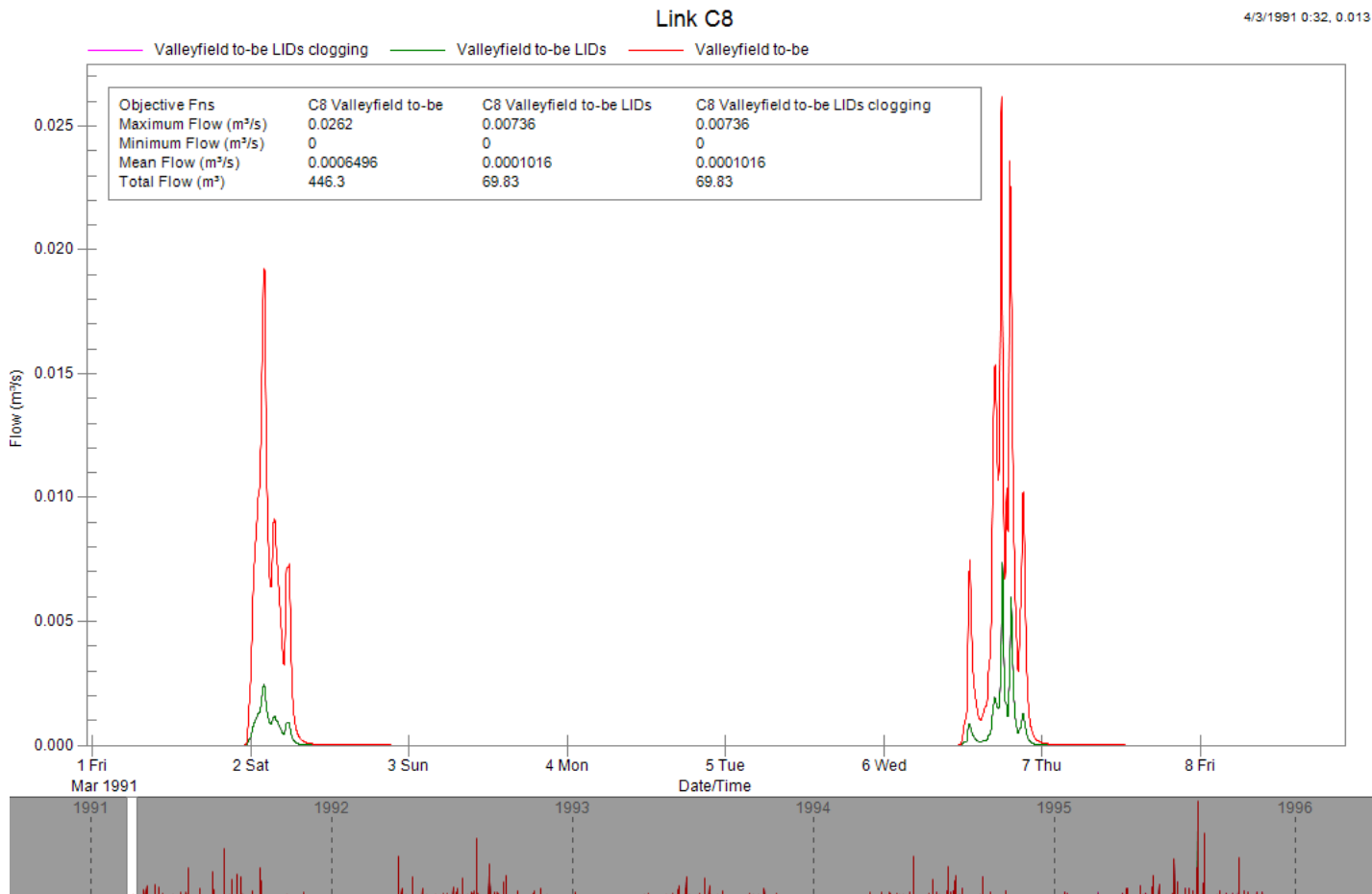
Note: use a drain coefficient of 0 if the LID unit has no underdrain.

Add Del OK Cancel

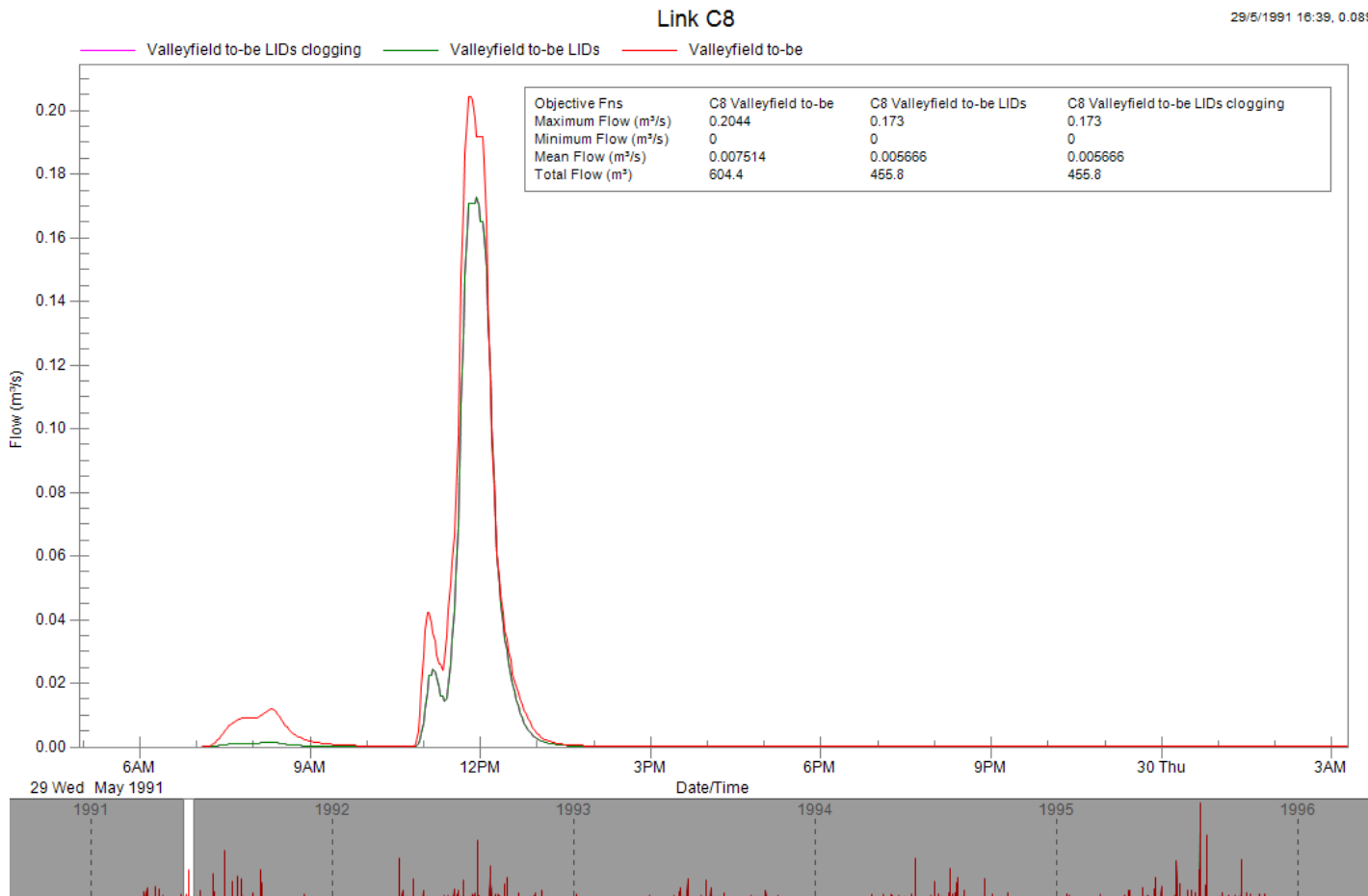
Continuous LID analysis



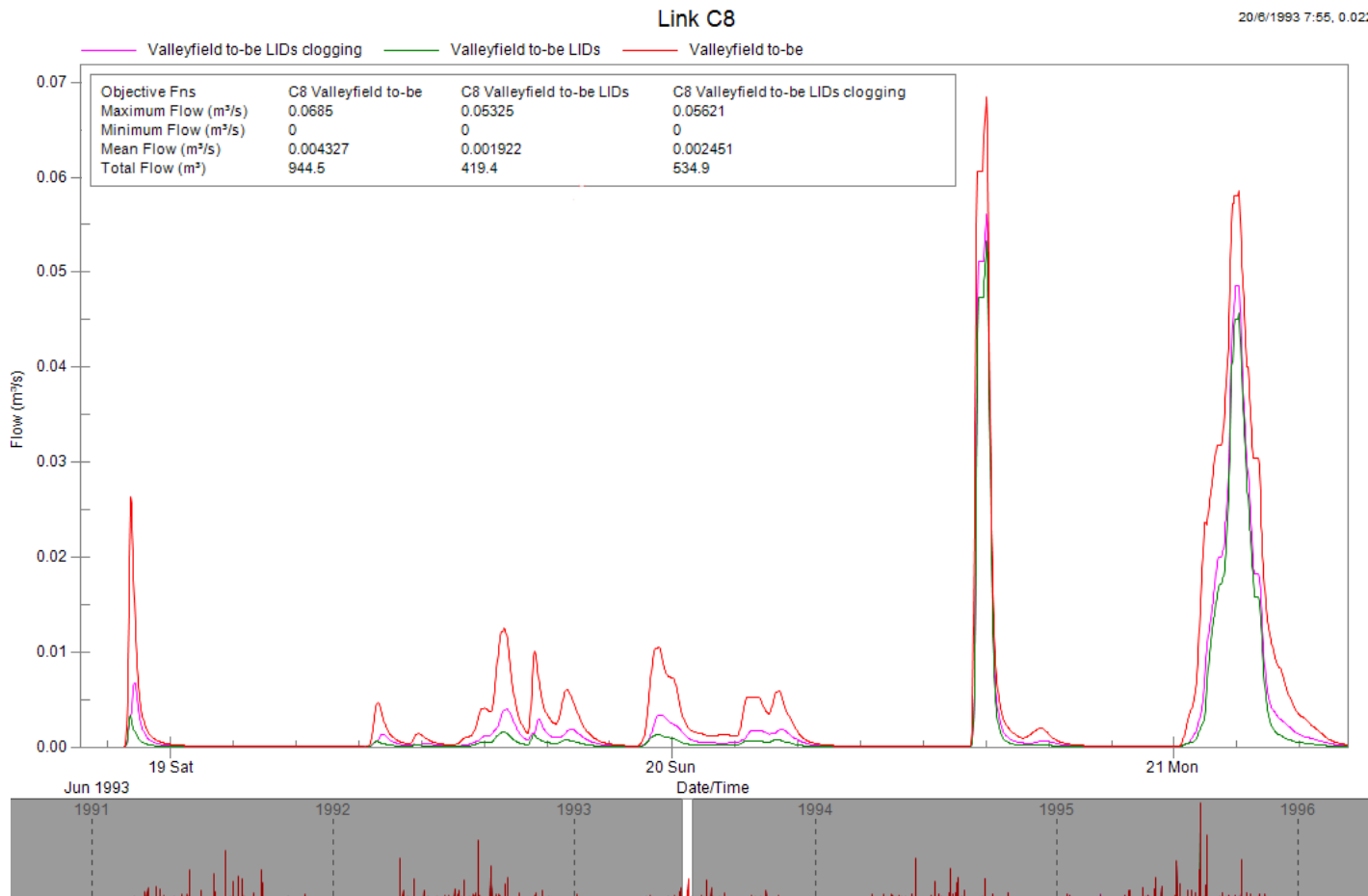
Continuous LID analysis: small events



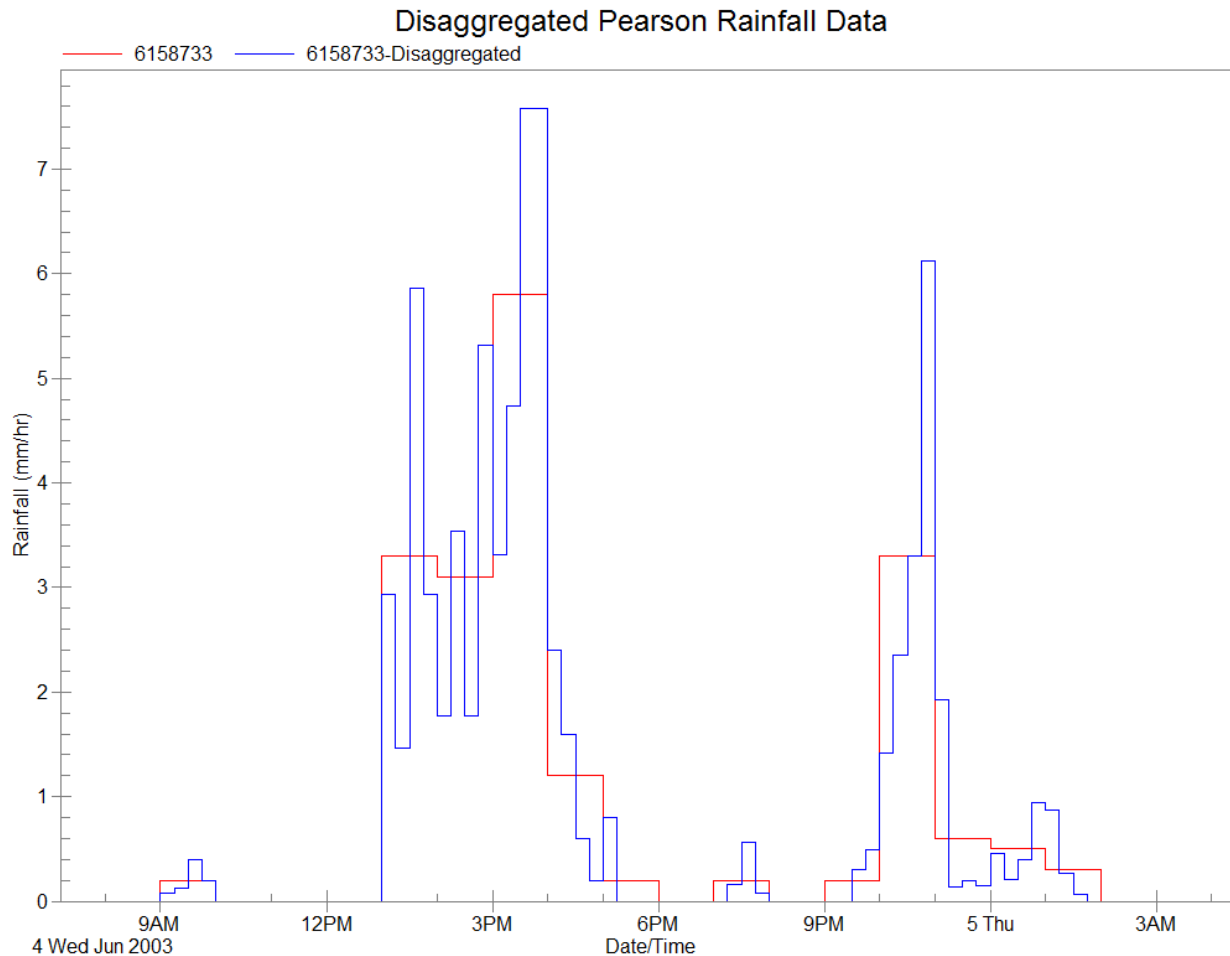
Continuous LID analysis: large events



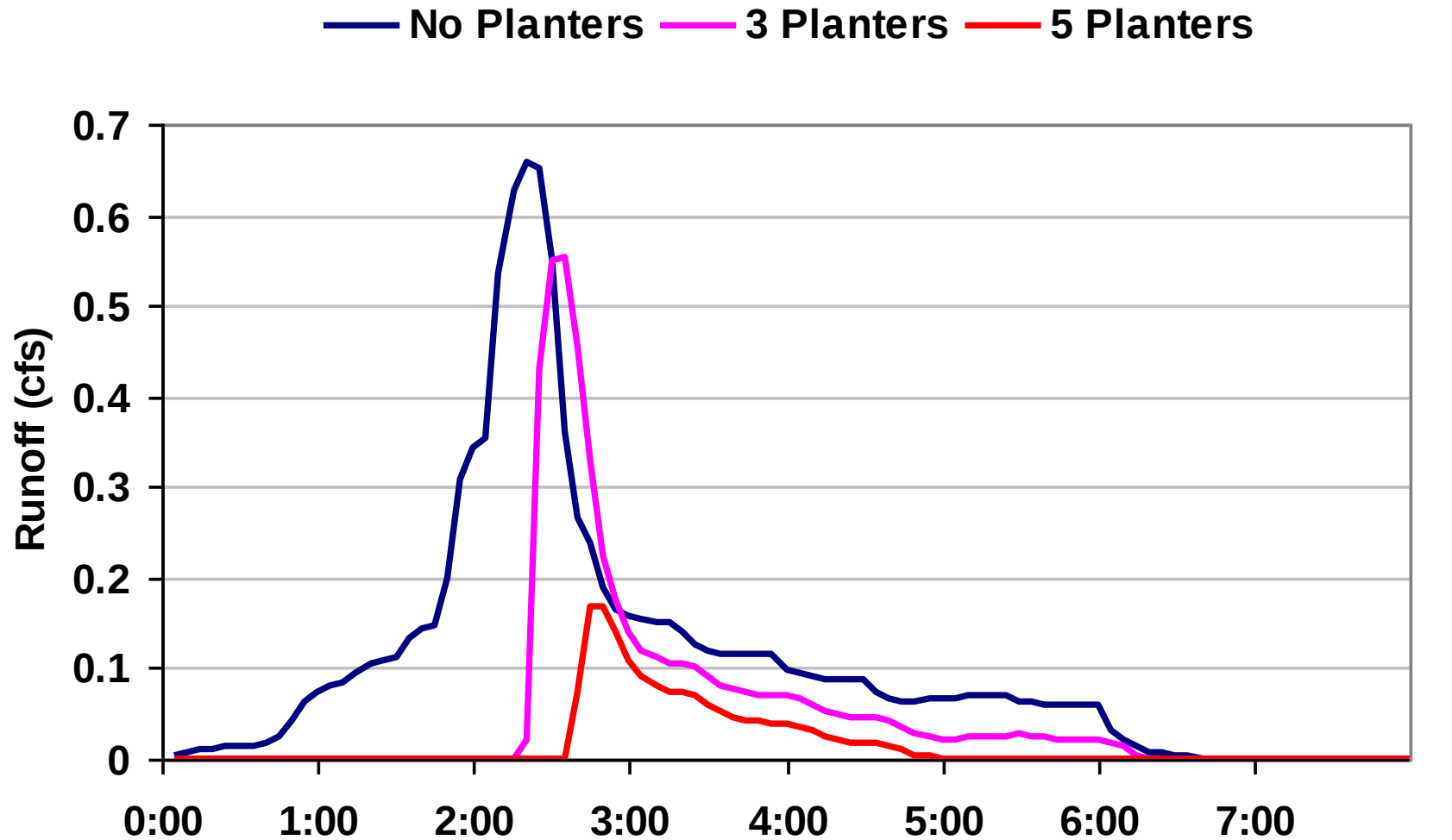
Continuous LID analysis: clogging potential



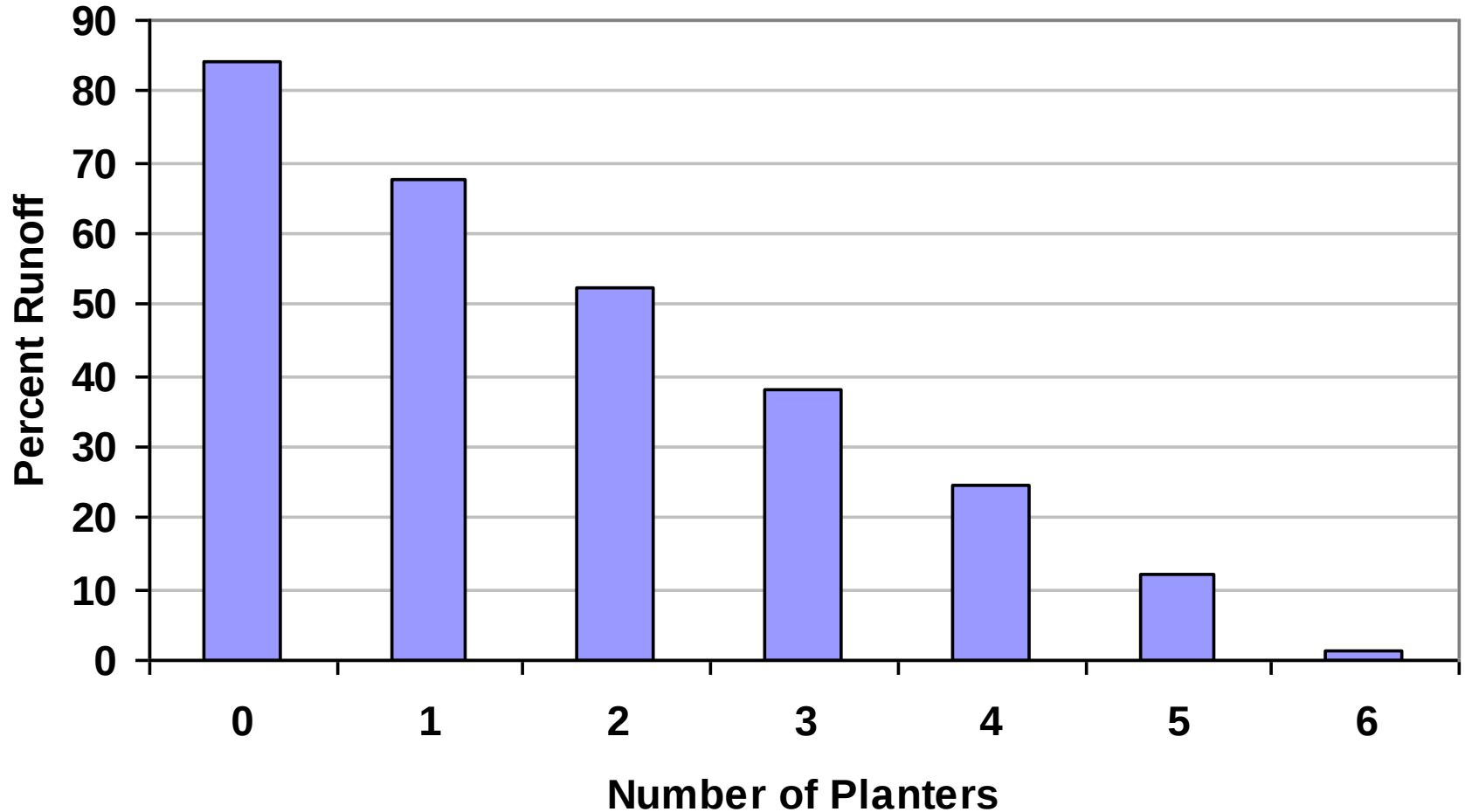
Enabling continuous LID analysis: Rainfall Processing with PCSWMM



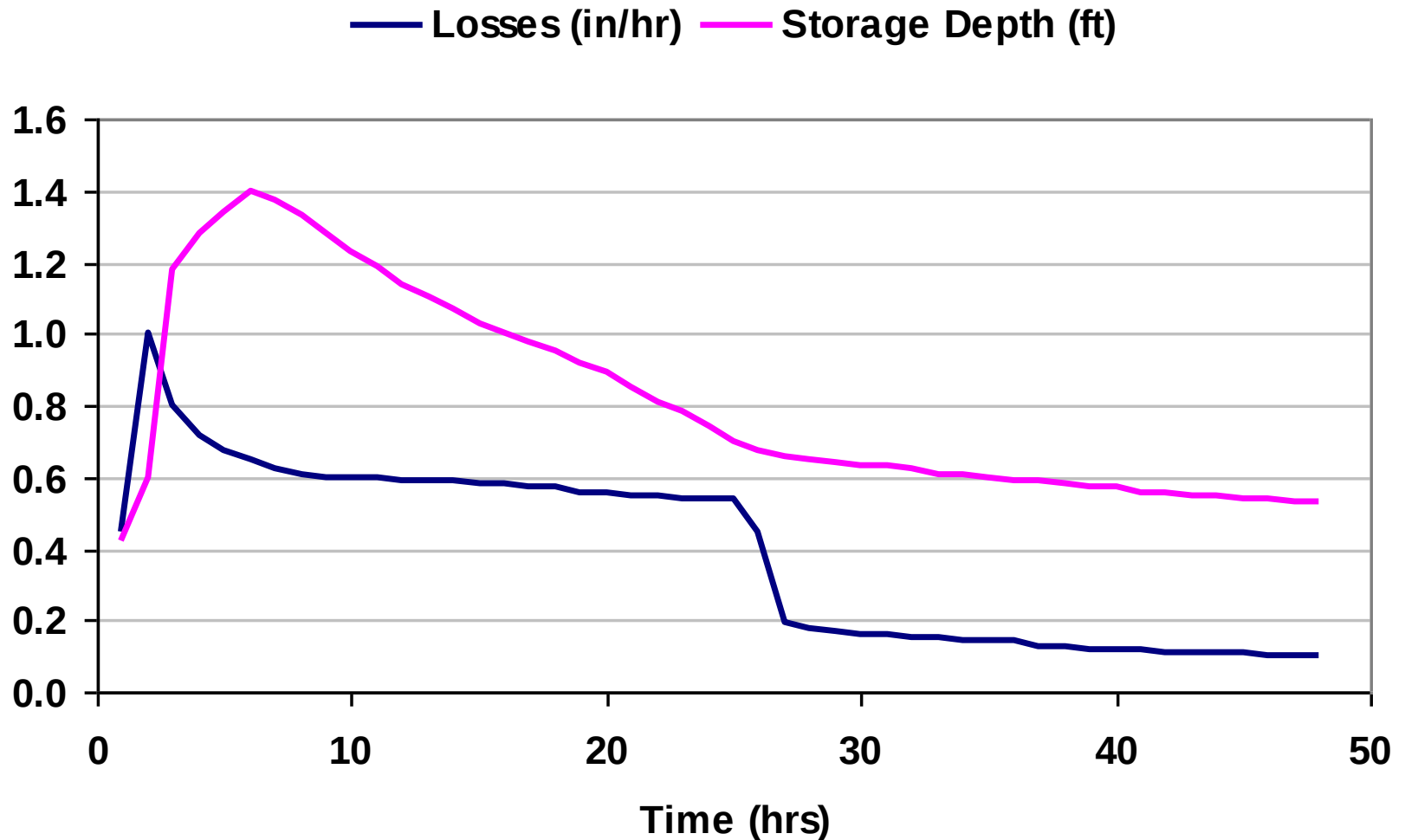
Runoff for 1-inch, 6-hr Event



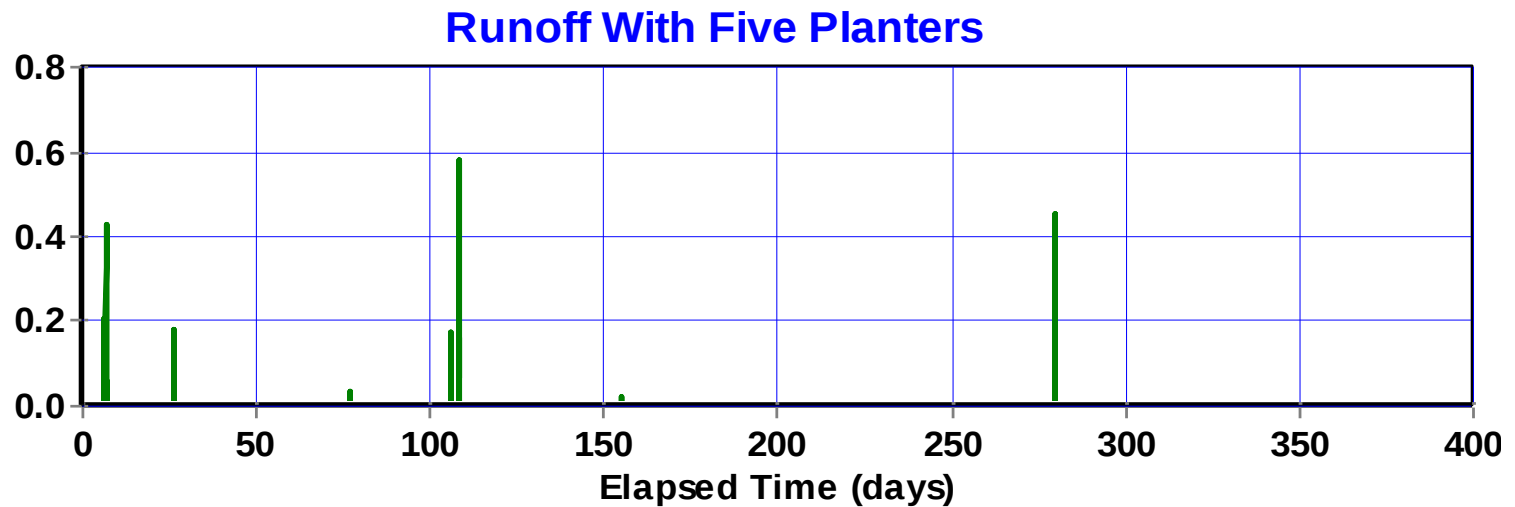
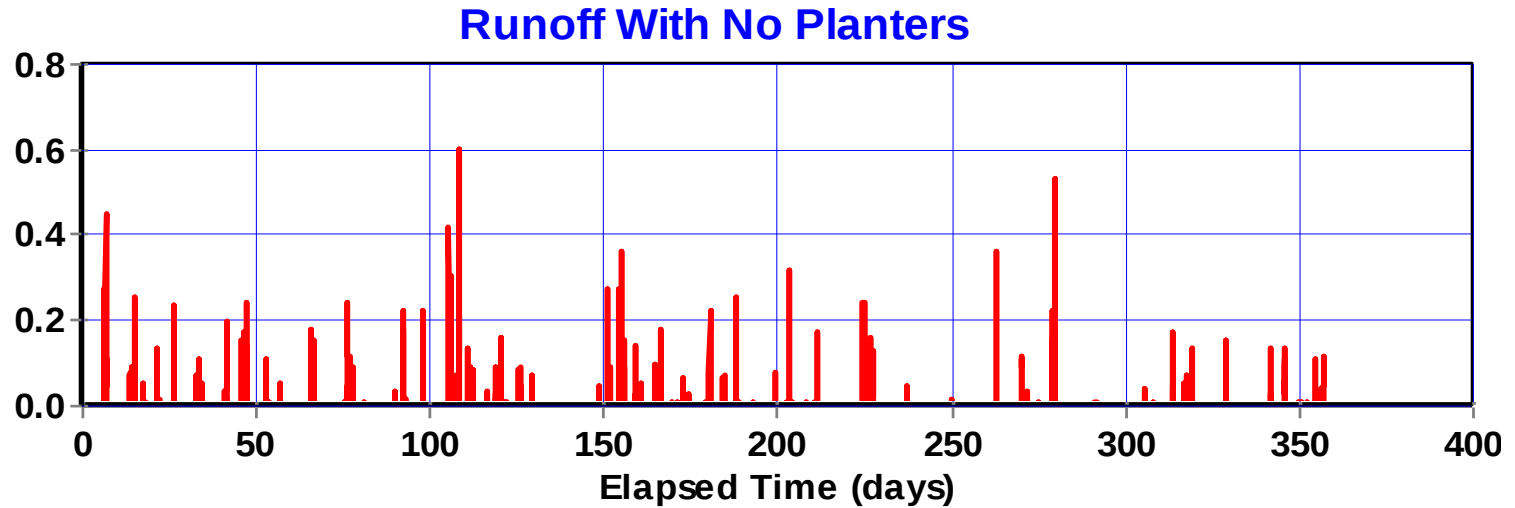
Effect of Number of Planters



Loss of Stored Water Over Time

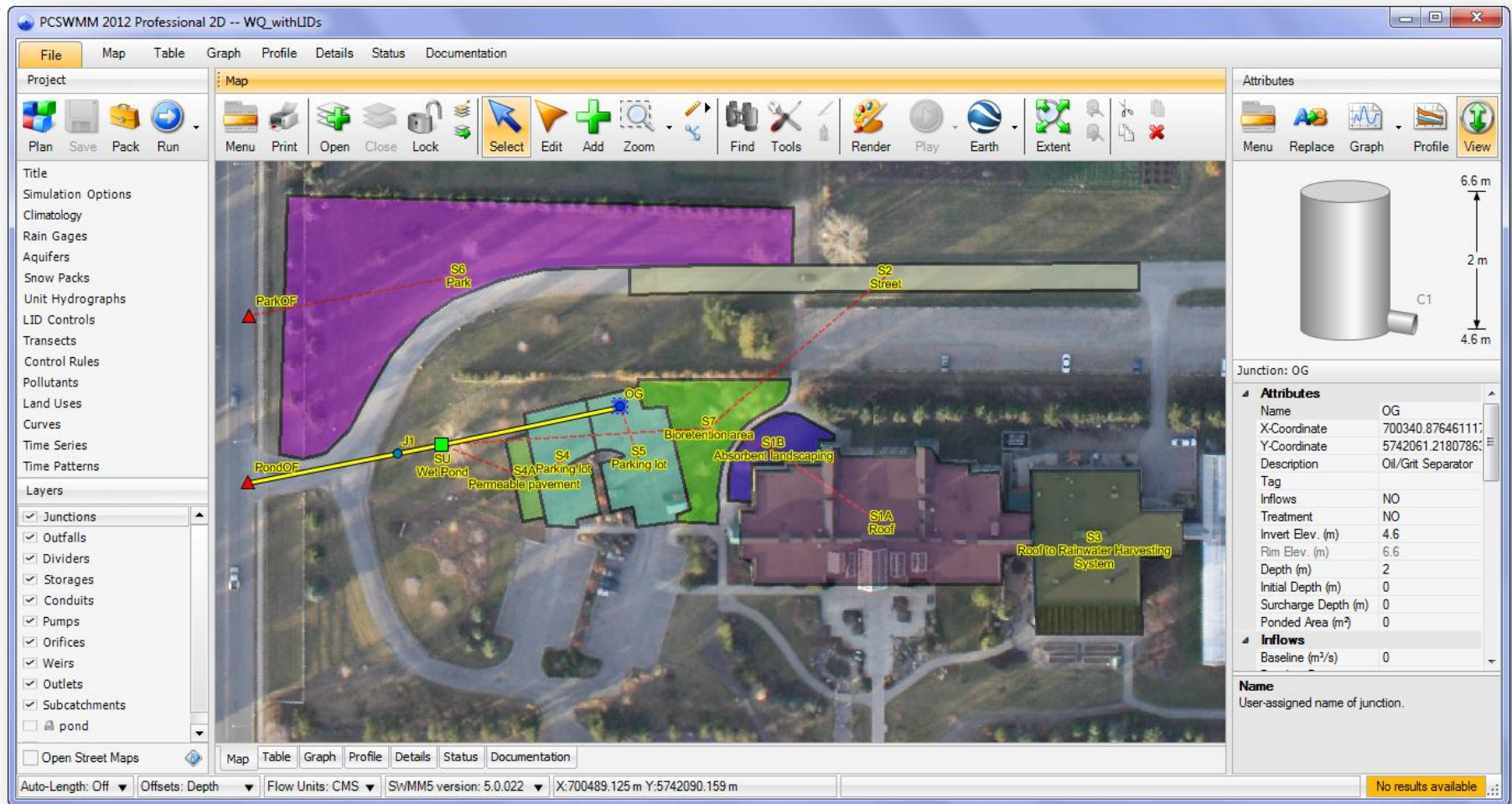


Long Term Performance



Rossman (2009)

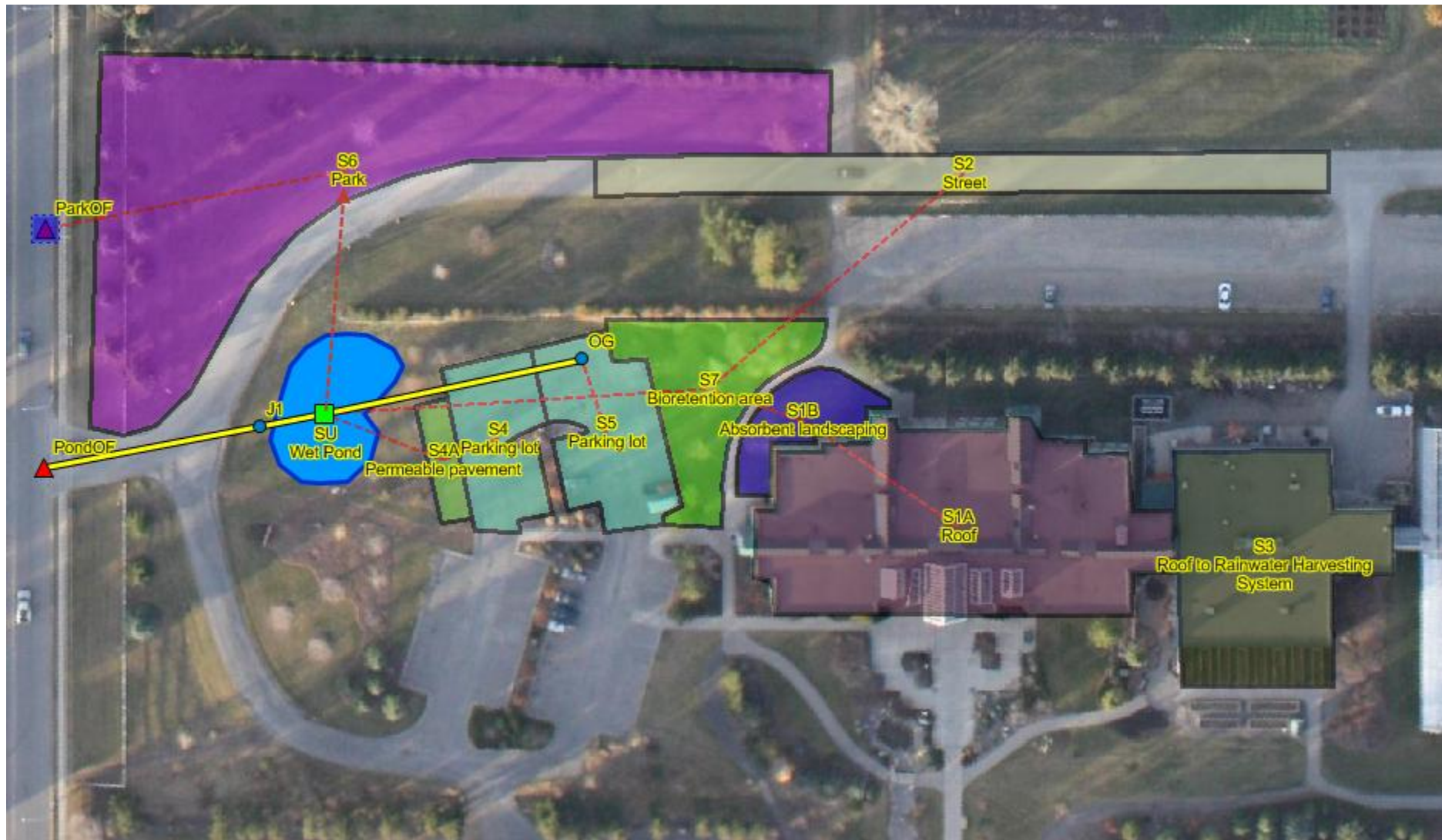
Olds College Demonstration Project



Olds College: lot-level analysis



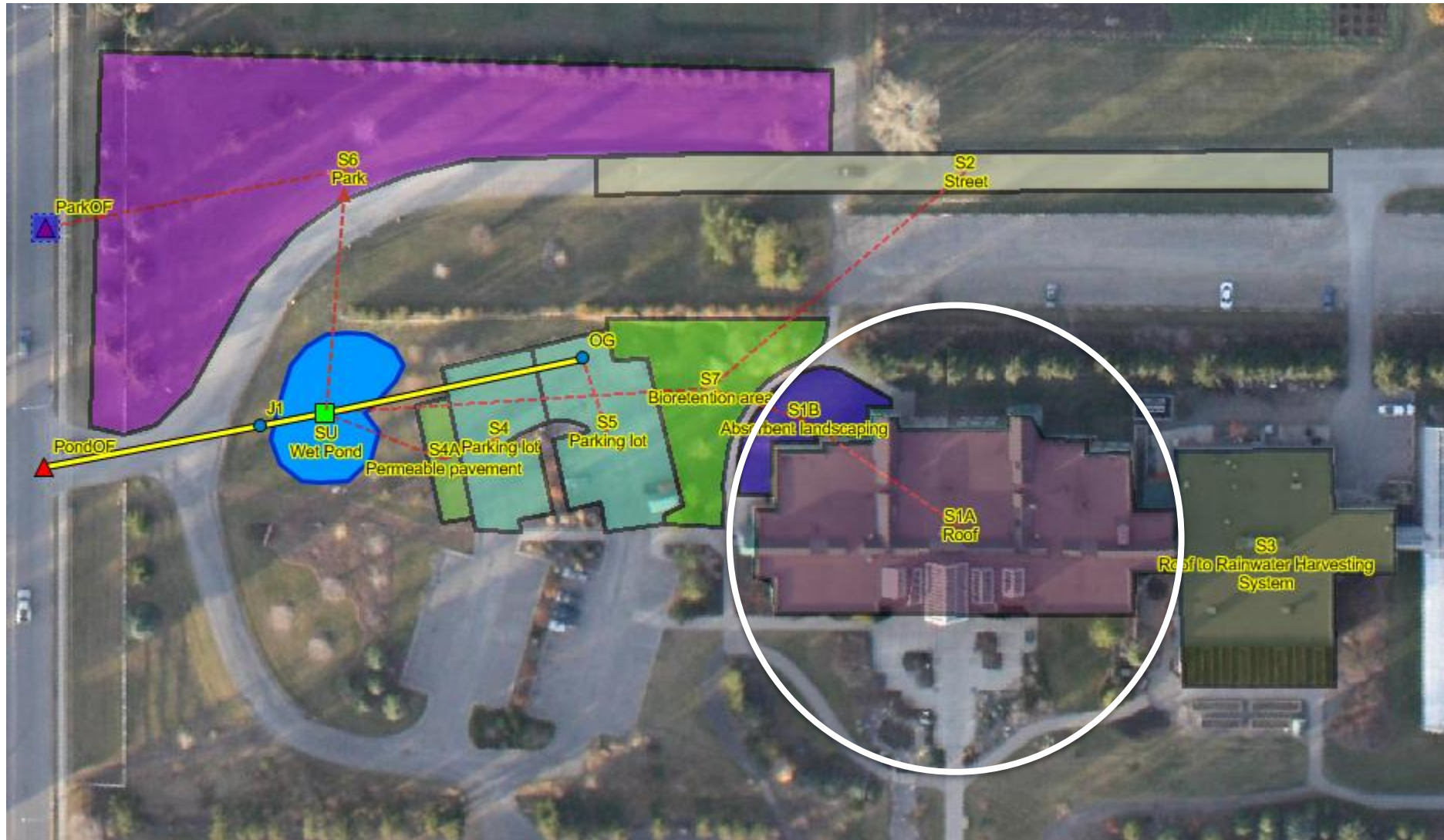
Olds College: subcatchments



Olds College : roof to cistern



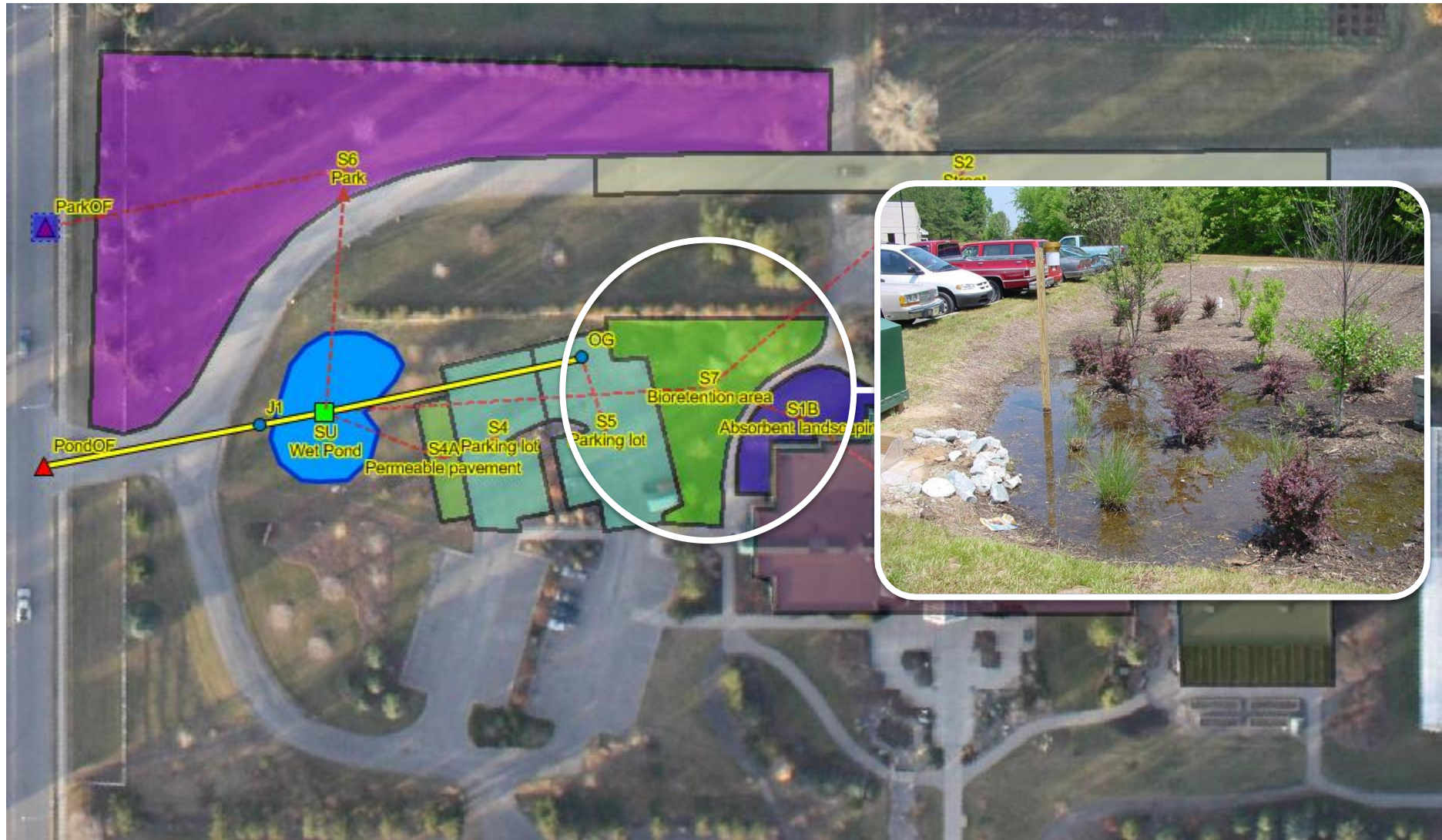
Olds College: roof to landscaping



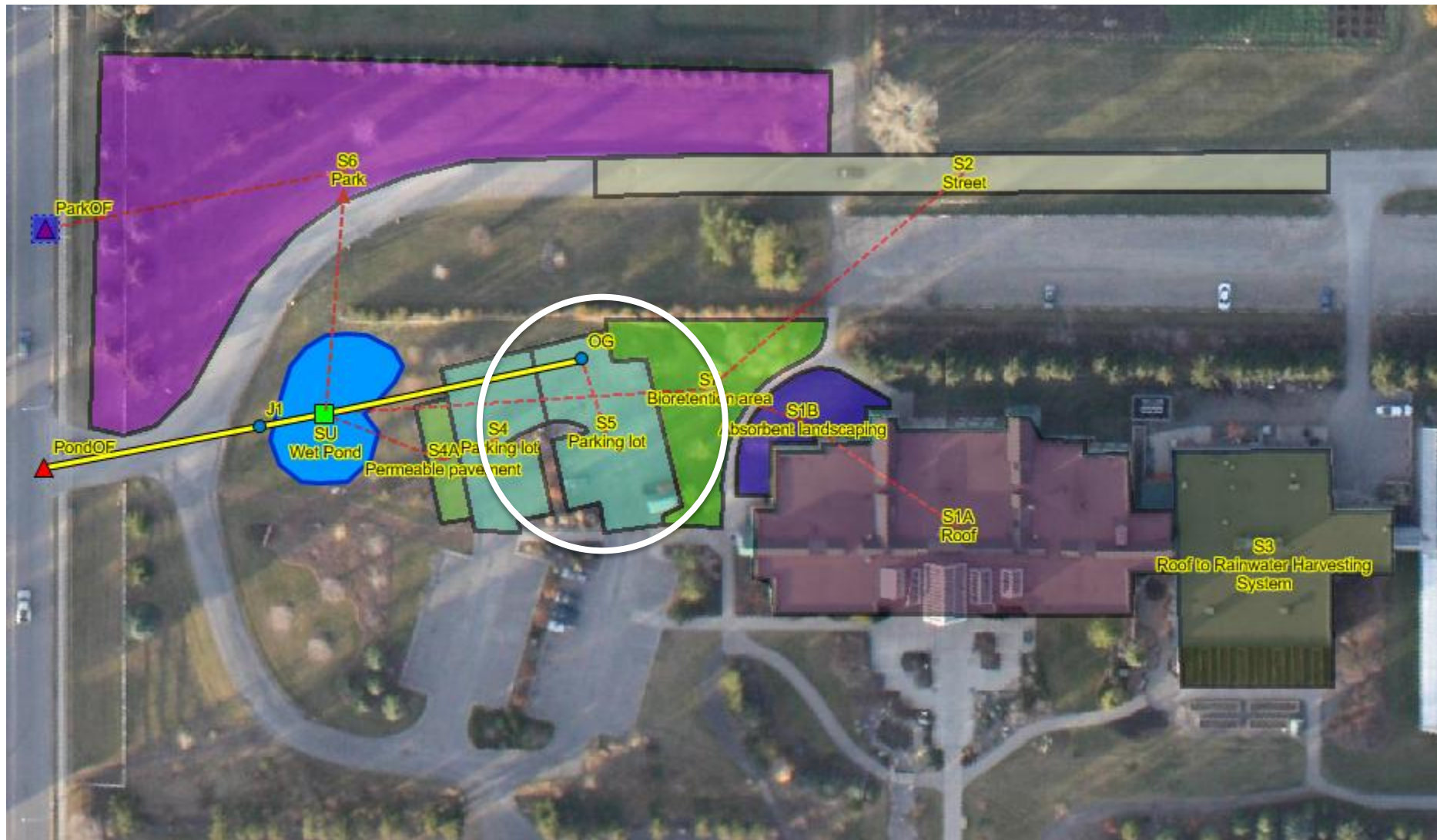
Olds College : absorbent landscaping



Olds College: bio-retention area



Olds College : parking lot 2



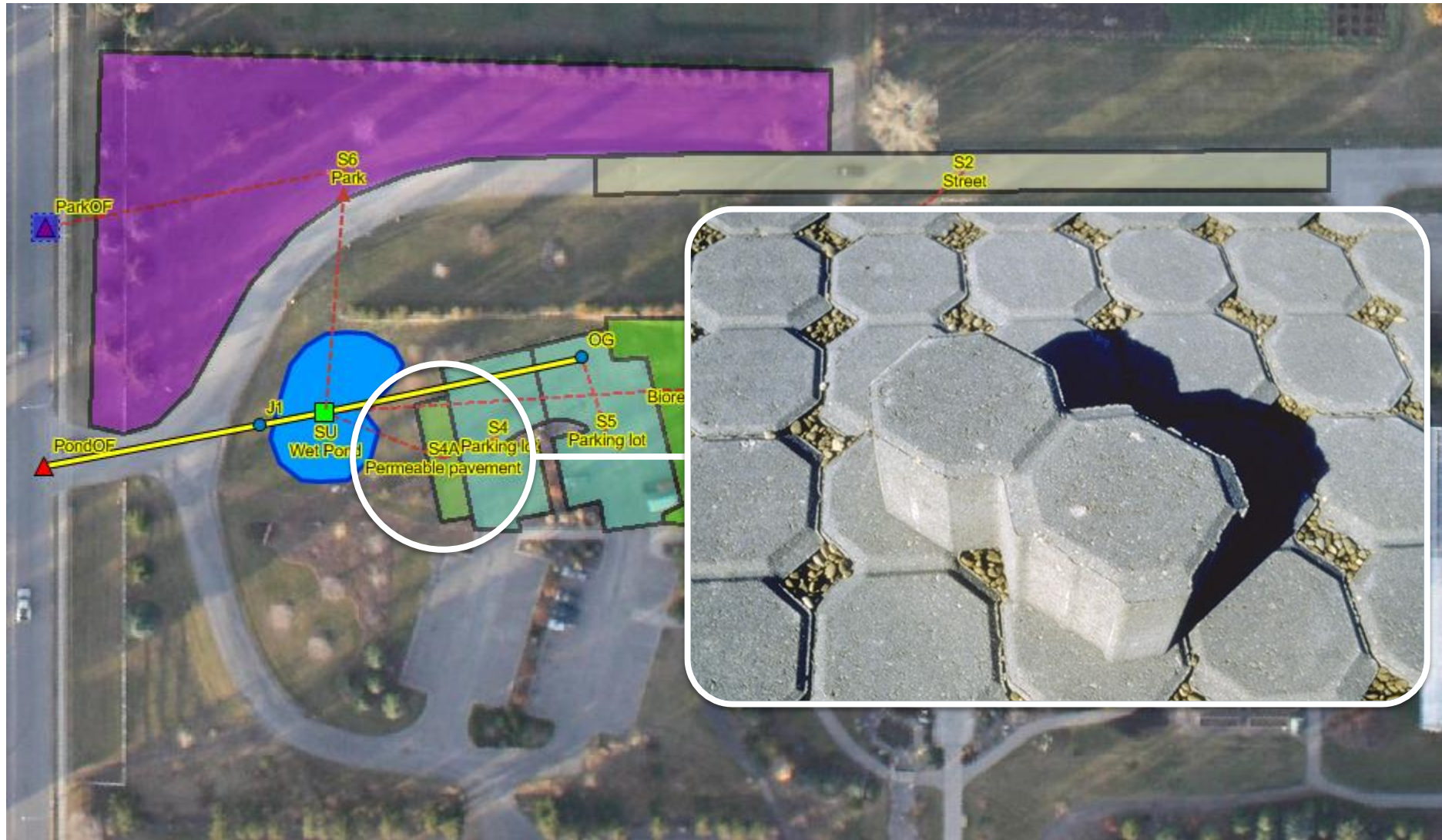
Olds College: oil & grit separator



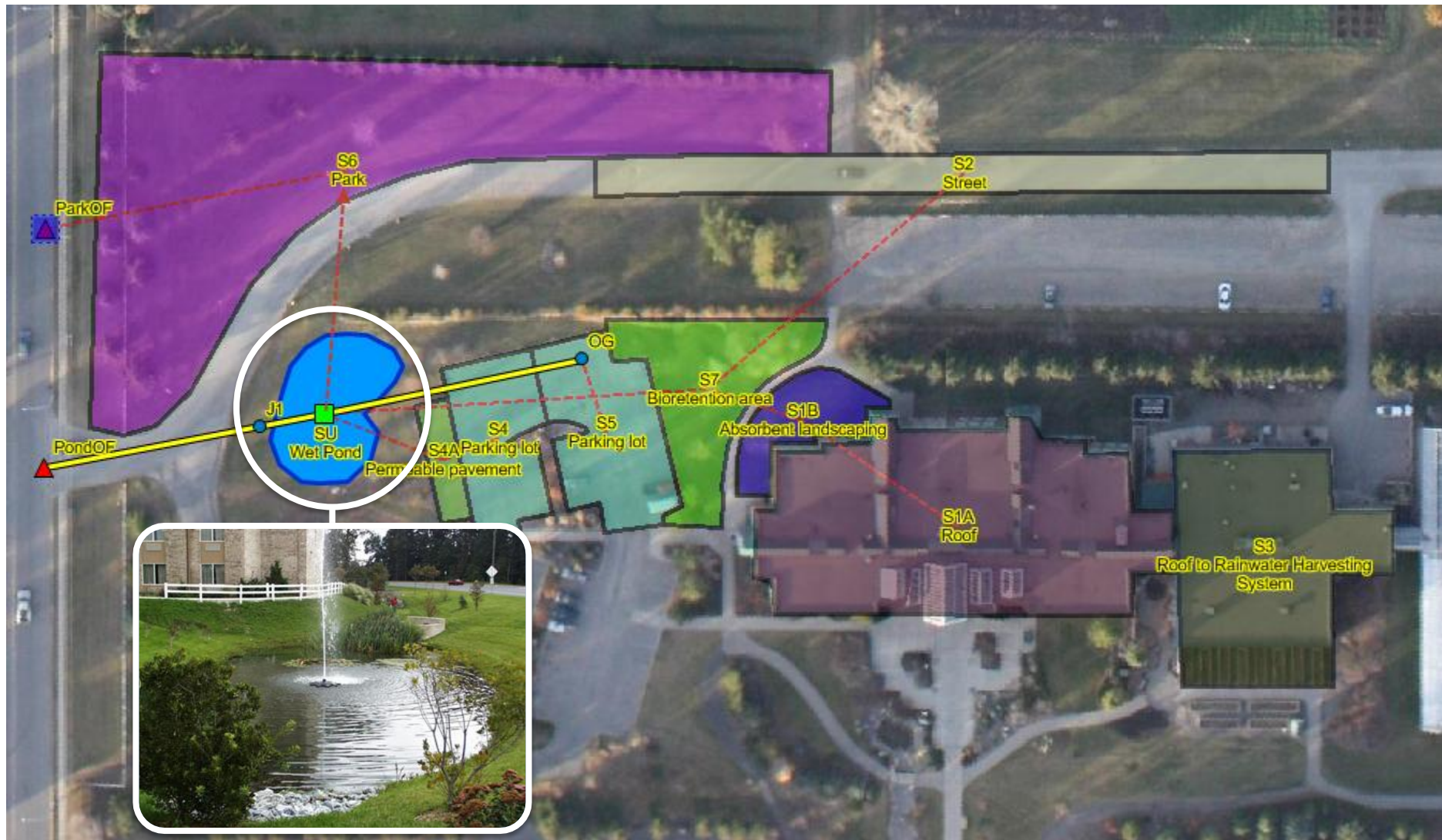
Olds College: parking lot 2



Olds College: permeable pavement



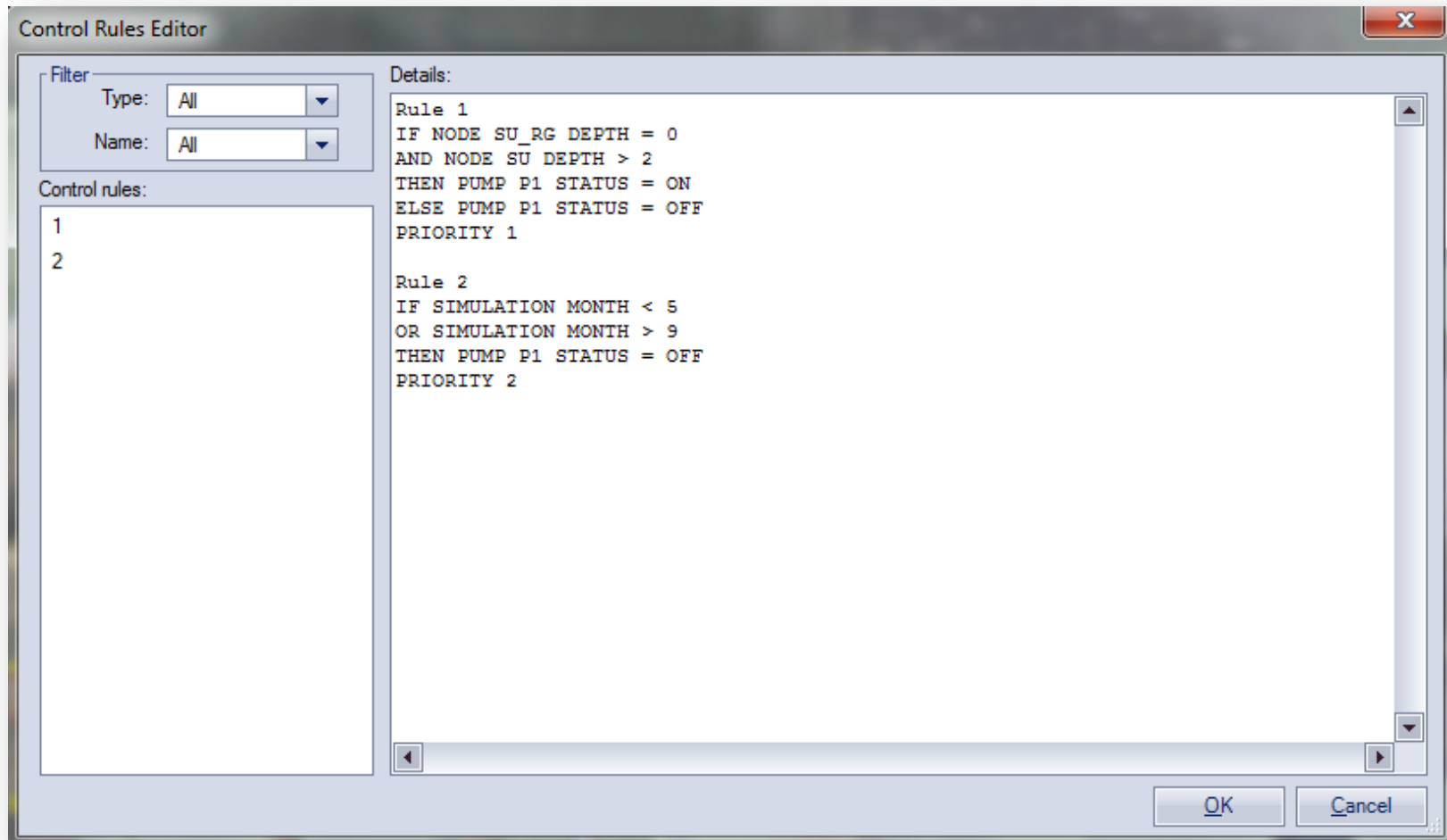
Olds College: wet pond



Olds College: Irrigation



Continuous simulation of re-use



Irrigation

Weekly Watering Schedule #1 (Depth of Irrigation) (mm)

	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Jan							
Feb							
Mar							
Apr							
May						10	
Jun			10			15	
Jul		10		10		15	
Aug		10		10		15	
Sep			10			15	
Oct							
Nov							
Dec							

If the rainfall in the preceding two days is more than 10 mm, irrigation is delayed.

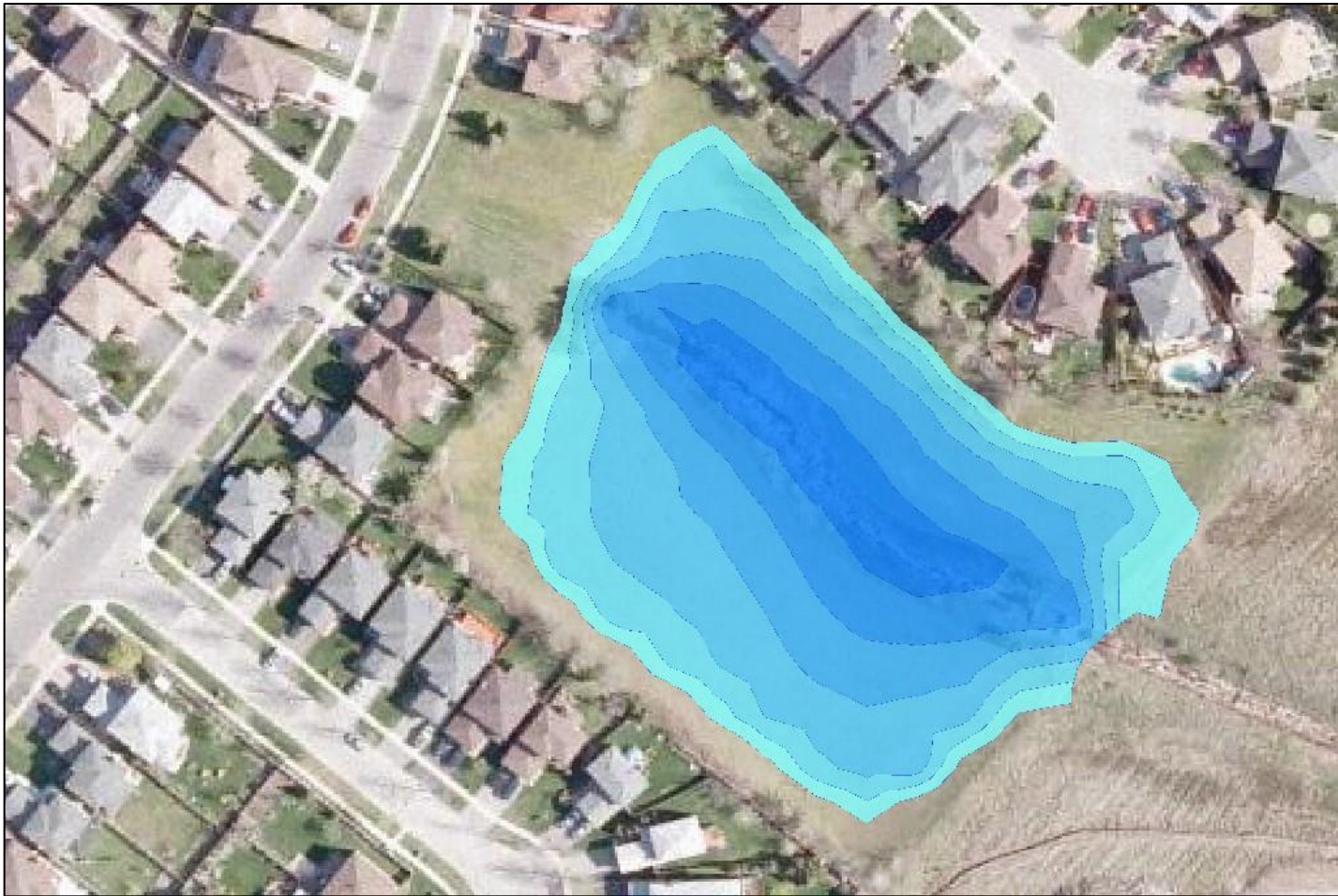
Irrigation

Weekly Watering Schedule #1 (Depth of Irrigation) (mm)

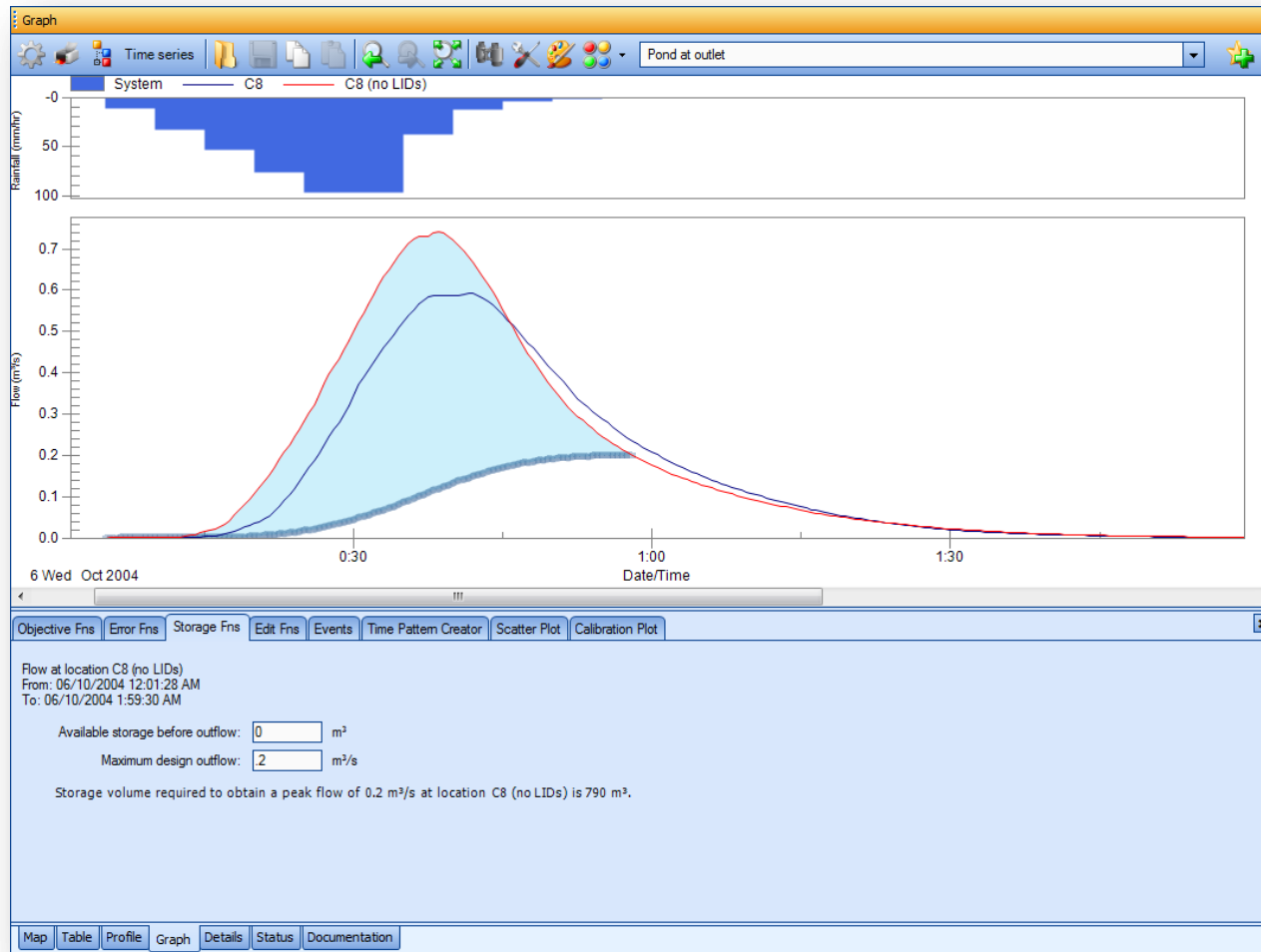
	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Jan							
Feb							
Mar							
Apr							
May						10	
Jun			10			15	
Jul		10		10		15	
Aug		10		10		15	
Sep			10			15	
Oct							
Nov							
Dec							

- Rule 1
IF SIMULATION MONTH = 5
AND SIMULATION DAY = 6
AND NODE SU_RG DEPTH = 0
AND NODE SU DEPTH > 2
THEN PUMP P1 SETTING = 1
- Rule 2
IF SIMULATION MONTH = 6
AND SIMULATION DAY = 3
AND NODE SU_RG DEPTH = 0
AND NODE SU DEPTH > 2
THEN PUMP P1 SETTING = 1
- Rule 3
IF SIMULATION MONTH = 6
AND SIMULATION DAY = 6
AND NODE SU_RG DEPTH = 0
AND NODE SU DEPTH > 2
THEN PUMP P1 SETTING = 1.5
ELSE PUMP P1 STATUS = OFF

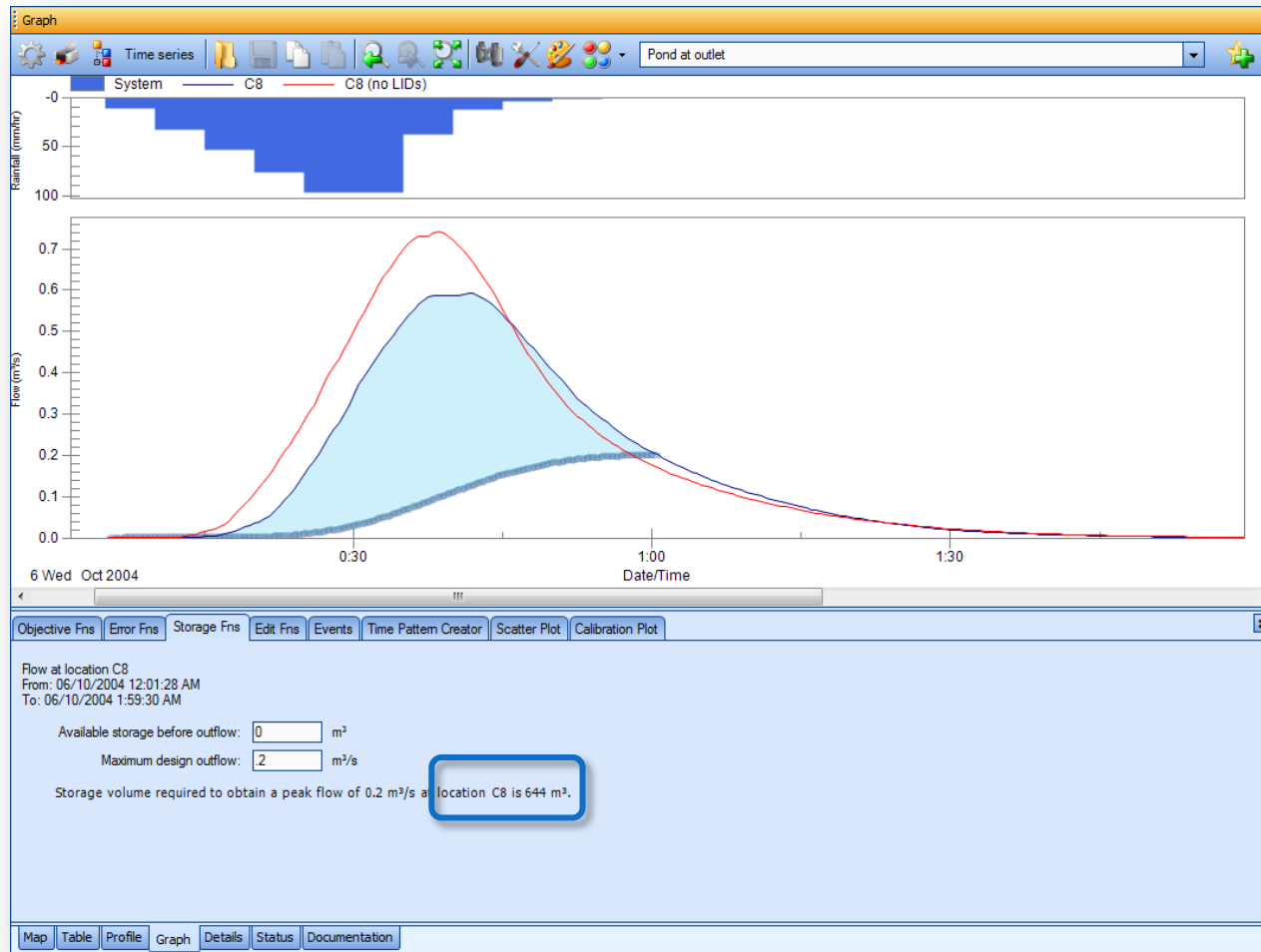
Single event LID analysis: detention pond sizing



Design storm analysis: pond sizing no LIDs



Design storm analysis: pond sizing with LIDs



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