Getting Started with EPA's Storm Water Management Model (SWMM)

Michelle Simon

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University of Cincinnati

Speaker Introduction

Michelle Simon, Ph.D., P.E. Chemical Engineer
Water Infrastructure Division,
Center for Environmental Solutions and Emergency Response,
Office of Research and Development
Cincinnati, OH

EPA Technical POC for SWMM
(after the retirement of Lew Rossman
April 2017)

Please see Feb 2018 SWMM presentation on
https://www.epa.gov/waterdata/surface-water-quality-modeling-training

Disclaimer

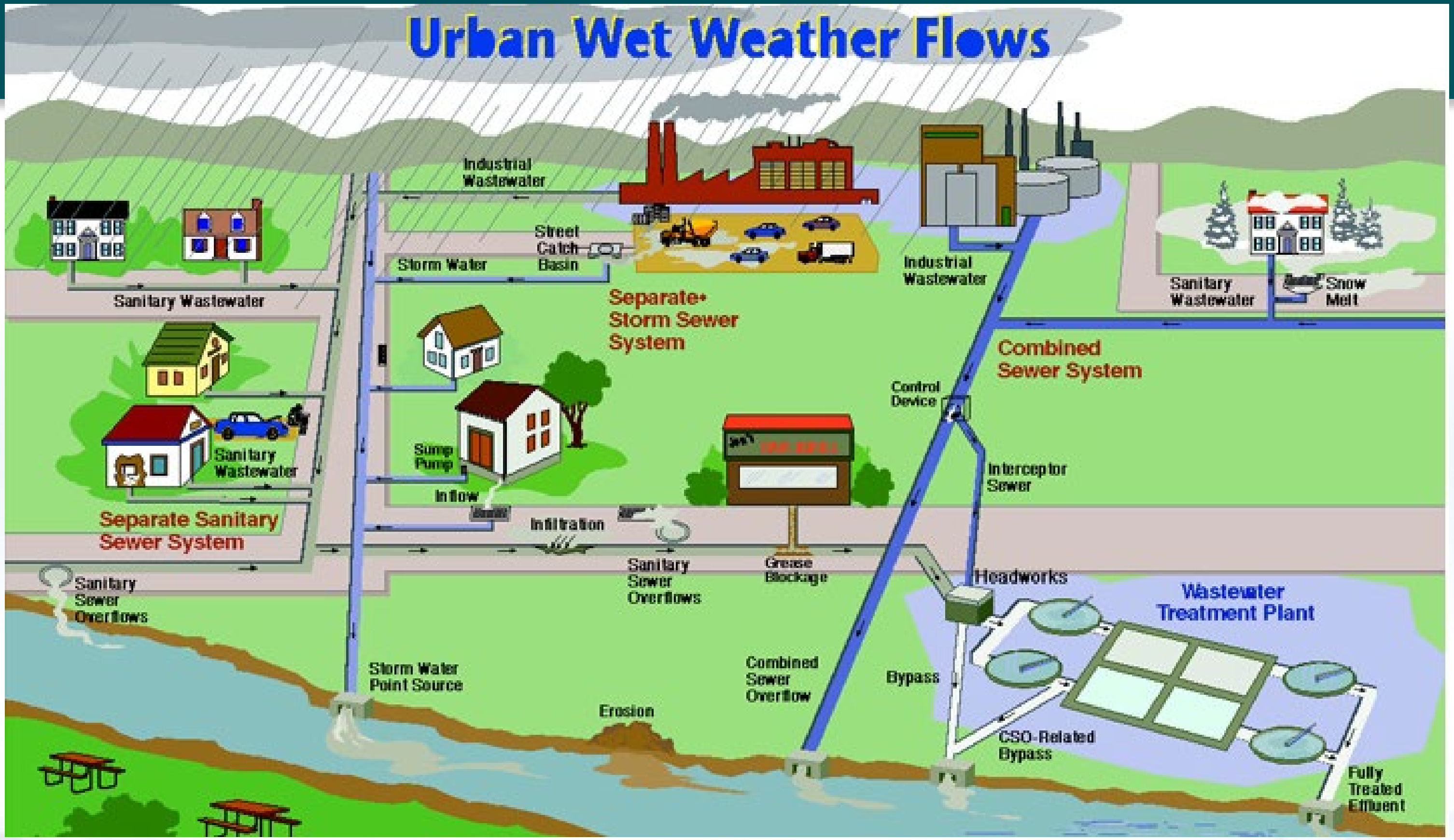
Any opinions expressed in this presentation are those of the author and do not necessarily reflect the views of the Agency, therefore, no official endorsement should be inferred. But it has been through USEPA's official clearance process. **Any mention of trade names or commercial products does not constitute USEPA or my personal endorsement or recommendation for use.**

Outline

Storm Water Management Model

- Definition of SWMM
- Fundamentals of SWMM
    - Hydrology
    - Water Quality
    - Hydraulics
- National Stormwater Calculator
- Location of National Databases
- Technical Support
- Demonstration of some of the Features in SWMM
- Discussion & Questions

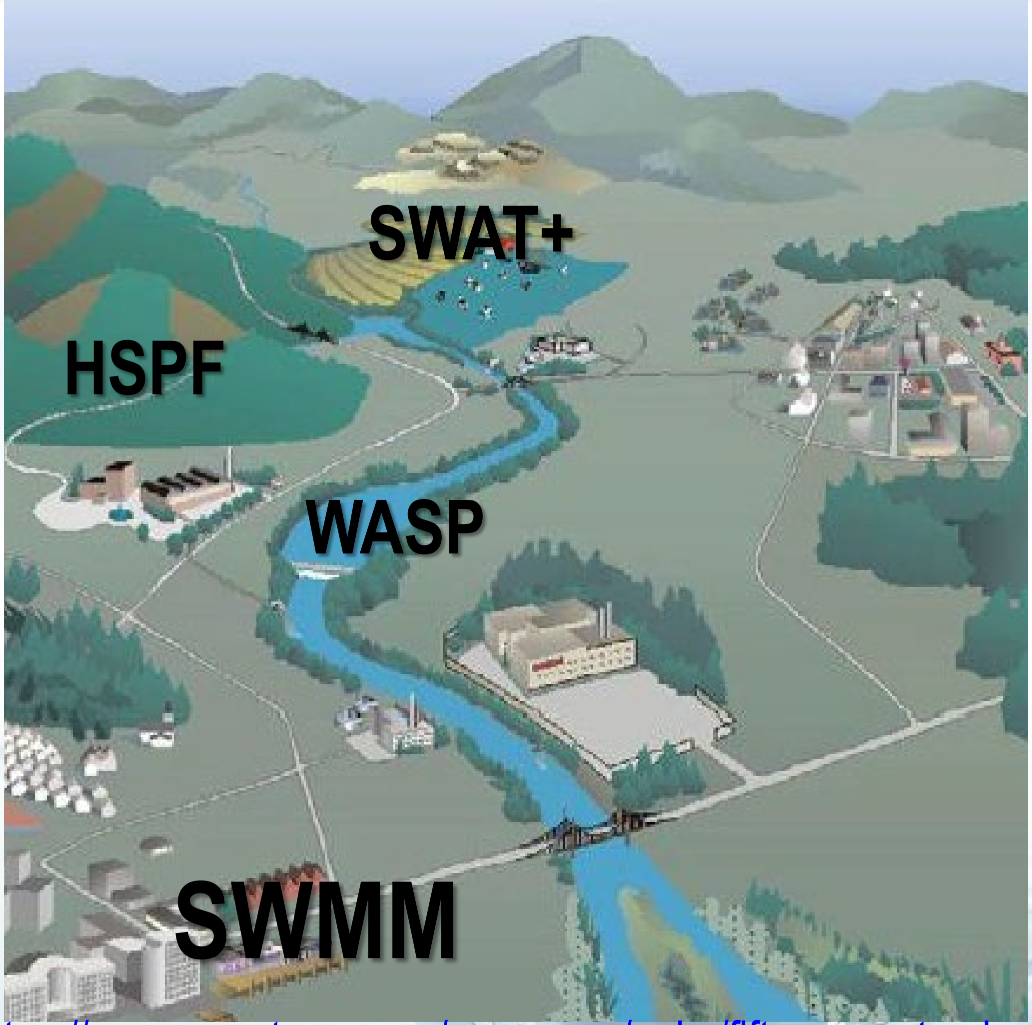
What is SWMM?



SWMM is a public domain, distributed, dynamic hydrologic - hydraulic - water quality model used for continuous simulation of runoff quantity and quality from primarily urban areas.

United States Environmental Protection Agency

How SWMM, HSPF, SWAT, and WASP Relate



https://cfpub.epa.gov/watertrain/pdf/modules/WshedModTools.pdf

https://www.aquaterra.com/resources/pubs/fiftyyearwatershedconferencePrograms.php

What is SWMM Used For?

Design and sizing of drainage system components.

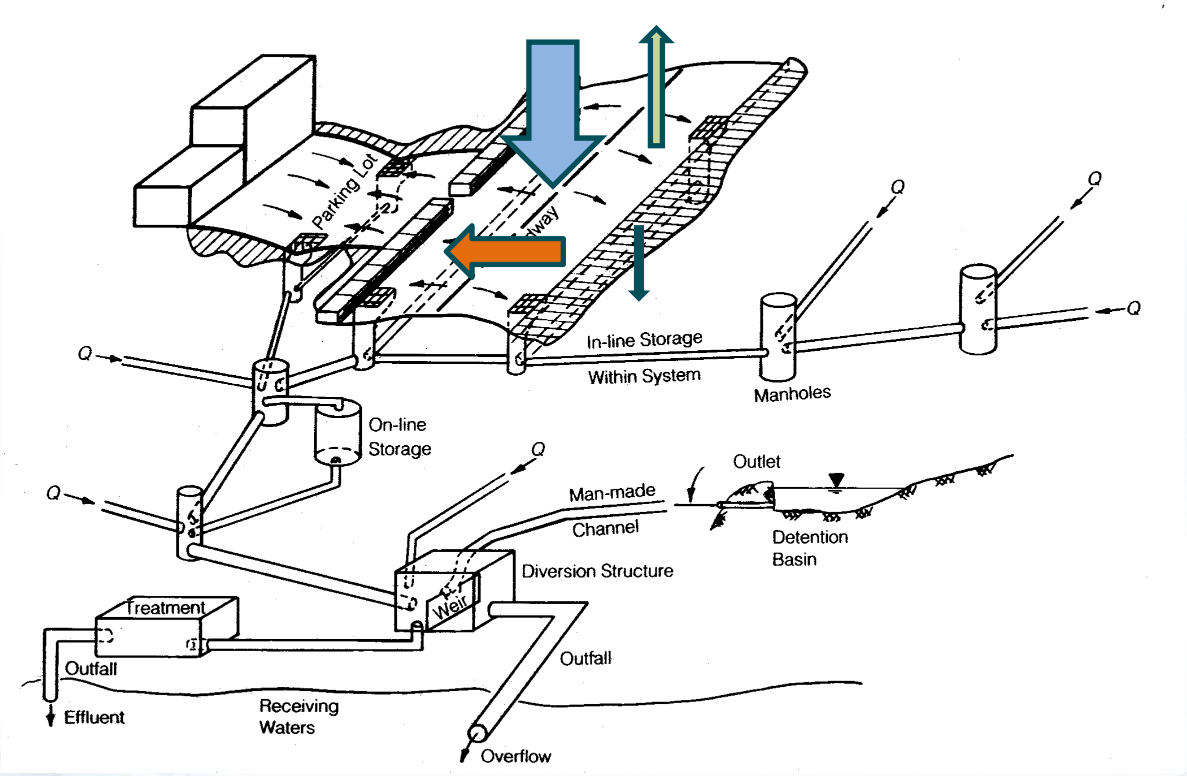
Control of combined and sanitary sewer overflows.

Modeling Inflow & Infiltration in sanitary sewer systems.

Generating non-point source pollutant loadings for load allocation studies.

Evaluating green infrastructure for sustainability goals.

How does SWMM Model?

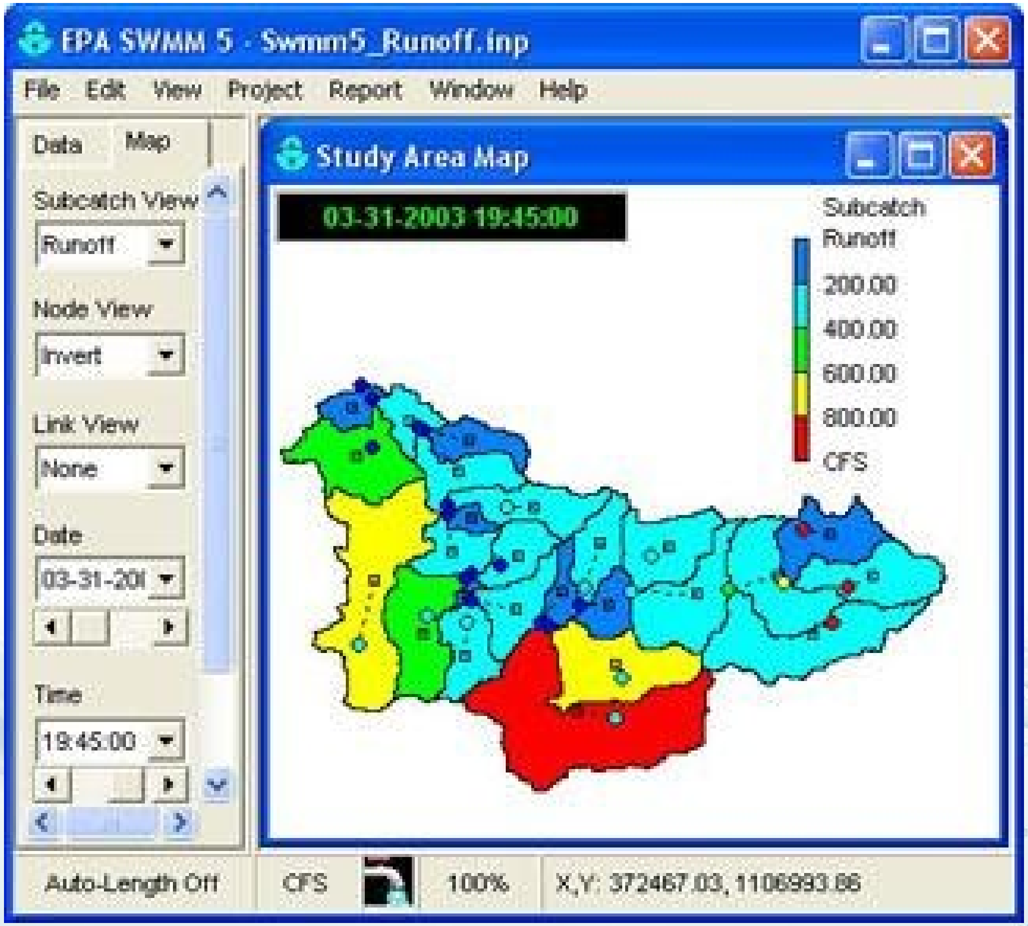


SWMM is a **distributed**, **dynamic rainfall-runoff** simulation model used for **single event** or long-term (**continuous**) simulation of runoff quantity and quality from **primarily urban** areas.

United States Environmental Protection Agency

Storm Water Management Model

https://www.epa.gov/water-research/storm-water-management-model-swmm



SWMM Webpage, continued

https://www.epa.gov/water-research/storm-water-management-model-swmm

Software

Date	Description
7/20/2020	Self-Extracting Installation Program for SWMM 5.1.015 (EXE) (32 MB)
02/18/2020	Self-Extracting Installation Program for SWMM 5.1.014 (EXE) (31 MB)
12/11/2014	SWMM-CAT Download Version 1 (4 MB)
05/25/2005	Utility for converting SWMM 4 data files to SWMM 5 files (EXE) Version 1.2 (2 MB)

SWMM Webpage, continued

https://www.epa.gov/water-research/storm-water-management-model-swmm

Documentation

Date	Title
09/30/2015	SWMM 5.1 User's Manual
09/01/2014	SWMM-CAT User's Guide
01/29/2016	SWMM Reference Manual Volume I—Hydrology
08/07/2017	SWMM Reference Manual Volume II—Hydraulics
09/08/2016	SWMM Reference Manual Volume III—Water Quality
01/31/2017	SWMM Technical Fact Sheet
07/06/2010	SWMM Applications Manual (ZIP) (7 MB)
09/19/2006	Quality Assurance Report for Dynamic Wave Flow Routing (ZIP) (3 MB)

EPA/600/R-15/162A | January 2016 | www2.epa.gov/water-research

EPA
United States
Enviromental Protection
Agency

Storm Water Management Model Reference Manual

Volume I – Hydrology (Revised)

EPA
United States
Environmental Protection
Agency

EPA/600/R-17/111 www.epa.gov/water-research

Storm Water Management Model Reference Manual

Volume II –Hydraulics

United States
Environmental Protection
Agency

EPA/600/R-16/093 | July 2016 | www.epa.gov/water-research

Plus LID Modules

Storm Water Management Model Reference Manual

Volume III – Water Quality

SWMM Reference Manuals

Documentation

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09/30/2015	SWMM 5.1 User's Manual
09/01/2014	SWMM-CAT User's Guide
01/29/2016	SWMM Reference Manual Volume I—Hydrology
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09/19/2006	Quality Assurance Report for Dynamic Wave Flow Routing (ZIP) (3 MB)

4.4 Green-Ampt Method

The Green-Ampt equation (Green and Ampt, 1911) has received considerable attention in recent years. The original equation was for infiltration with excess water at the surface at all times. Mein and Larson (1973) showed how it could be adapted to a steady rainfall input and proposed a way in which the capillary suction parameter could be determined. Chu (1978) has shown the applicability of the equation to the unsteady rainfall situation, using data for a field catchment. The Green-Ampt method was added into SWMM III in 1981 by R.G. Mein and W. Huber (Huber et al., 1981).

4.4.1 Governing Equations

The Green-Ampt conceptualization of the infiltration process is one in which infiltrated water moves vertically downward in a saturated layer, beginning at the surface (Figure 4-5). In the wetted zone the moisture content θ is at saturation θ_s while the moisture content in the un-wetted zone is at some known initial level θ_i.

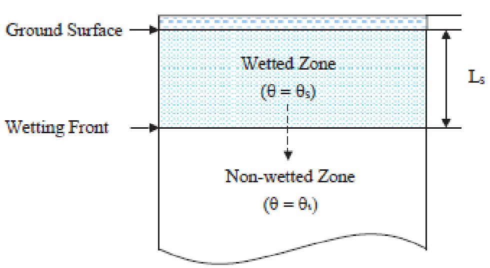

Figure 4-5 Two-zone representation of the Green-Ampt infiltration model (after Nicklow et al., 2006).

The water velocity within the wetted zone is given by Darcy's Law as a function of the saturated hydraulic conductivity K_s, the capillary suction head along the wetting front ψ_s, the depth of ponded water at the surface d, and the depth of the saturated layer below the surface L_s:

$$f_p = K_s\left[\frac{d + L_s + \psi_s}{L_s}\right] \qquad (4\text{-}26)$$

The depth of the saturated layer L_s can be expressed in terms of the cumulative infiltration, F, and the initial moisture deficit to be filled below the wetting front, $\theta_d = \theta_s - \theta_i$ as $L_s = F/\theta_d$. Substituting this into Equation 4-26 and assuming that d is small compared to the other depths gives the Green-Ampt equation for saturated conditions:

$$f_p = K_s\left[1 + \frac{\psi_s \theta_d}{F}\right] \qquad (4\text{-}27)$$

Equation 4-27 applies only after a saturated layer develops at the ground surface. Prior to this point in time the infiltration capacity will equal the rainfall intensity:

$$f_p = i \qquad (4\text{-}28)$$

As time increases, one can test whether saturation has been reached by solving 4-27 for F (which will be denoted as F_s) with f_p set equal to i and check if this value equals or exceeds the actual cumulative infiltration F:

$$F_s = \frac{K_s \psi_s \theta_d}{i - K_s} \qquad (4\text{-}29)$$

Note that there is no calculation of F_s when $i <= K_s$, although F still gets updated during such periods. Finally, in this scheme the actual infiltration f is the same as the potential value f_p:

$$f = f_p \qquad (4\text{-}30)$$

The two equations are illustrated in Figure 4-6 for the situation $K_s = 0.25$ in/hr, $\psi_s = 6.5$ in, and $\theta_d = 0.20$. The initial, flat portion of the curve corresponds to $f = i$, up to the point where $F = F_s$ (Equation 4-29). The remainder of the curve corresponds to the potential rate computed with Equation 4-27. Note that the infiltration rate approaches K_s (0.25 in/hr) asymptotically.

Use the SWMM Tutorial's

CHAPTER 2 – QUICK START TUTORIAL

This chapter provides a tutorial on how to use EPA SWMM. If you are not familiar with the elements that comprise a drainage system, and how these are represented in a SWMM model, you might want to review the material in Chapter 3 first.

2.1 Example Study Area

In this tutorial we will model the drainage system serving a 12-acre residential area. The system layout is shown in Figure 2-1 and consists of subcatchment areas[3] *S1* through *S3*, storm sewer conduits *C1* through *C4*, and conduit junctions *J1* through *J4*. The system discharges to a creek at the point labeled *Out1*. We will first go through the steps of creating the objects shown in this diagram on SWMM's study area map and setting the various properties of these objects. Then we will simulate the water quantity and quality response to a 3-inch, 6-hour rainfall event, as well as a continuous, multi-year rainfall record.

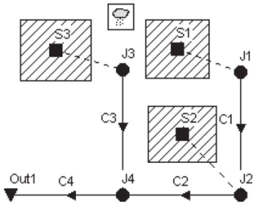

Figure 2-1 Example study area

2.2 Project Setup

Our first task is to create a new SWMM project and make sure that certain default options are selected. Using these defaults will simplify the data entry tasks later on.

1. Launch EPA SWMM if it is not already running and select **File** >> **New** from the Main Menu bar to create a new project.
2. Select **Project** >> **Defaults** to open the Project Defaults dialog.

[3] A subcatchment is an area of land containing a mix of pervious and impervious surfaces whose runoff drains to a common outlet point, which could be either a node of the drainage network or another subcatchment.

Documentation

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09/30/2015	SWMM 5.1 User's Manual
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EPA United States Environmental Protection Agency

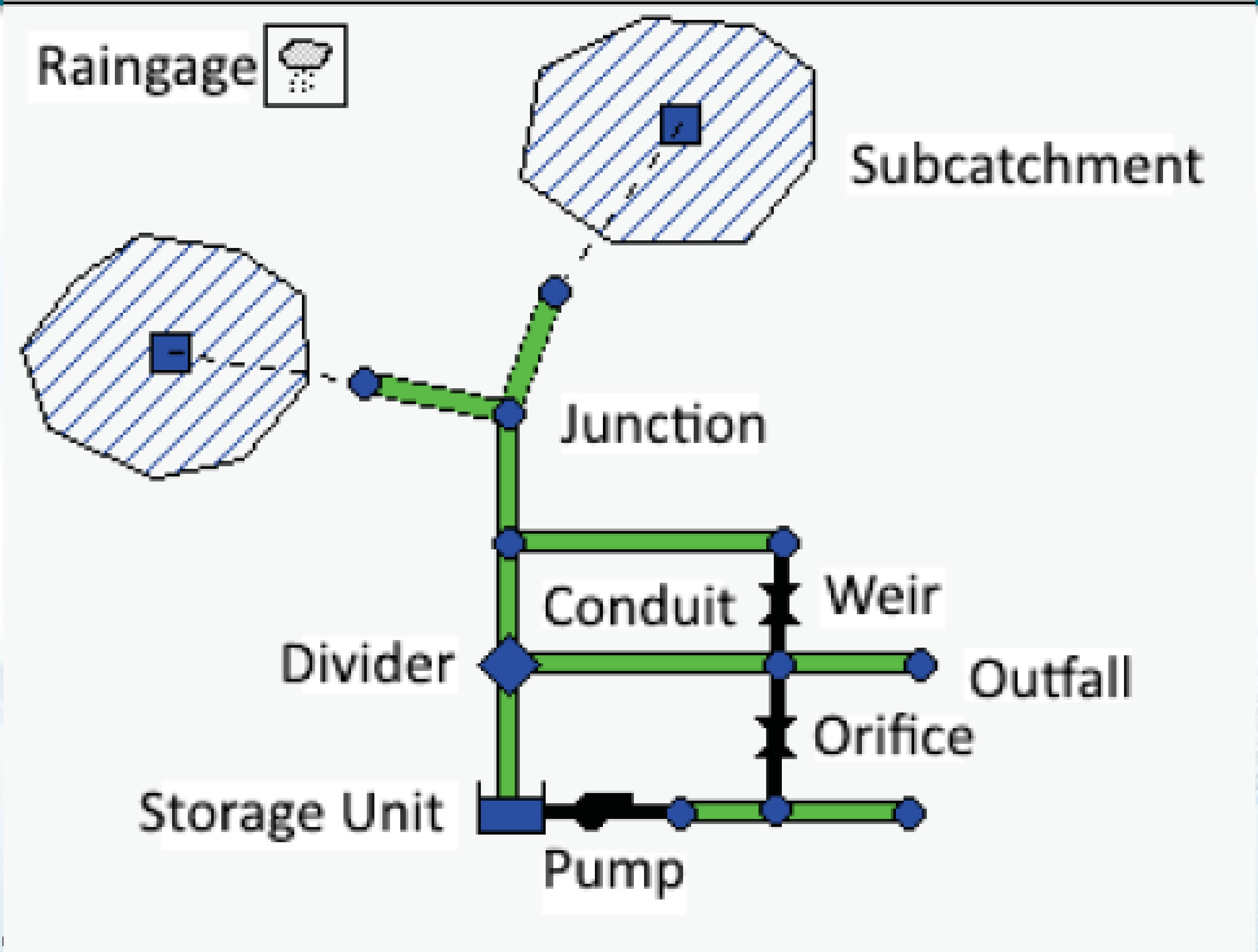
https://swmm5.org/2017/08/14/epa-swmm5-tutorial-with-images-for-swmm-5-1-012/

Storm Water Management Model User's Manual Version 5.1

Demonstration of SWMM

- Walk through governing equations
  - Hydrology
  - Low Impact Development
  - Water Quality
  - Hydraulics
- Then Stormwater Calculator
- Demonstrate SWMM

SWMM's Conceptual Model



Hydrology – Governing equations Reference Manual I Chapter 3

From conservation of mass, the net change in depth *d* per unit of time *t* is the difference between inflow and outflow rates over the subcatchment:

d/t = Q/A (cfs/ft^2) = ft/sec

$$\frac{\partial d}{\partial t} = r + i - e - f - q \qquad (3\text{-}1)$$

where:

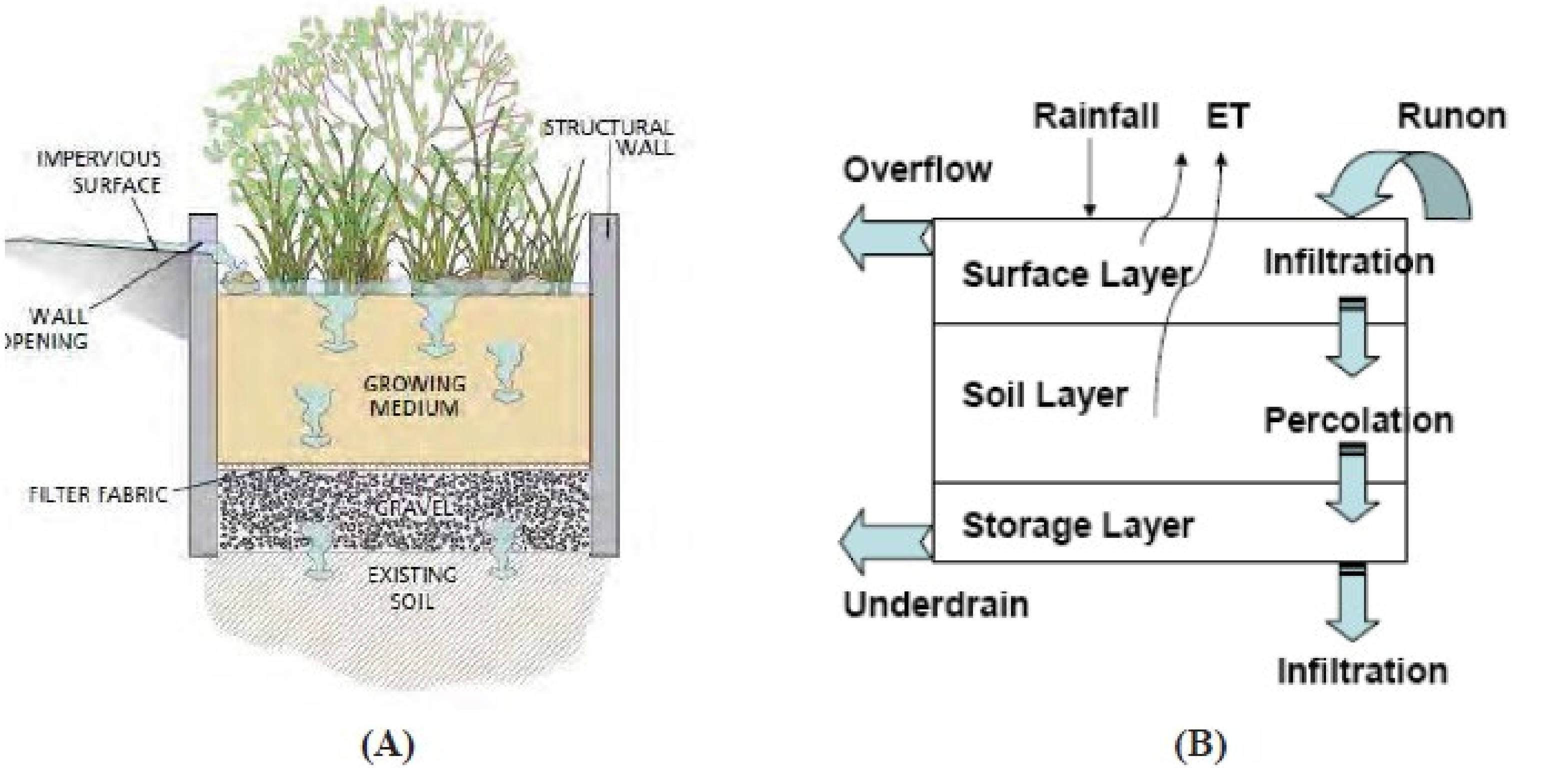
- r = rate of upstream runon (ft/s)
- i = rate of rainfall + snowmelt (ft/s)
- e = surface evaporation rate (ft/s)
- f = infiltration rate (ft/s)
- q = runoff rate (ft/s).

Note that the fluxes *r, i, e, f,* and *q* are expressed as flow rates per unit area.

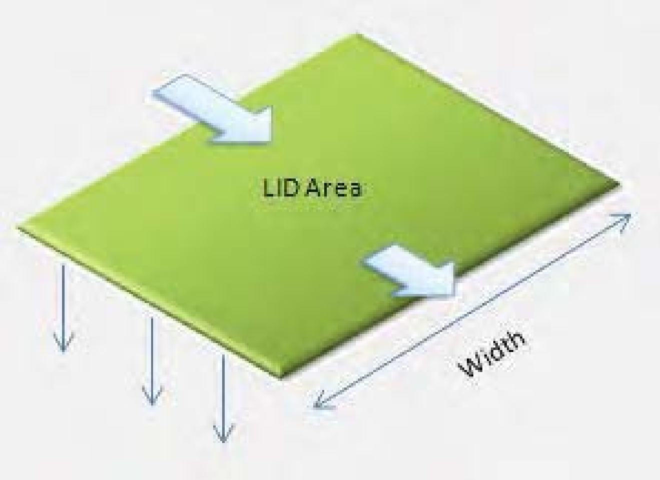
Hydrology Reference Manual Equation 3-1 (modified)

LID Modeling in SWMM

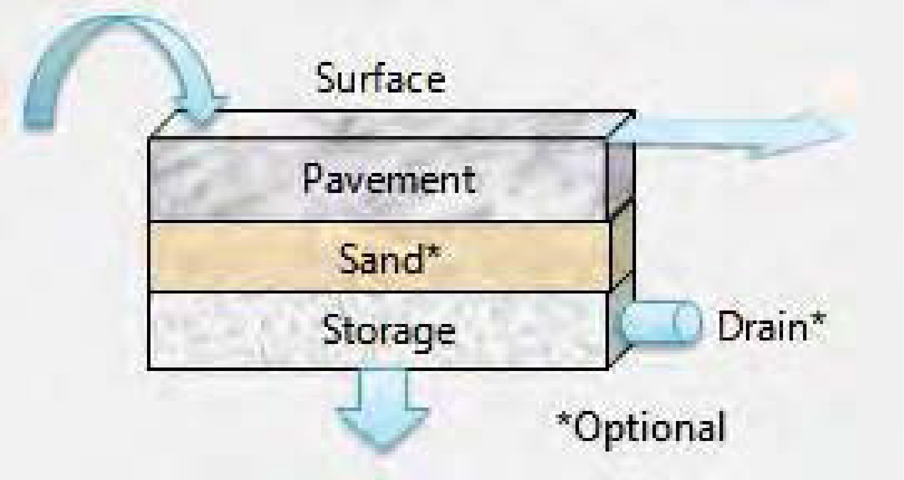
Green Infrastructure Subcatchment Reference Manual III Chapter 6



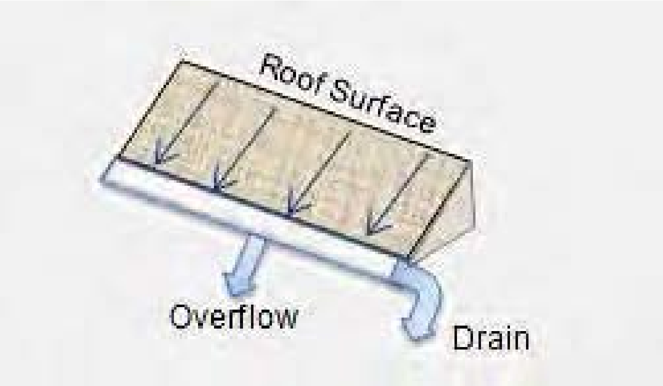
More Green Infrastructure Subcatchments



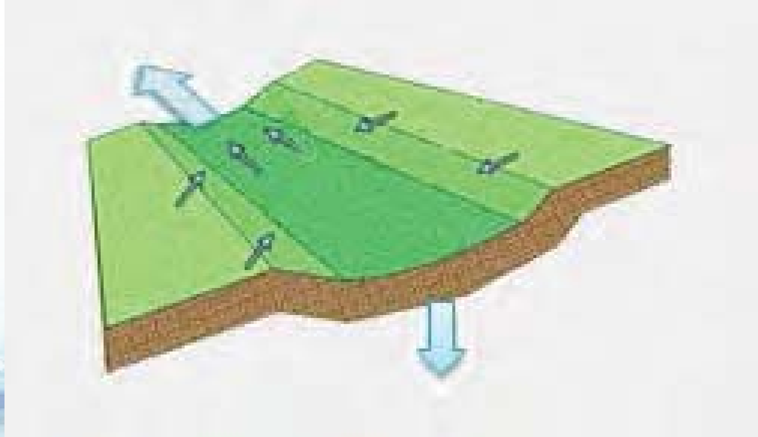
Green Roof



Permeable Pavement



Roof Disconnection



Vegetative Swale

Types of LIDs Modeled


Disconnection

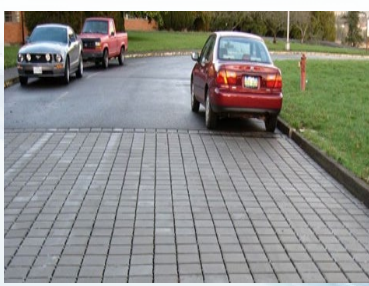

Infiltration Basin


Bioretention and Rain Garden

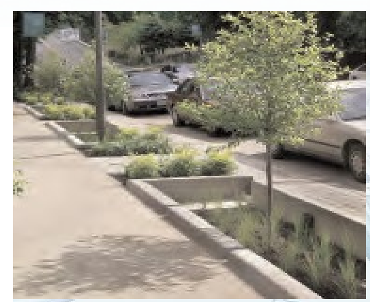

Cistern


Infiltration Trench

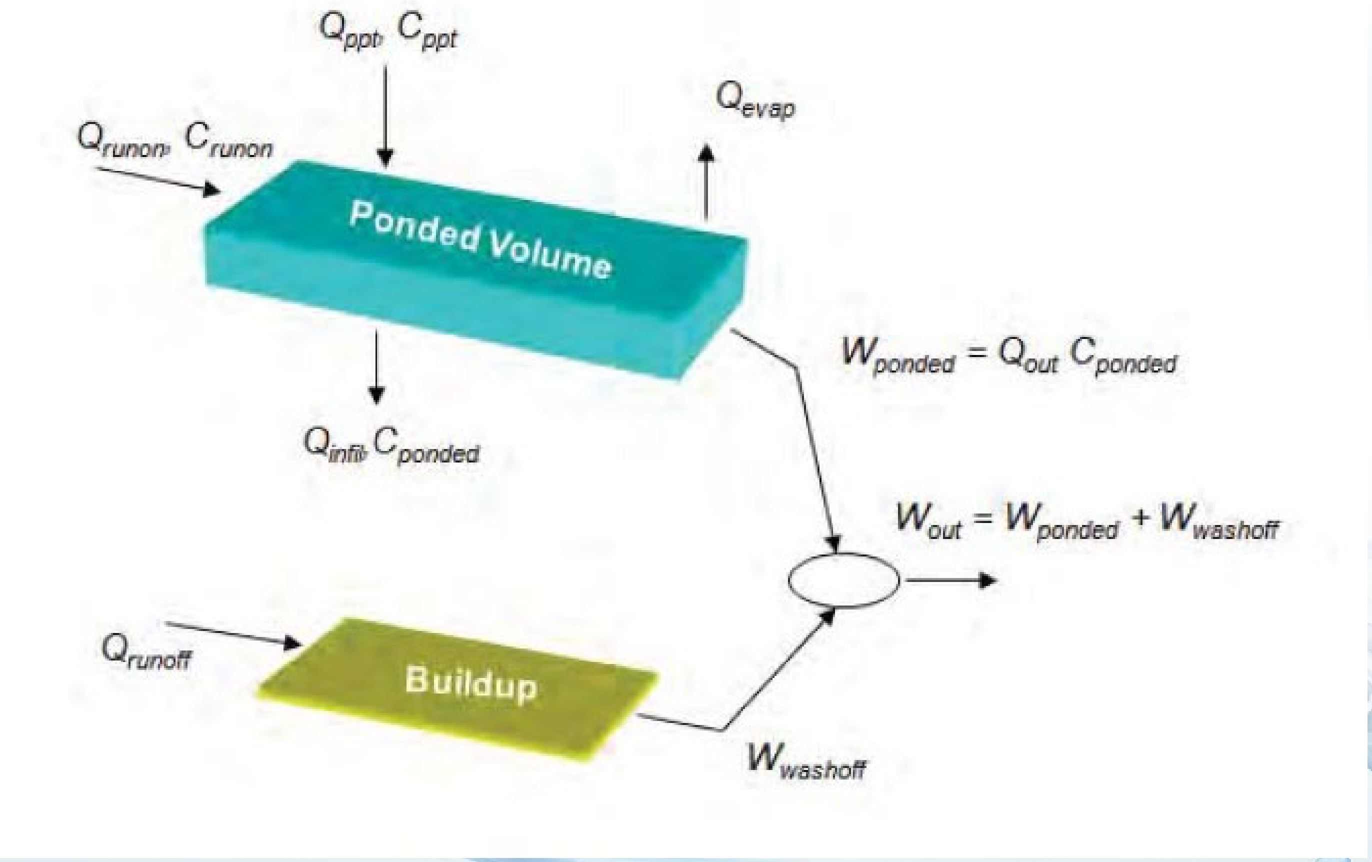

Green Roof


Porous Pavement


Vegetative Swale

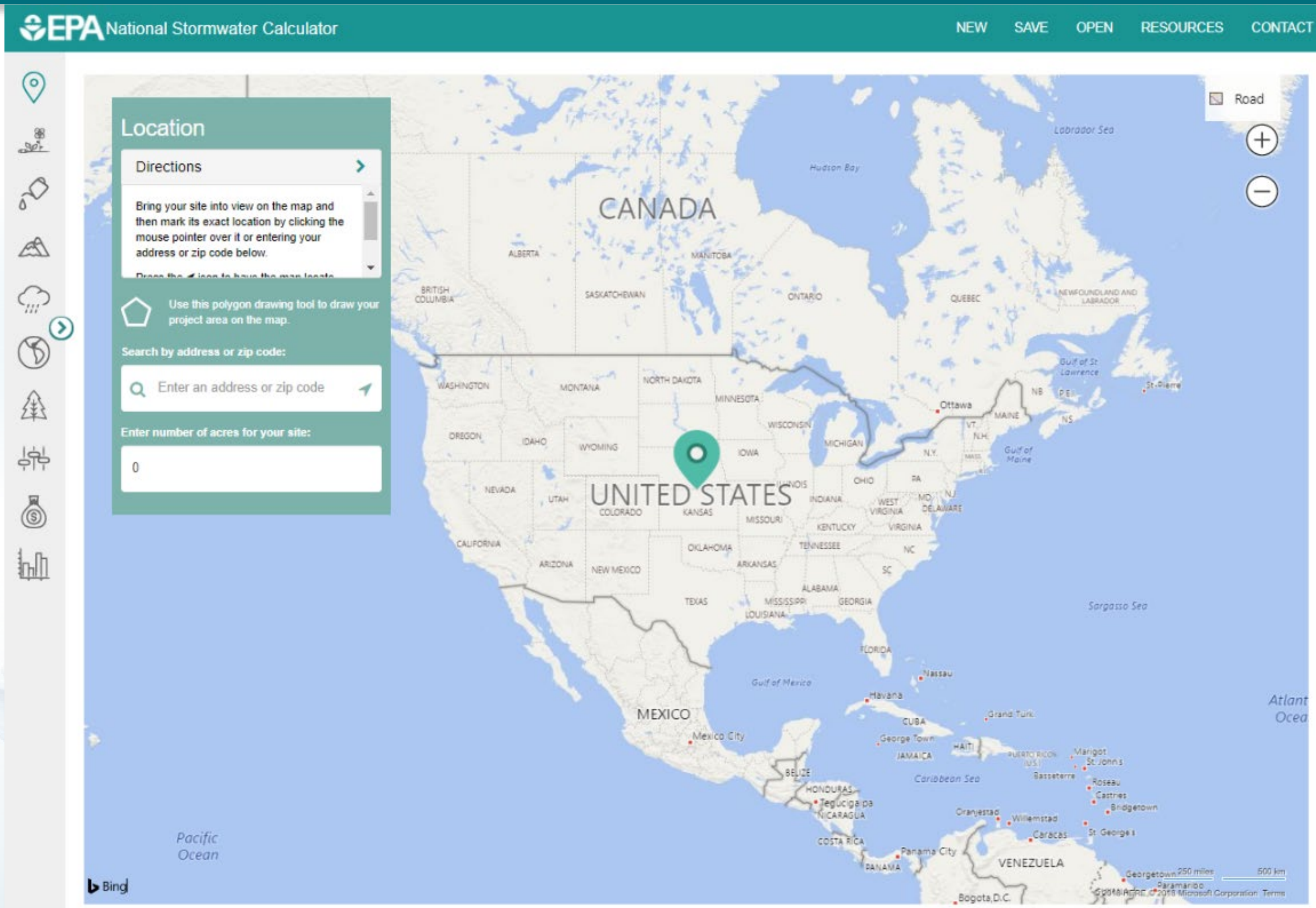

Street Planter

Pollutant Buildup and Wash off Reference Manual III Chapters 3 and 4

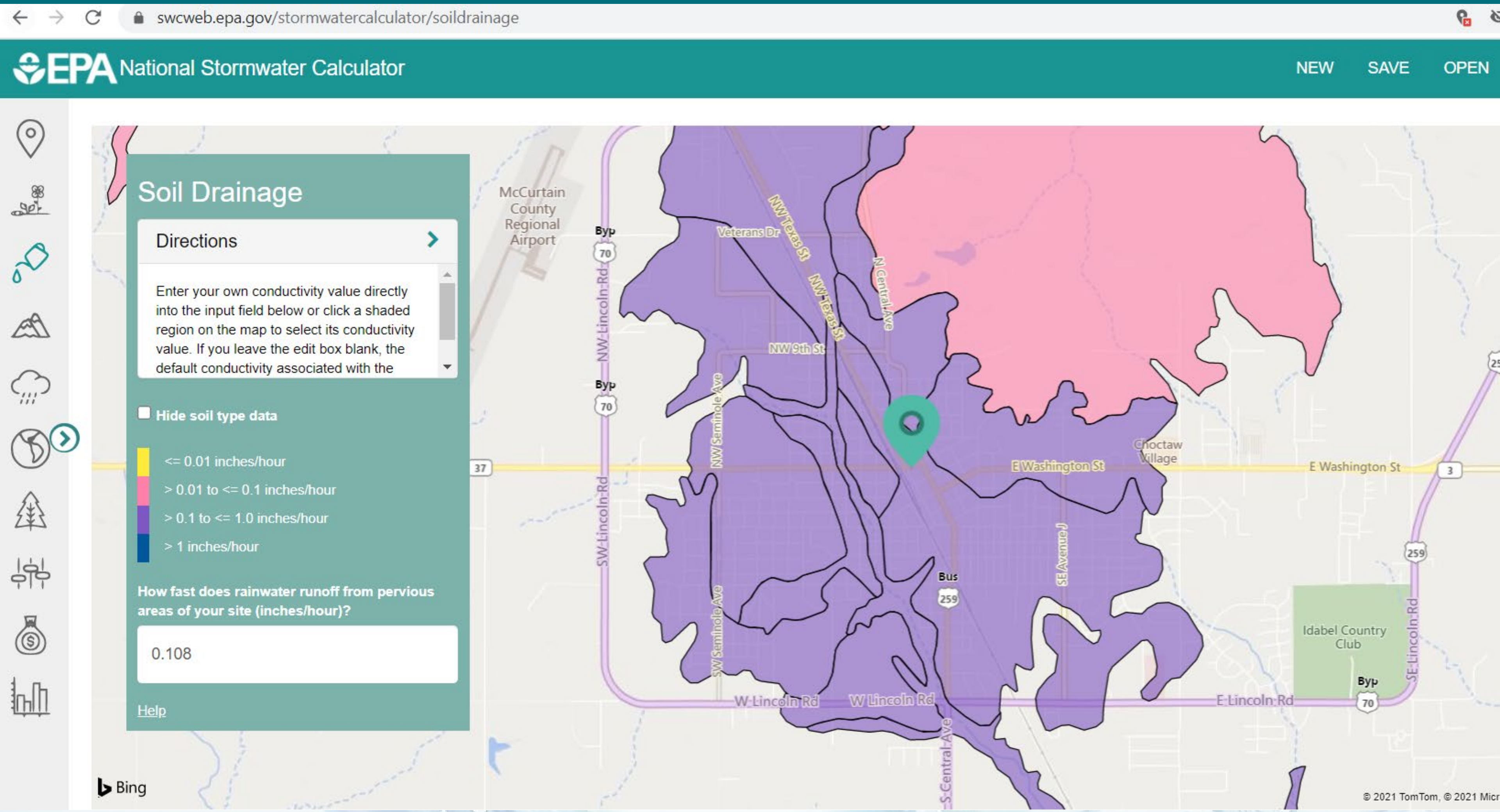


National Stormwater Calculator

https://www.epa.gov/water-research/national-stormwater-calculator

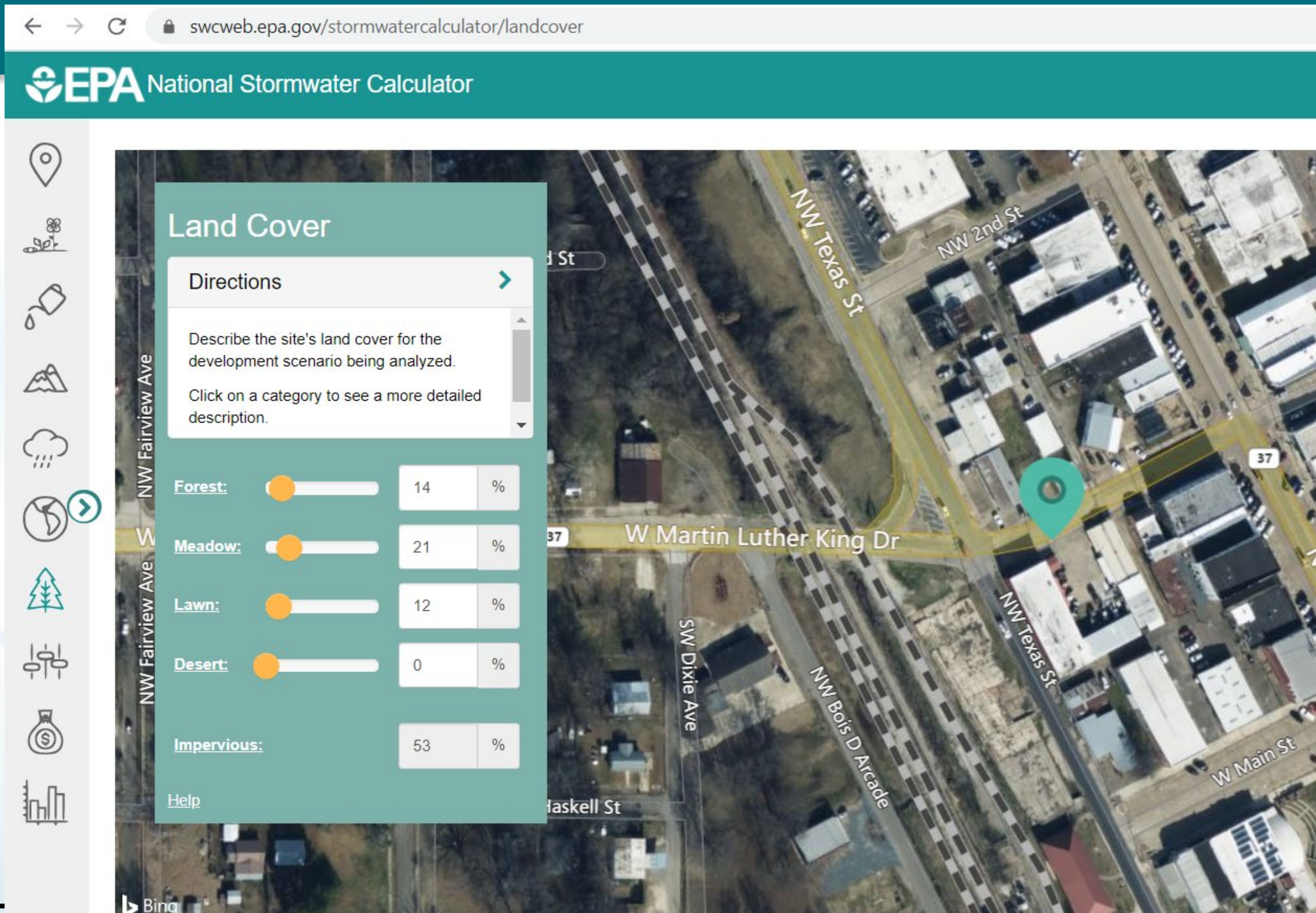


National Stormwater Calculator



Displays soil properties obtained from querying the NRCS SSURGO database

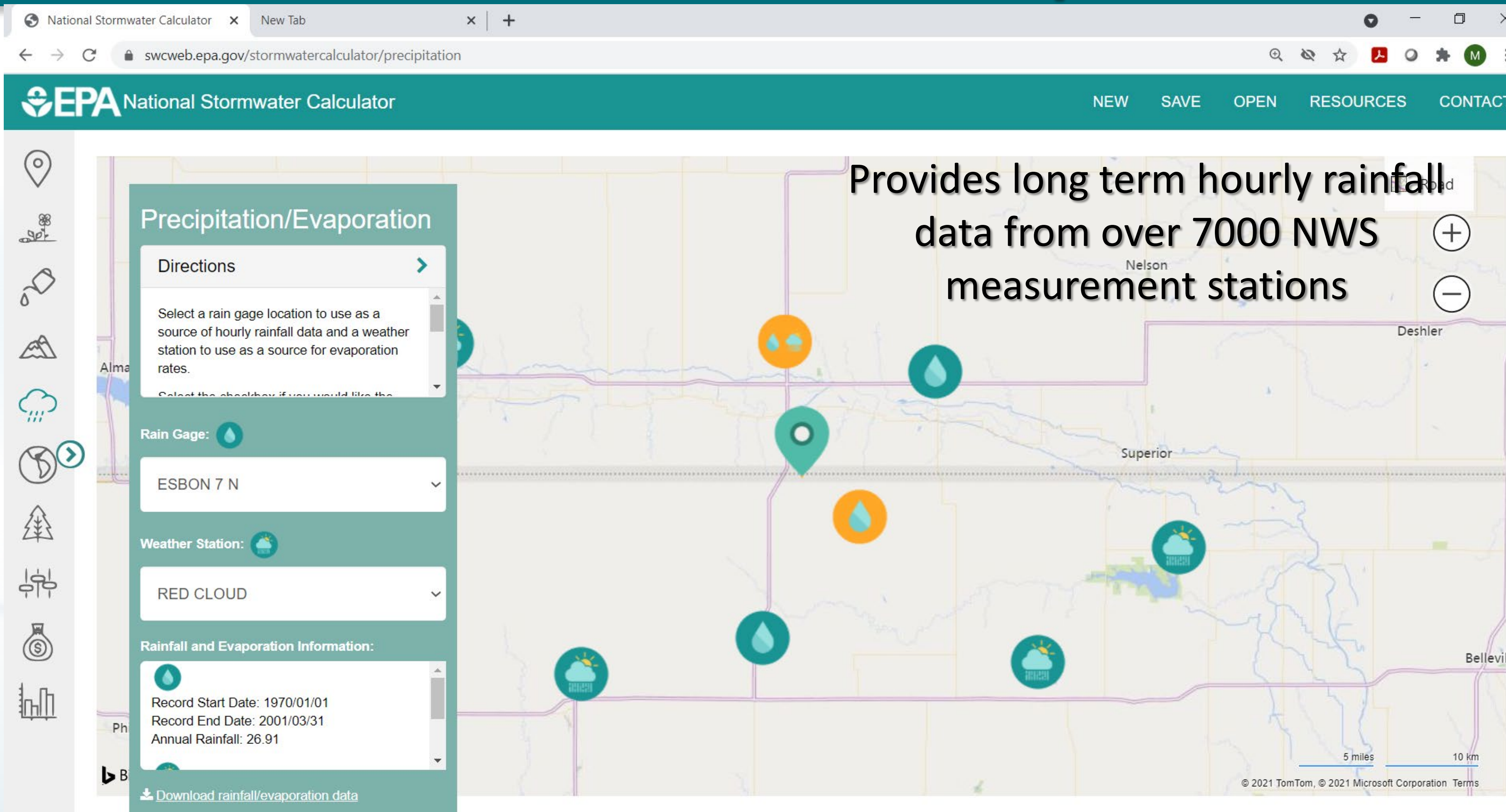
Land Use



swcweb.epa.gov/stormwatercalculator/landcover
EPA National Stormwater Calculator
Land Cover
Directions
Describe the site's land cover for the development scenario being analyzed.
Click on a category to see a more detailed description.
Forest: 14 %
Meadow: 21 %
Lawn: 12 %
Desert: 0 %
Impervious: 53 %
Help
NW Fairview Ave
W Martin Luther King Dr
NW Texas St
NW 2nd St
SW Dixie Ave
NW Bois D Arcade
W Main St
Haskell St
37
Bing

Climatology
Reference Manual I Chapter 2

Provides long term hourly rainfall data from over 7000 NWS measurement stations



National Stormwater Calculator
LID Calculation

The user specifies the site's land cover and selects a set of LID controls.

LID Controls

Directions

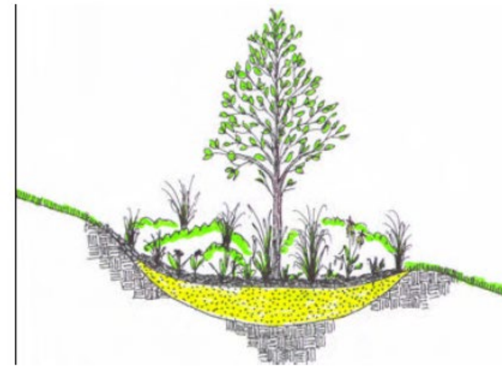
Enter the percentage of your site's impervious area you would like to be treated by the listed LID Controls.

Click a practice to learn more about it or to

Disconnection:	0	%
Rain Harvesting:	0	%
Rain Gardens:	27	%
Green Roofs:	0	%
Street Planters:	0	%
Infiltration Basins:	0	%
Permeable Pavement:	0	%
Design Storm for Sizing:	2	in.

Help

Rain Gardens



Rain Gardens are shallow depressions filled with an engineered soil mix that supports vegetative growth. They are usually used on individual home lots to capture roof runoff.

Typical soil depths range from 6 to 18 inches

The Capture Ratio is the ratio of the rain garden's area to the impervious area that drains onto it.

Learn More

Ponding Height:	6	in.
Soil Media Thickness:	12	in.
Soil Media Conductivity:	10	in./hr
% Capture Ratio:	5	%

☐ Pre-Treatment

Size for Design Storm | Save and Return | Restore Defaults

National Stormwater Calculator

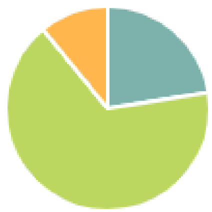
The Calculator runs SWMM to generate daily rainfall/runoff statistics.

Summary Results

Current Scenario

Annual Rainfall: 25.47 in.

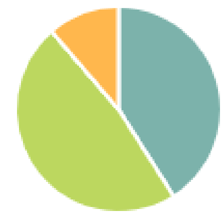
Runoff | Infiltration | Evaporation



Baseline Scenario

Annual Rainfall: 25.47 in.

Runoff | Infiltration | Evaporation



Statistic	Current Scenario	Baseline Scenario
Average Annual Rainfall (inches)	25.47	25.47
Average Annual Runoff (inches)	5.74	10.49
Days per Year with Rainfall	48.72	48.72
Days per Year with Runoff	17.49	27.93
Percent of Wet Days Retained	64.10	42.67
Smallest Rainfall w/ Runoff (inches)	0.28	0.10
Largest Rainfall w/o Runoff (inches)	0.62	0.36
Max Rainfall Retained (inches)	2.54	1.57

National Stormwater Calculator

The Calculator can provide ballpark costs.

Cost Summary

Estimate of Probable Capital Costs (estimates in 2018 US $)

Maintenance Costs | Graphical View

	Drainage Area %	Has Pre-Treatment?	Current Scenario (C)		Baseline Scenario (B)		Difference (C - B)	
Cost By LID Control Type	**Current / Baseline**	**Current / Baseline**	**Low**	**High**	**Low**	**High**	**Low**	**High**
Disconnection	0 / 0	No / No	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Rainwater Harvesting	0 / 0	No / No	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Rain Gardens	27 / 27	No / No	$5,932.68	$11,501.71	$5,932.68	$11,501.71	$0.00	$0.00
Green Roofs	27 / 0	No / No	$66,500.50	$139,338.81	$0.00	$0.00	$66,500.50	$139,338.81
Street Planters	0 / 0	No / No	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Infiltration Basins	0 / 0	No / No	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Permeable Pavement	40 / 0	No / No	$178,055.69	$237,830.20	$0.00	$0.00	$178,055.69	$237,830.20
Total	**94 / 27**	**Varies**	**$250,488.86**	**$388,670.72**	**$5,932.68**	**$11,501.71**	**$244,556.19**	**$377,169.01**

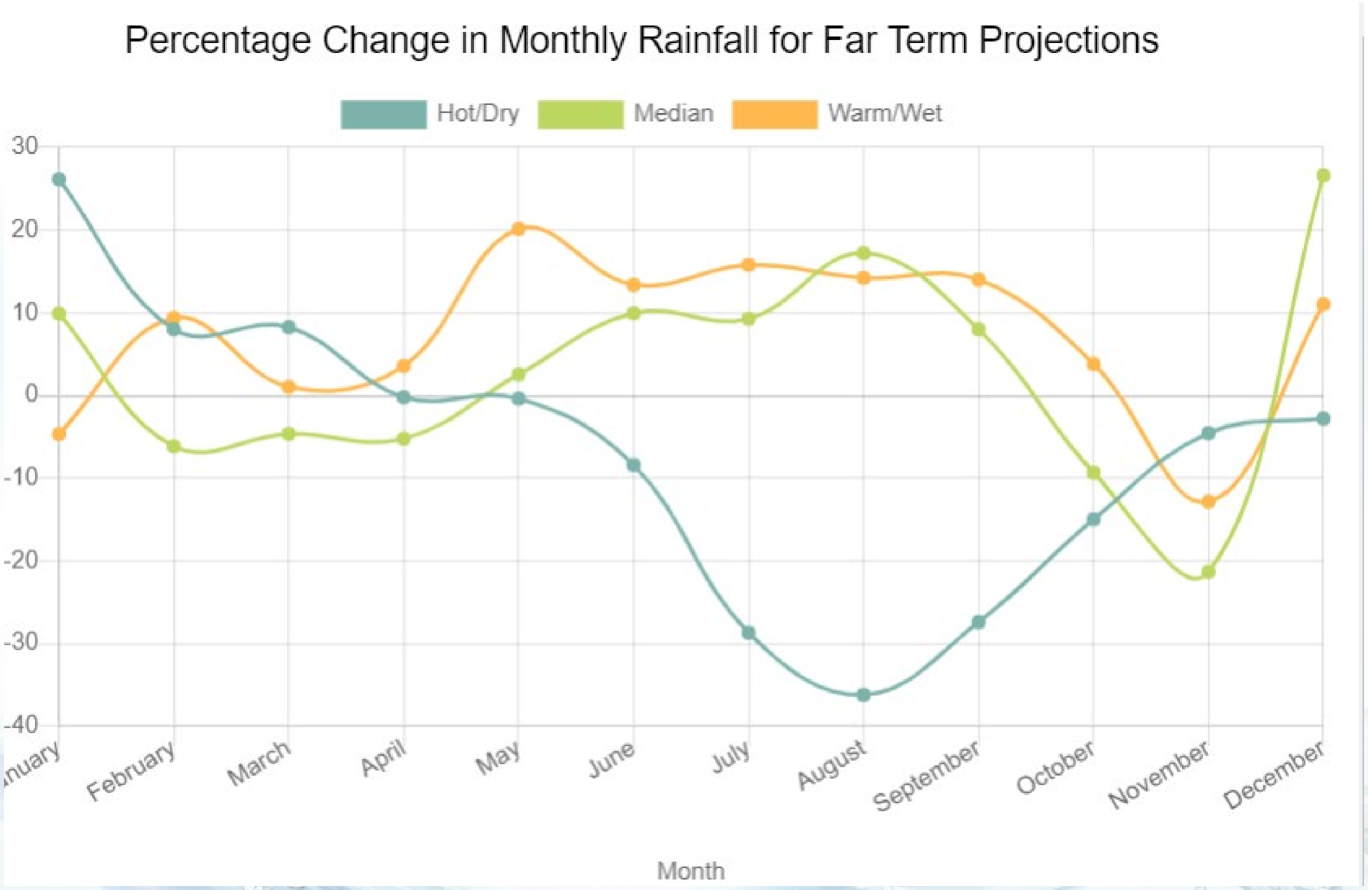
Note: site complexity variables that affect cost shown below:

	Current Scenario	Baseline Scenario
Dev. Type	Re-Development	Re-Development
Site Suitability	Poor	Poor
Topography	Mod. Flat (5% Slope)	Mod. Flat (5% Slope)
Soil Type	B	B
Cost Region	Denver(345 miles) 1.01	Denver(345 miles) 1.01

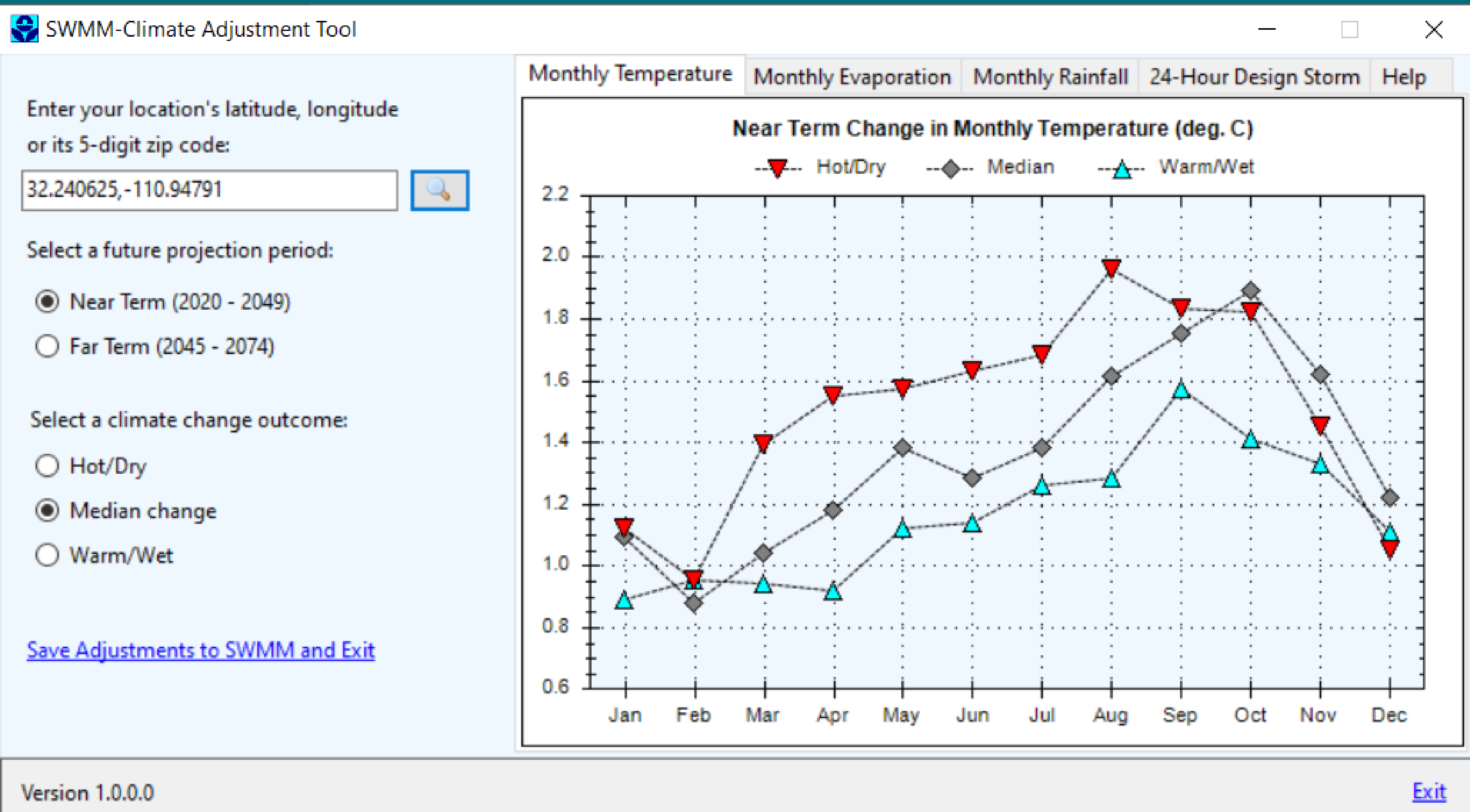
Chart Key

D - Disconnection	IB - Infiltration Basins
RH - Rain Harvesting	PP - Permeable Pavement
RG - Rain Gardens	
GR - Green Roofs	
SP - Street Planters	

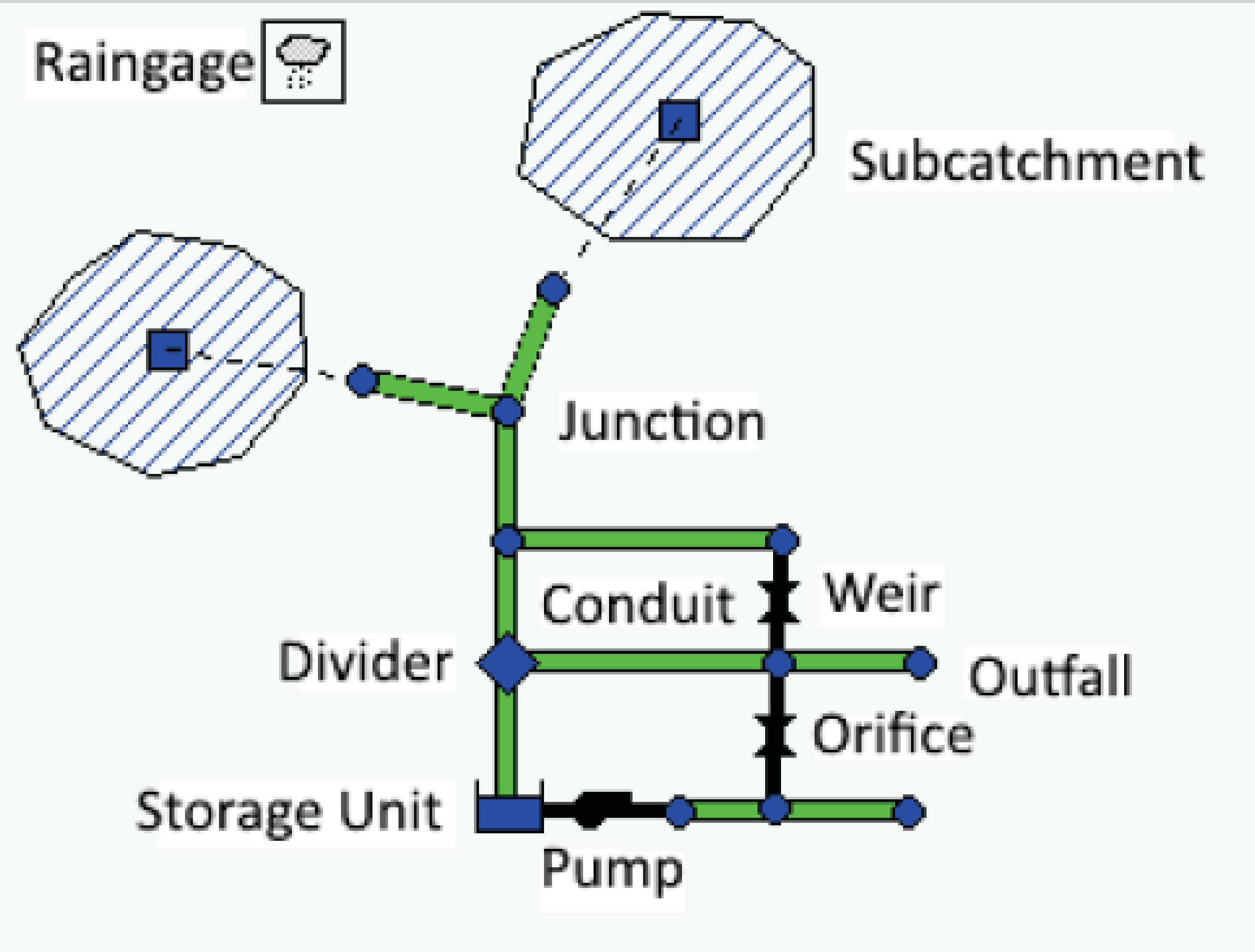
National Stormwater Calculator
Climate Change



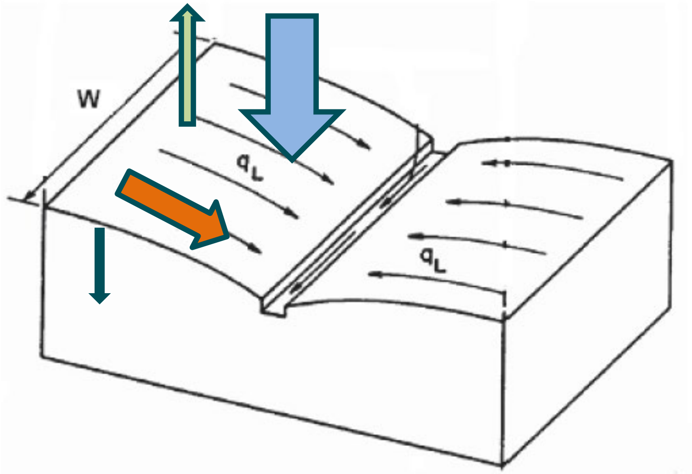
SWMM-CAT

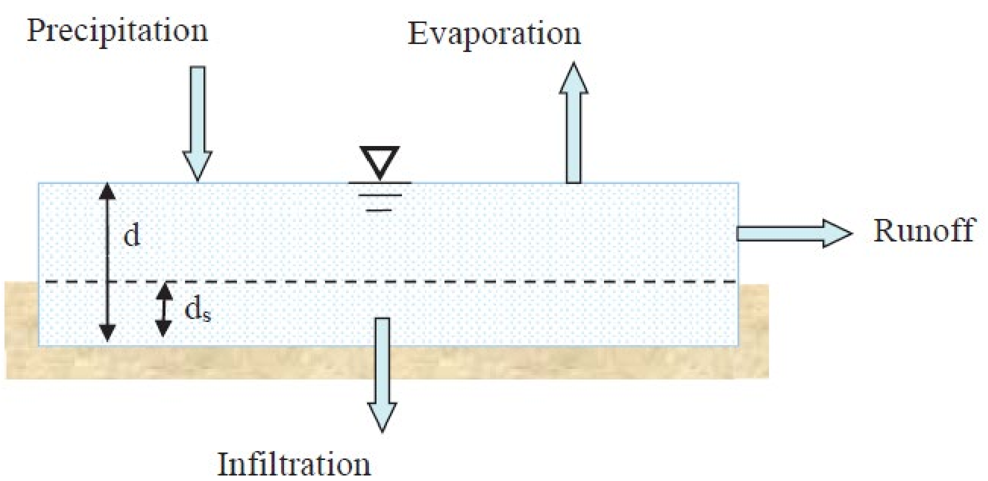

SWMM-Climate Adjustment Tool
Enter your location's latitude, longitude or its 5-digit zip code:
32.240625,-110.94791
Select a future projection period:
Near Term (2020 - 2049)
Far Term (2045 - 2074)
Select a climate change outcome:
Hot/Dry
Median change
Warm/Wet
Save Adjustments to SWMM and Exit
Monthly Temperature
Monthly Evaporation
Monthly Rainfall
24-Hour Design Storm
Help
Near Term Change in Monthly Temperature (deg. C)
Hot/Dry
Median
Warm/Wet
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Version 1.0.0.0
Exit

Pulling the Hydrology of SWMM together



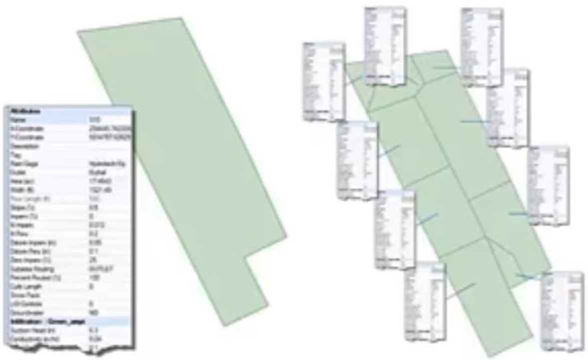
Idealized Subcatchment –
Reference Manual I Sections 3





Idealized Subcatchment (Courtesy of Rob James, CHI Water)

Subcatchment parameters

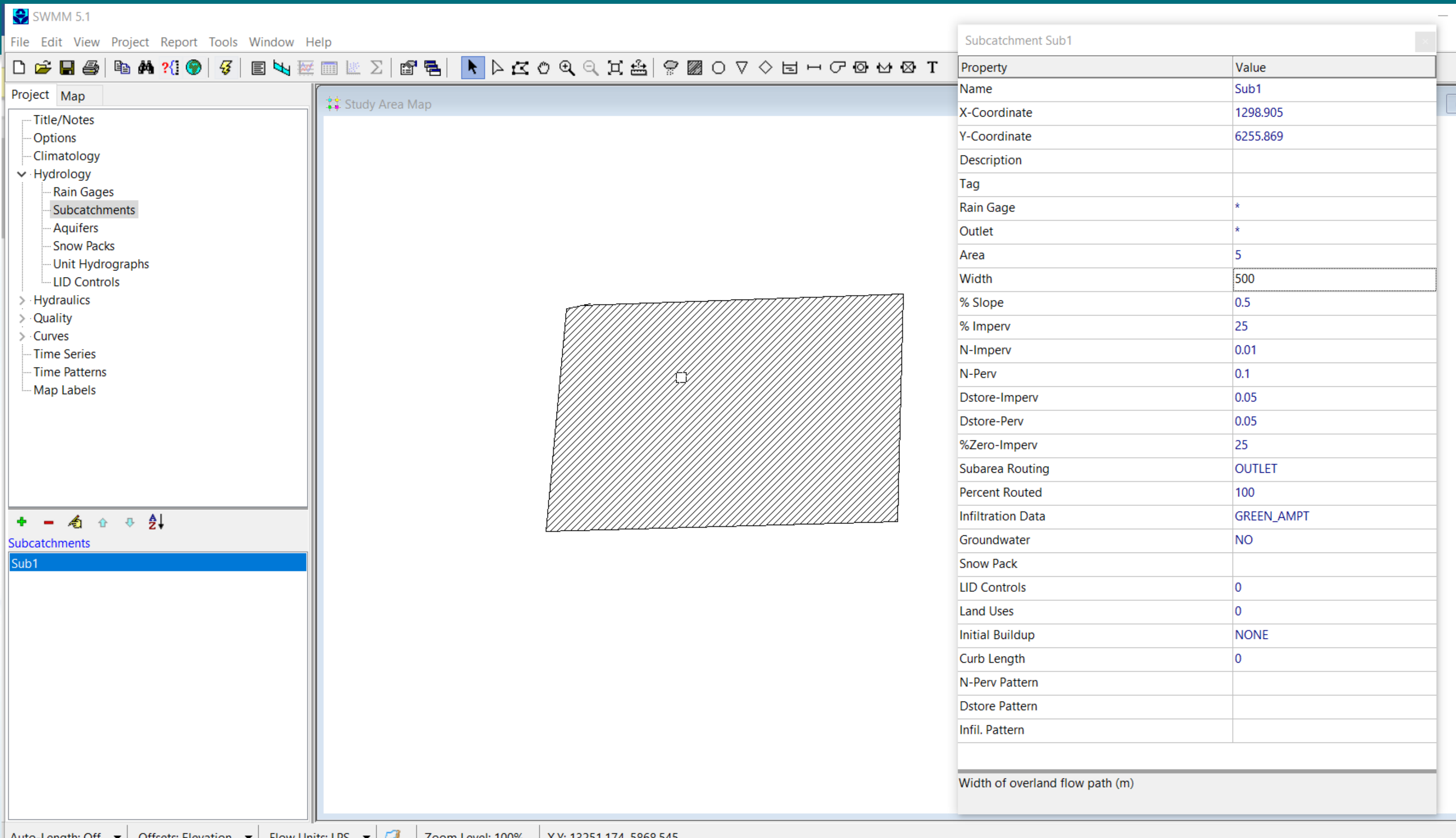


- Parameters may be averaged (lumped) over a coarse number of subcatchments
- Or further sub-divided (distributed) into a finer number of subcatchments

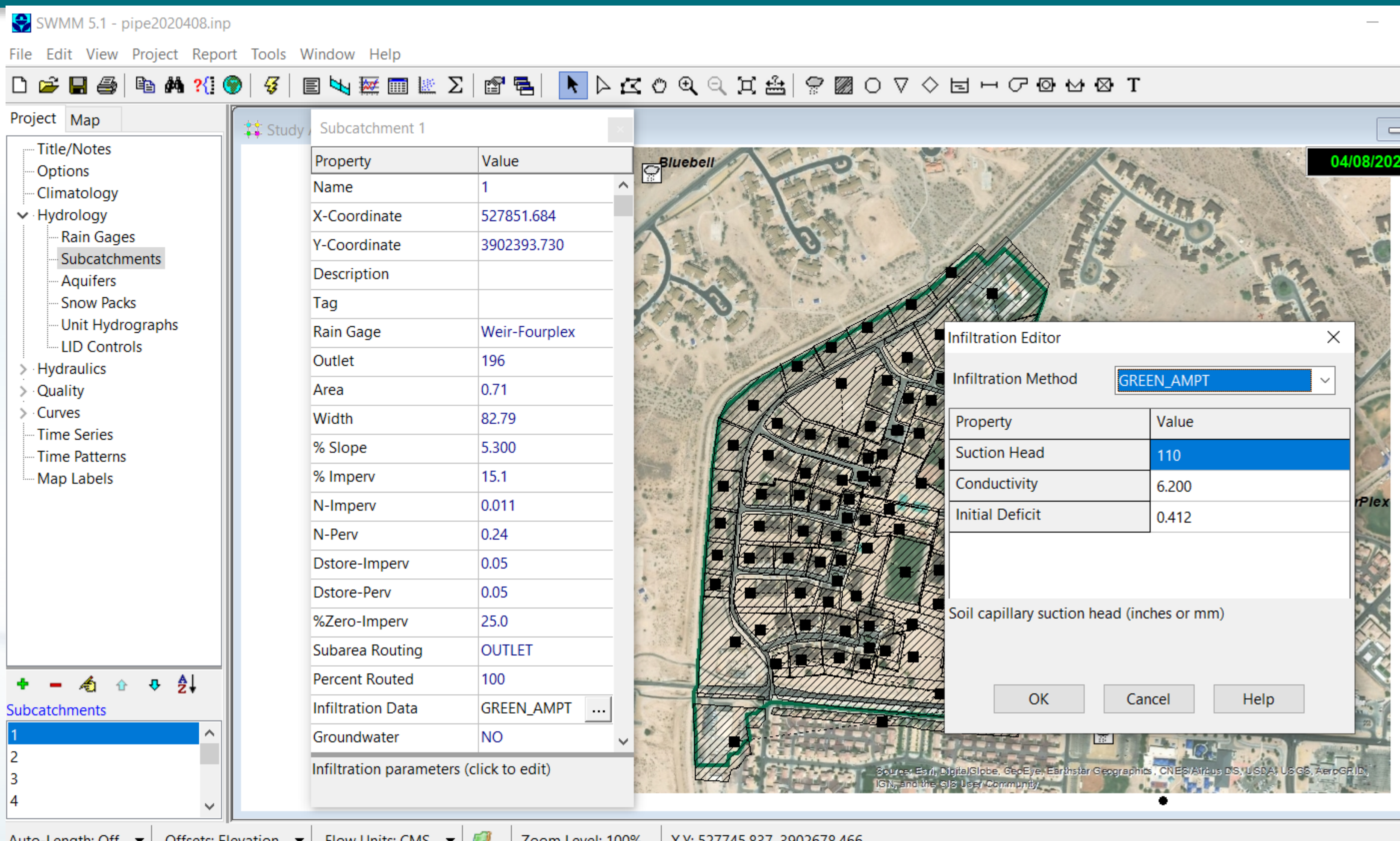
https://www.youtube.com/watch?v=HZnX_GsABUA

EPA United States Environmental Protection Agency

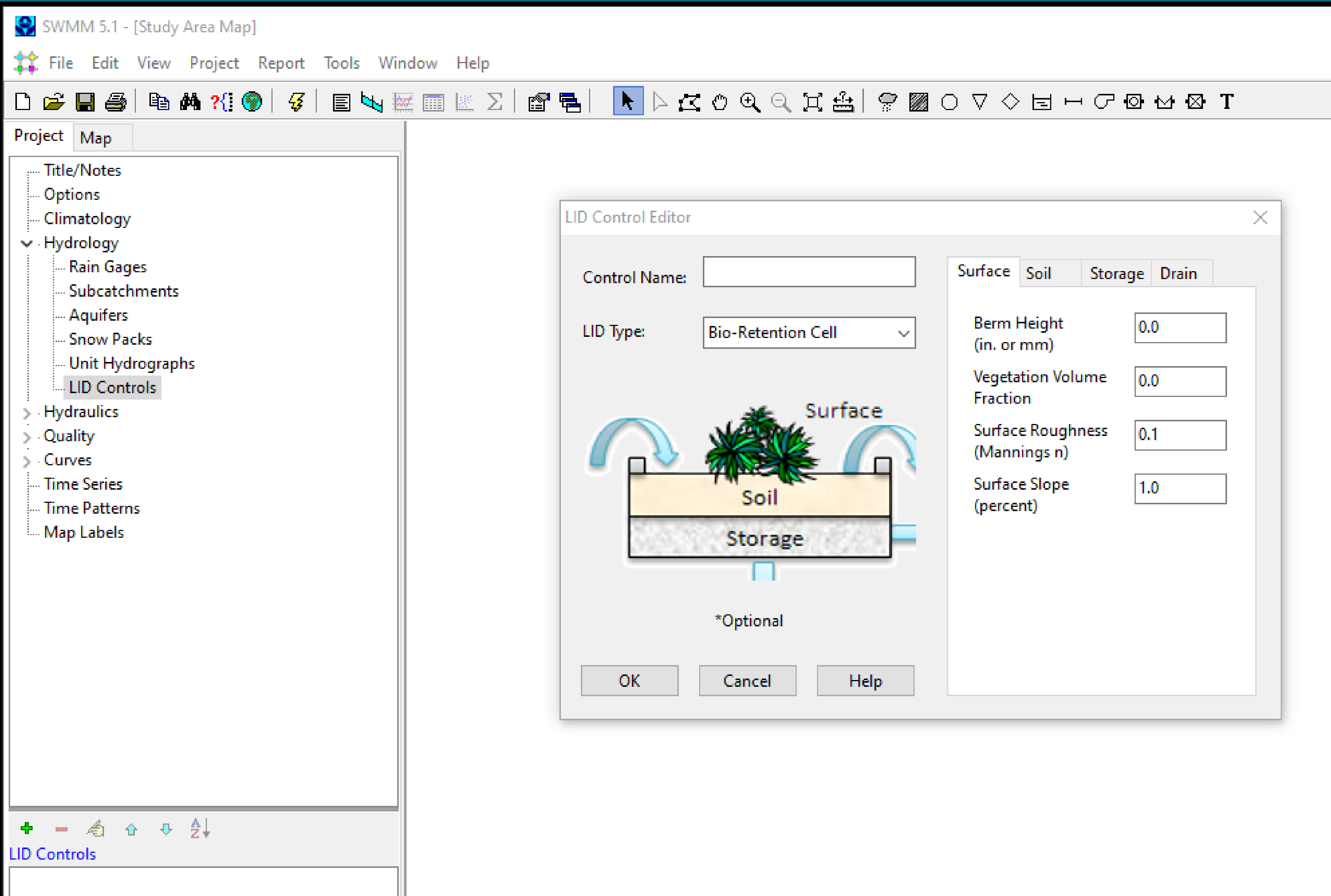
Subcatchments – Reference Manual I Section 3



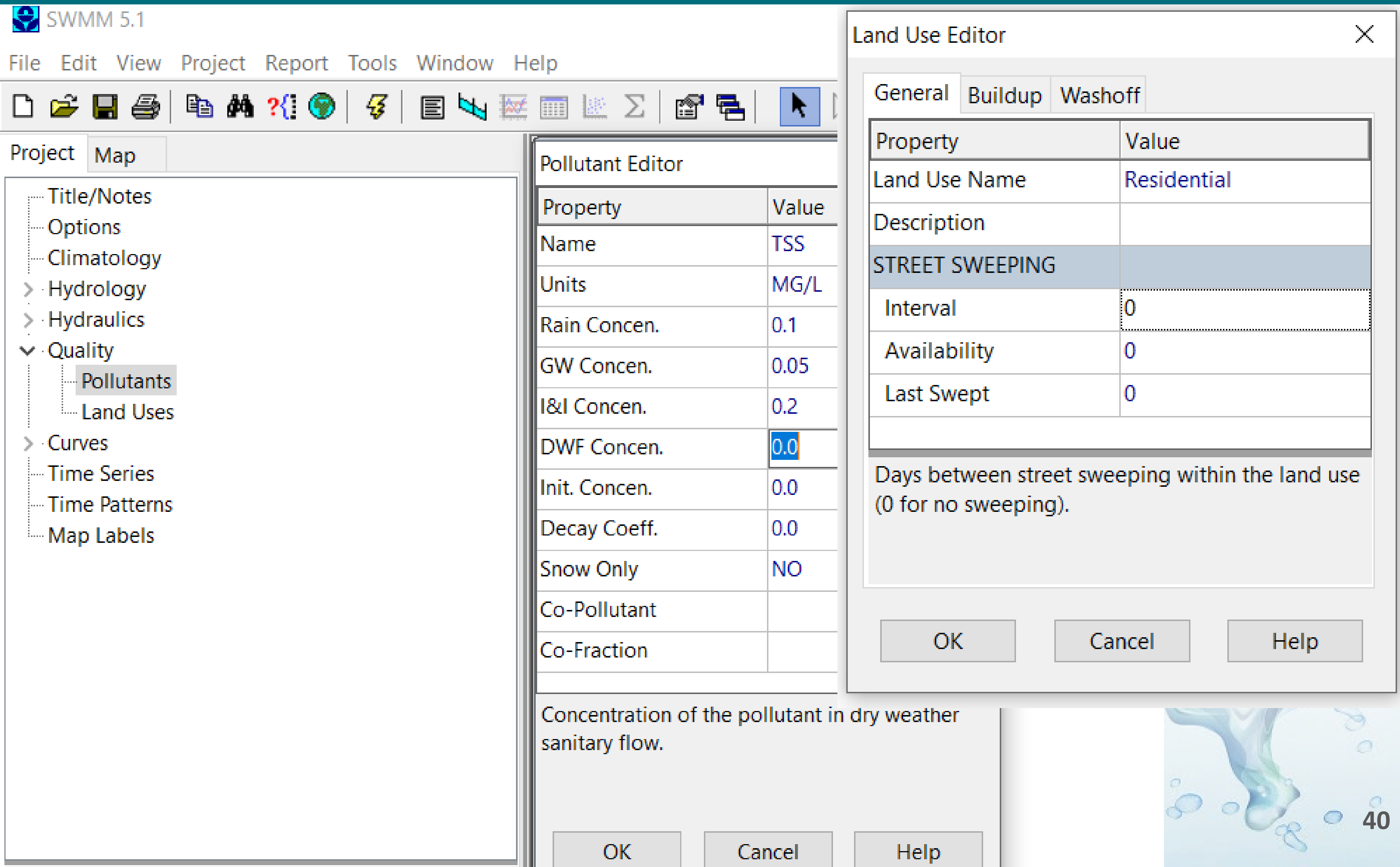
Mix of Infiltration Methods



LID Controls



Water Quality – see Reference Manual III and User's Manual



SWMM Demonstration

Getting started with SWMM following the User's Manual Chapter 2 Tutorial

CHAPTER 2 – QUICK START TUTORIAL

This chapter provides a tutorial on how to use EPA SWMM. If you are not familiar with the elements that comprise a drainage system, and how these are represented in a SWMM model, you might want to review the material in Chapter 3 first.

2.1 Example Study Area

In this tutorial we will model the drainage system serving a 12-acre residential area. The system layout is shown in Figure 2-1 and consists of subcatchment areas[3] *S1* through *S3*, storm sewer conduits *C1* through *C4*, and conduit junctions *J1* through *J4*. The system discharges to a creek at the point labeled *Out1*. We will first go through the steps of creating the objects shown in this diagram on SWMM's study area map and setting the various properties of these objects. Then we will simulate the water quantity and quality response to a 3-inch, 6-hour rainfall event, as well as a continuous, multi-year rainfall record.

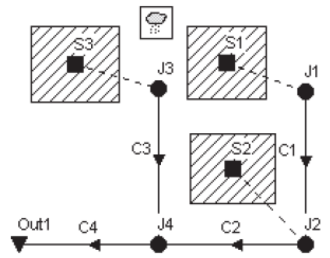
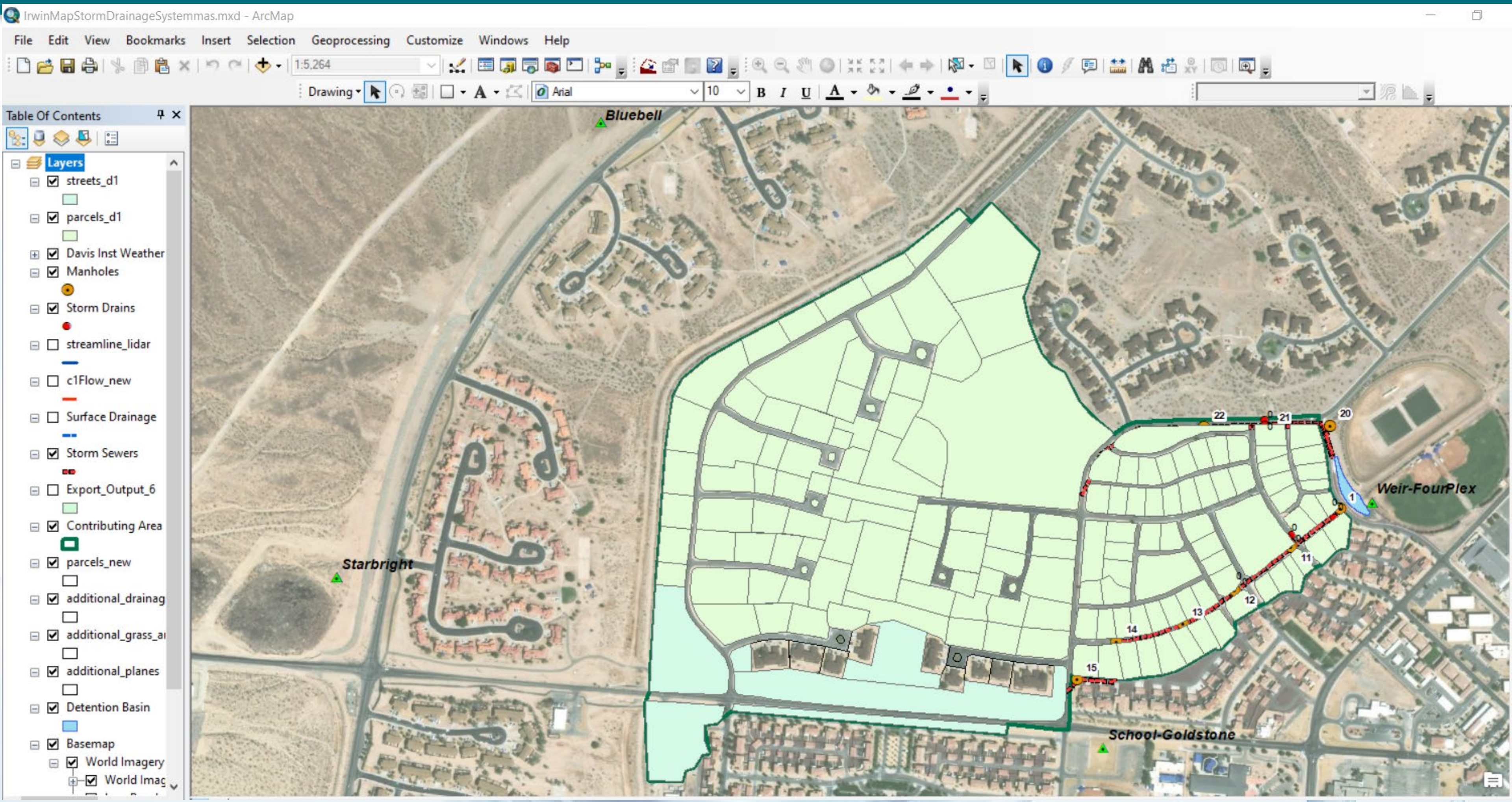
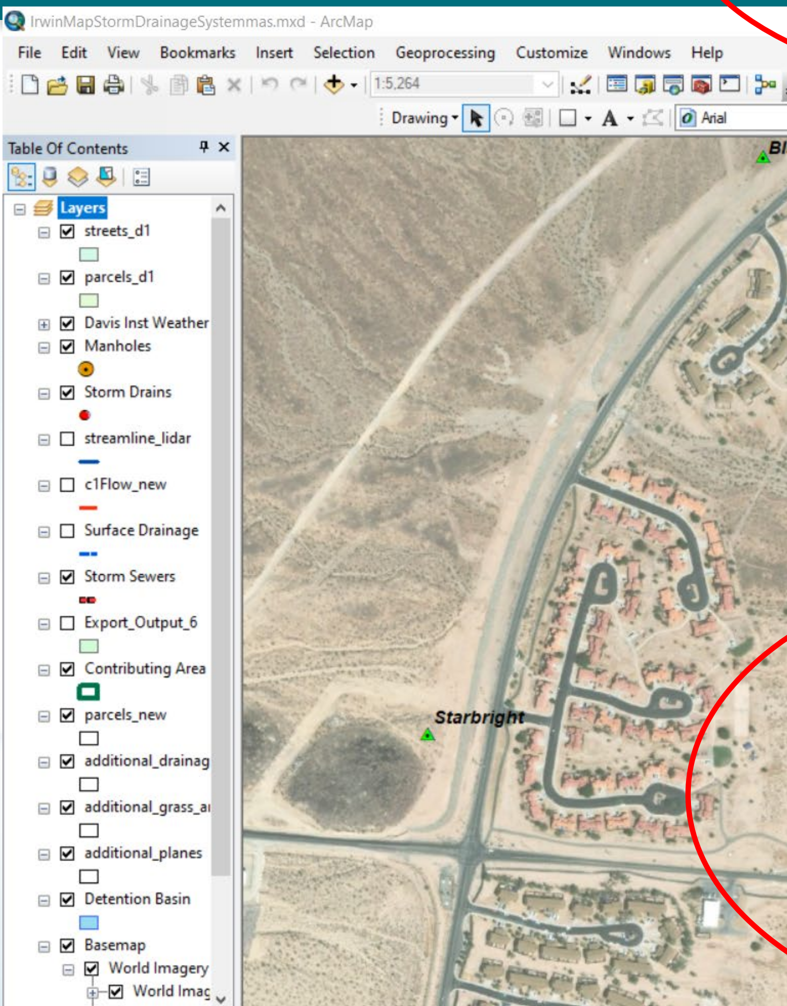


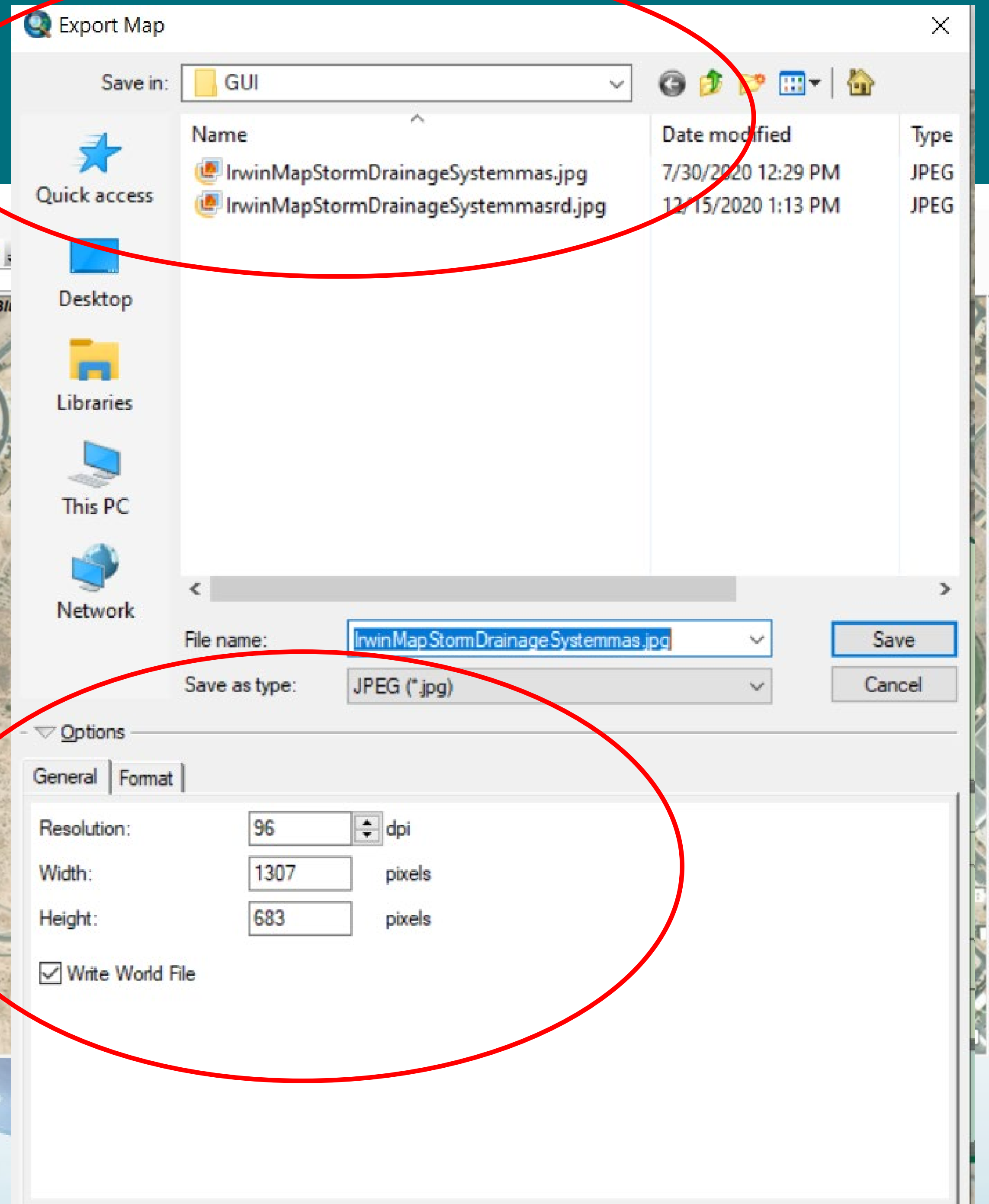
Figure 2-1 Example study area

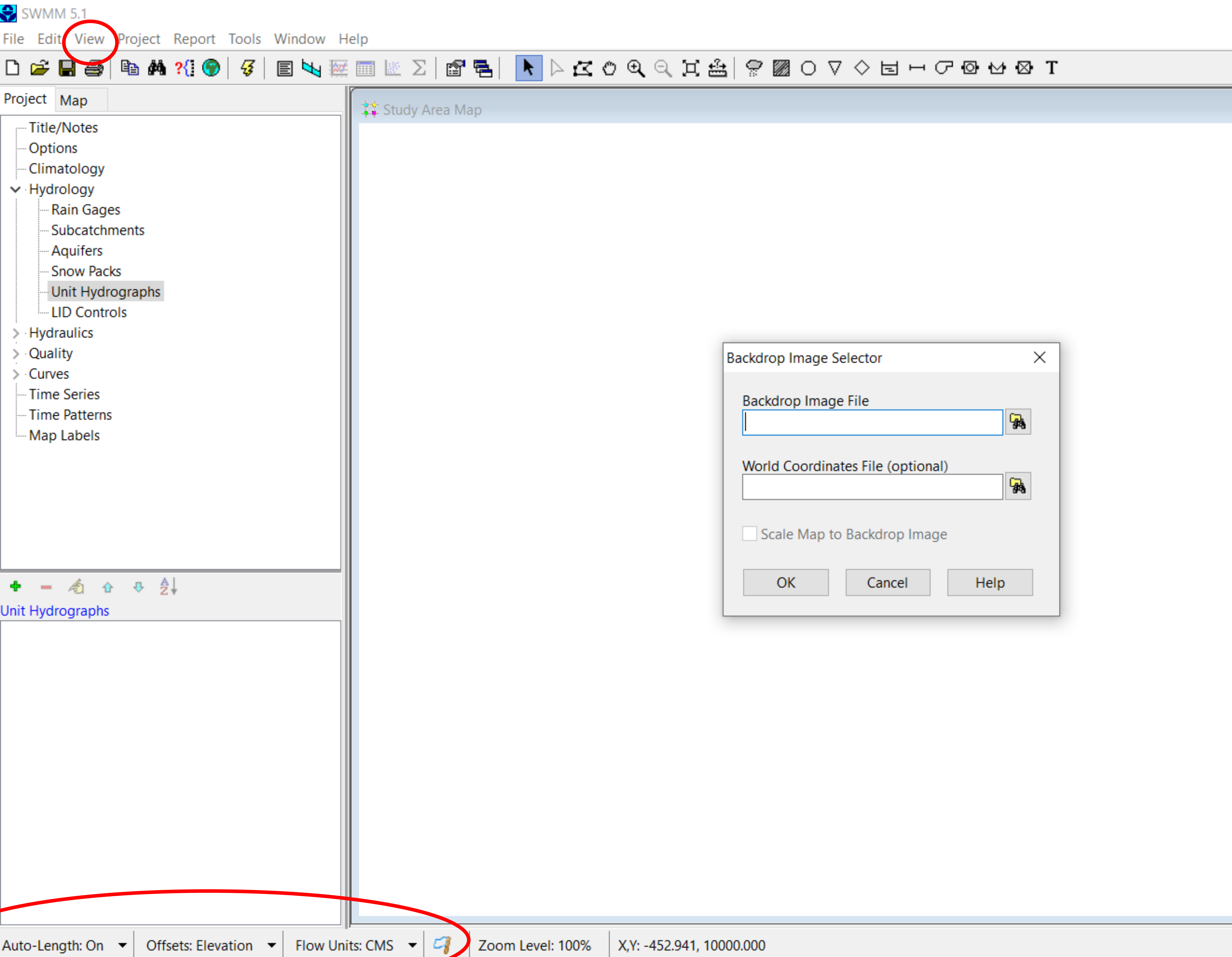
Export Map from ArcGIS



Export Map from ArcGIS






SWMM 5.1
File Edit View Project Report Tools Window Help
Project Map
Title/Notes
Options
Climatology
Hydrology
Rain Gages
Subcatchments
Aquifers
Snow Packs
Unit Hydrographs
LID Controls
Hydraulics
Quality
Curves
Time Series
Time Patterns
Map Labels
Unit Hydrographs
Study Area Map
Backdrop Image Selector
Backdrop Image File
World Coordinates File (optional)
Scale Map to Backdrop Image
OK
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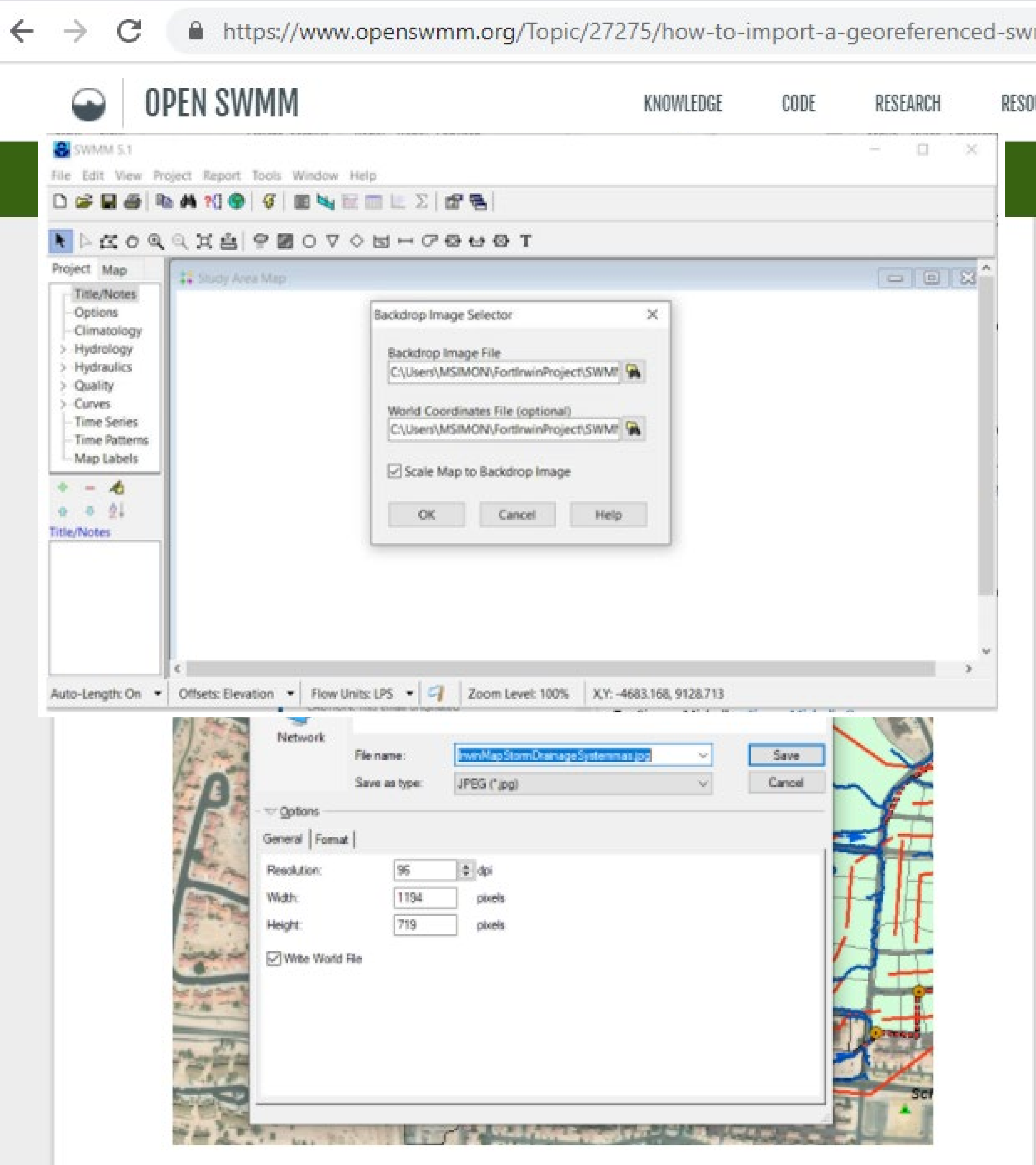
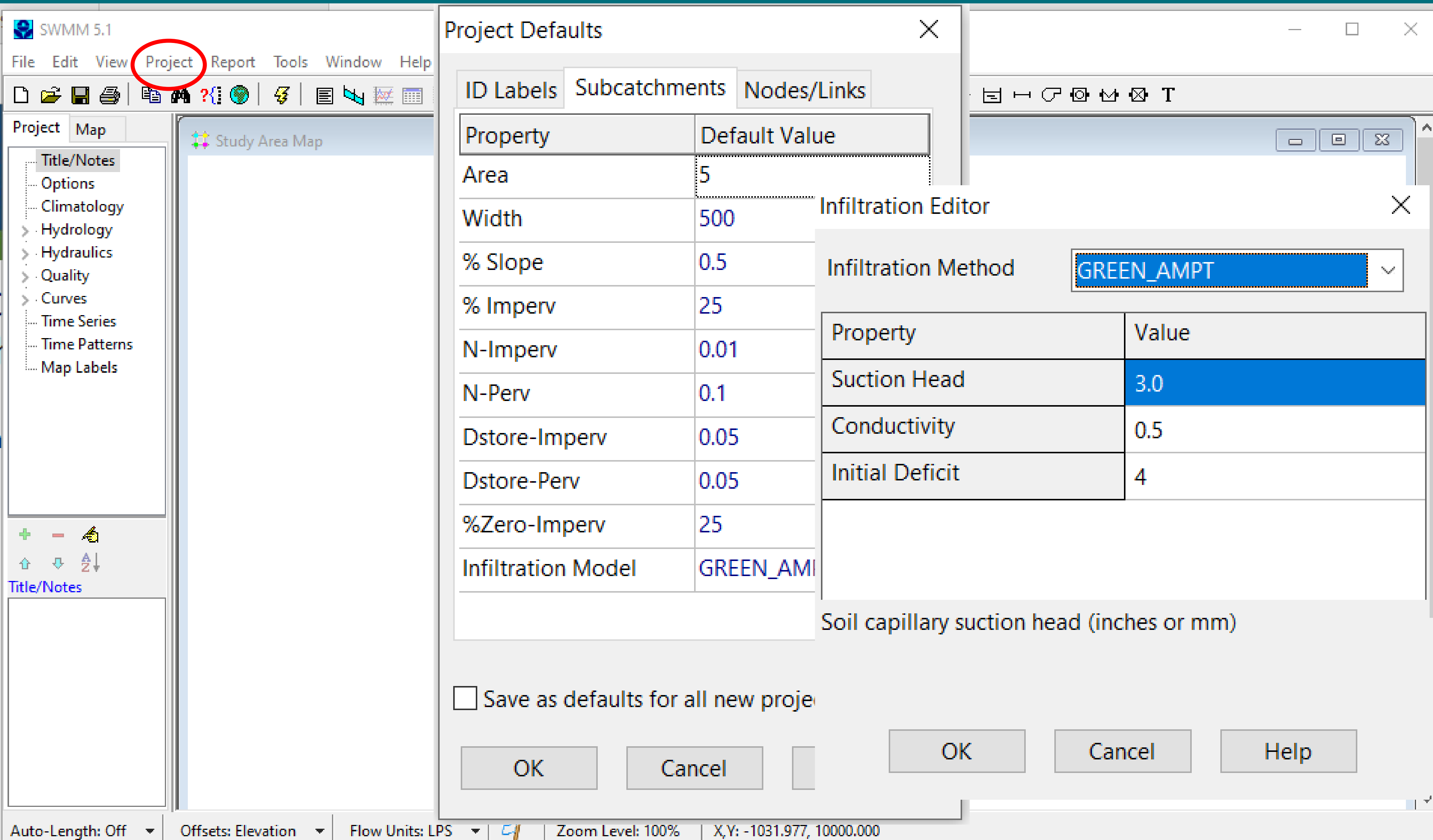
Help
Auto-Length: On
Offsets: Elevation
Flow Units: CMS
Zoom Level: 100%
X,Y: -452.941, 10000.000

Map

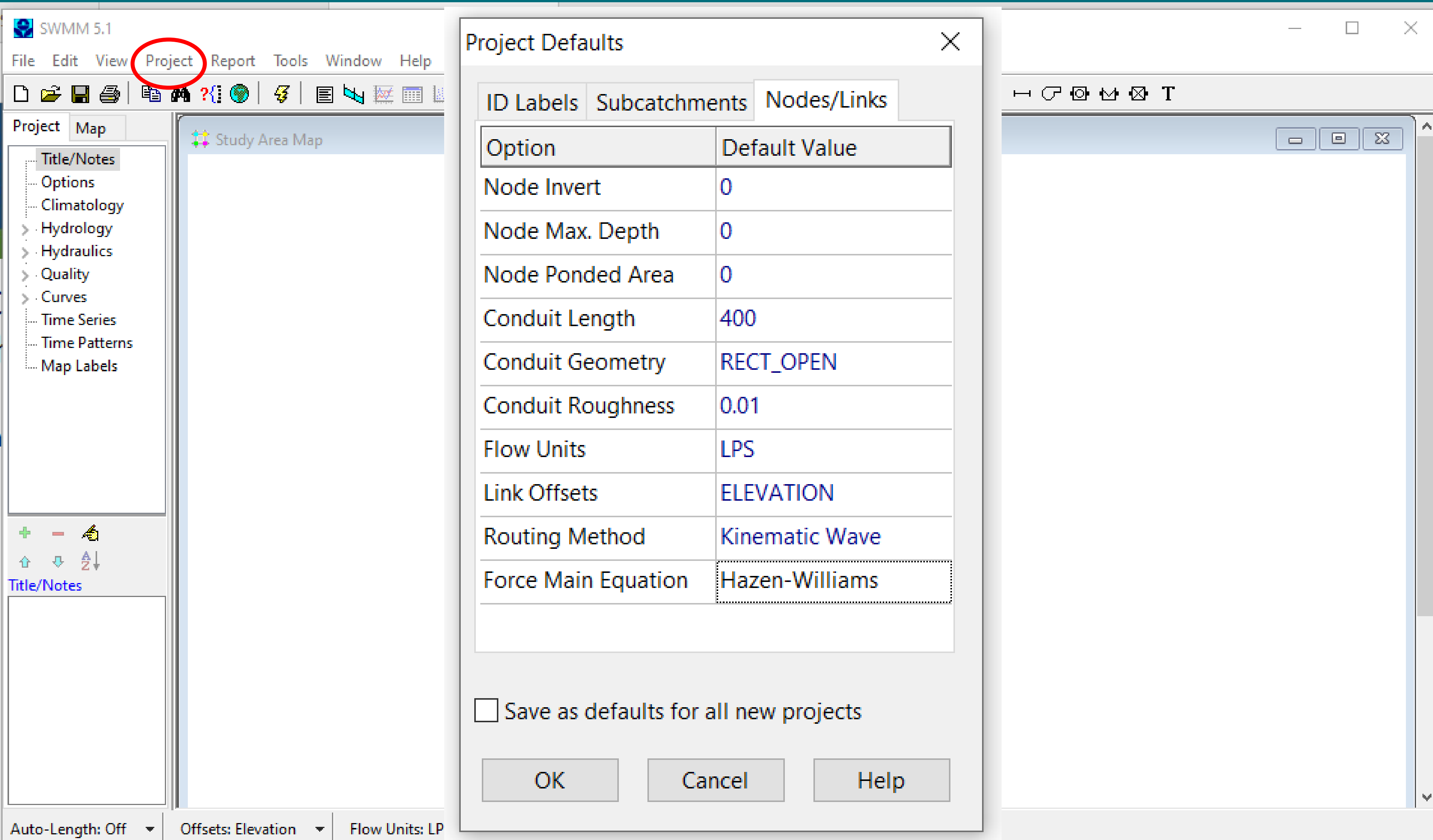


https://www.openswmm.org/Topic/27275/how-to-import-a-georeferenced-swmm-backdrop-with-world-coordinates-from-an-arcgis-map-into-swmm

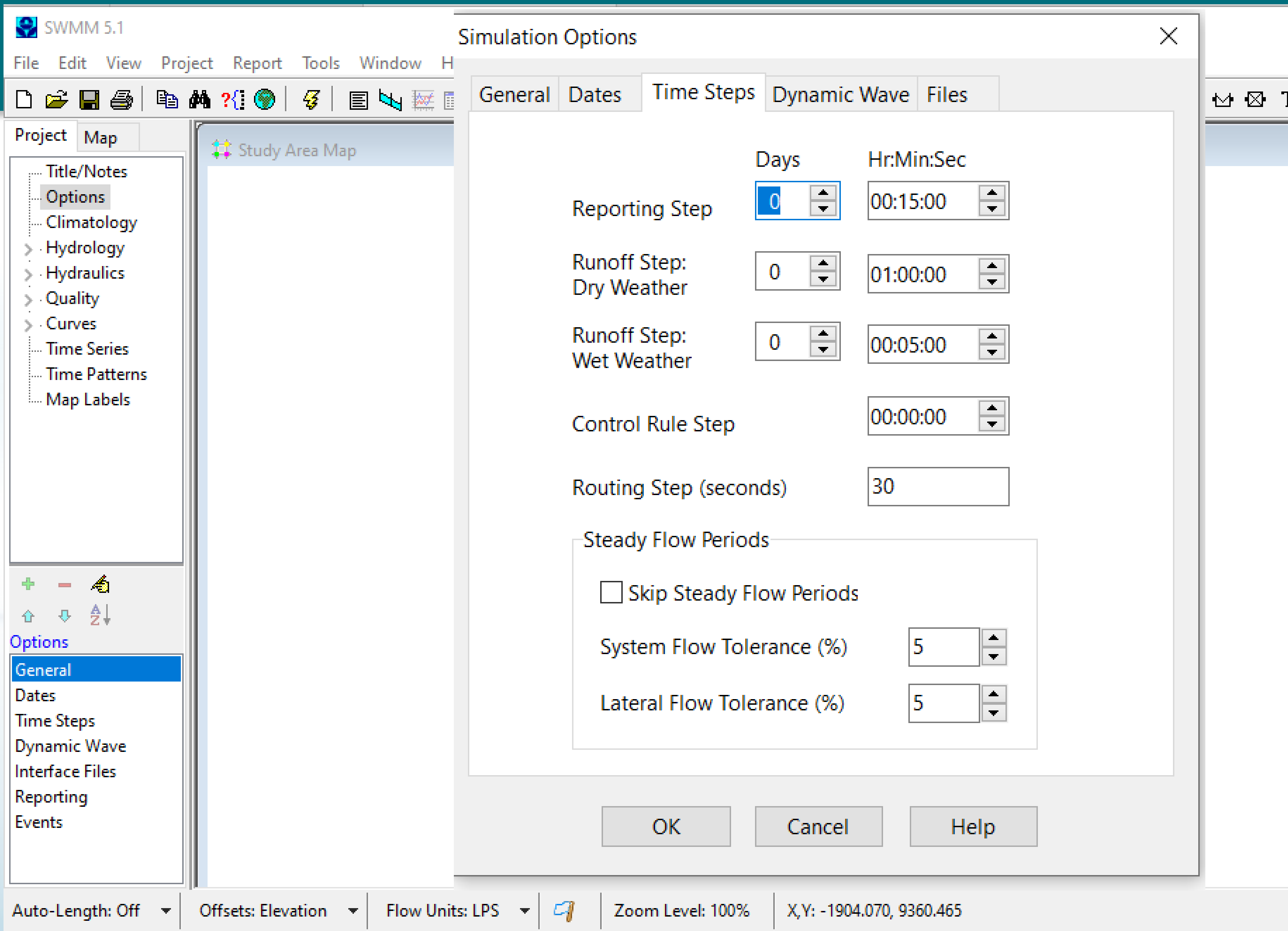
Project Defaults – see User’s Manual Chapter 2



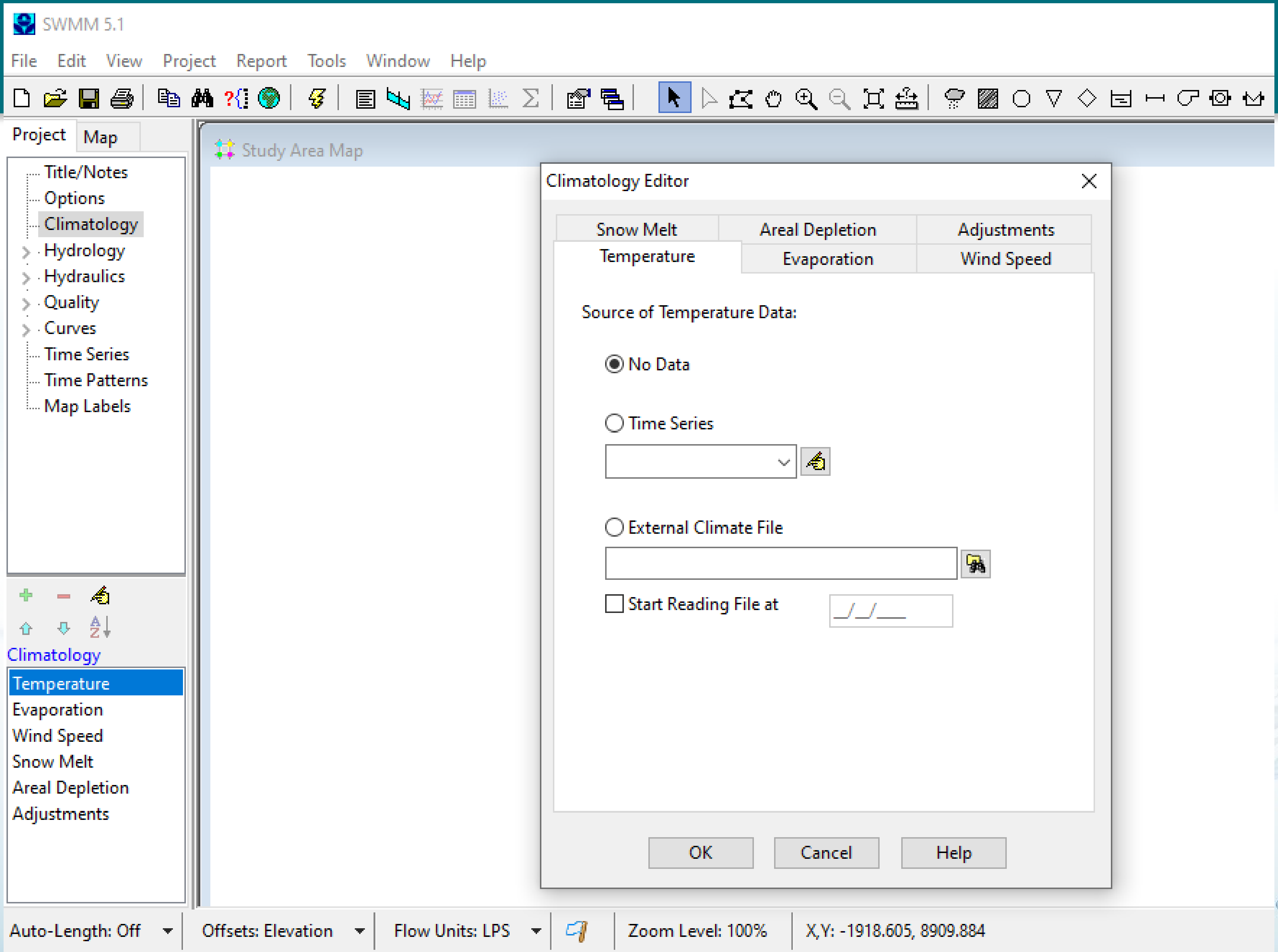
Project Defaults – see User's Manual Chapter 2



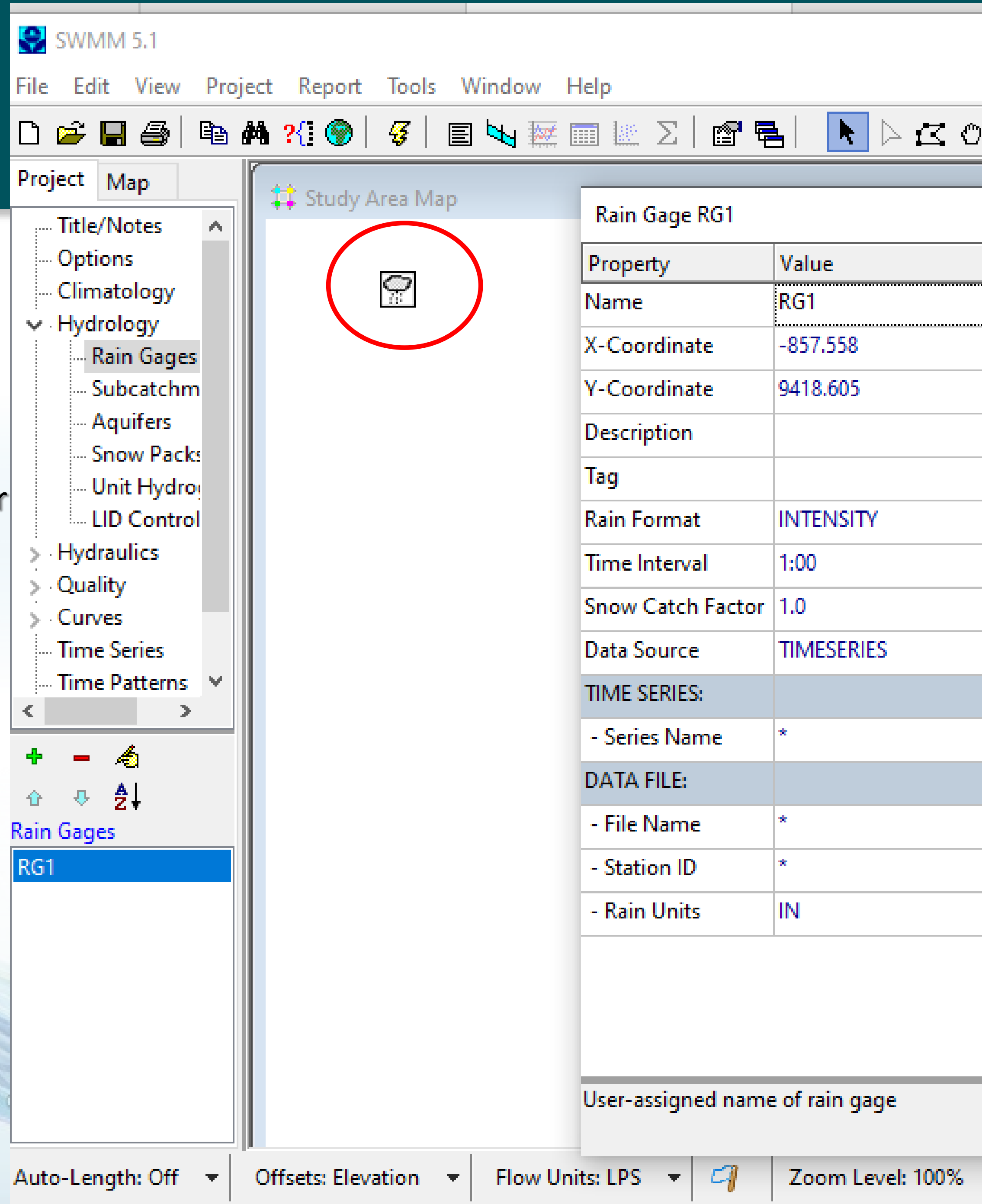
Options


SWMM 5.1
File
Edit
View
Project
Report
Tools
Window
Project
Map
Title/Notes
Options
Climatology
Hydrology
Hydraulics
Quality
Curves
Time Series
Time Patterns
Map Labels
Options
General
Dates
Time Steps
Dynamic Wave
Interface Files
Reporting
Events
Study Area Map
Simulation Options
General
Dates
Time Steps
Dynamic Wave
Files
Days
Hr:Min:Sec
Reporting Step
0
00:15:00
Runoff Step: Dry Weather
0
01:00:00
Runoff Step: Wet Weather
0
00:05:00
Control Rule Step
00:00:00
Routing Step (seconds)
30
Steady Flow Periods
Skip Steady Flow Periods
System Flow Tolerance (%)
5
Lateral Flow Tolerance (%)
5
OK
Cancel
Help
Auto-Length: Off
Offsets: Elevation
Flow Units: LPS
Zoom Level: 100%
X,Y: -1904.070, 9360.465

Climatology – See Manual I Section 2.2



Rain Gage



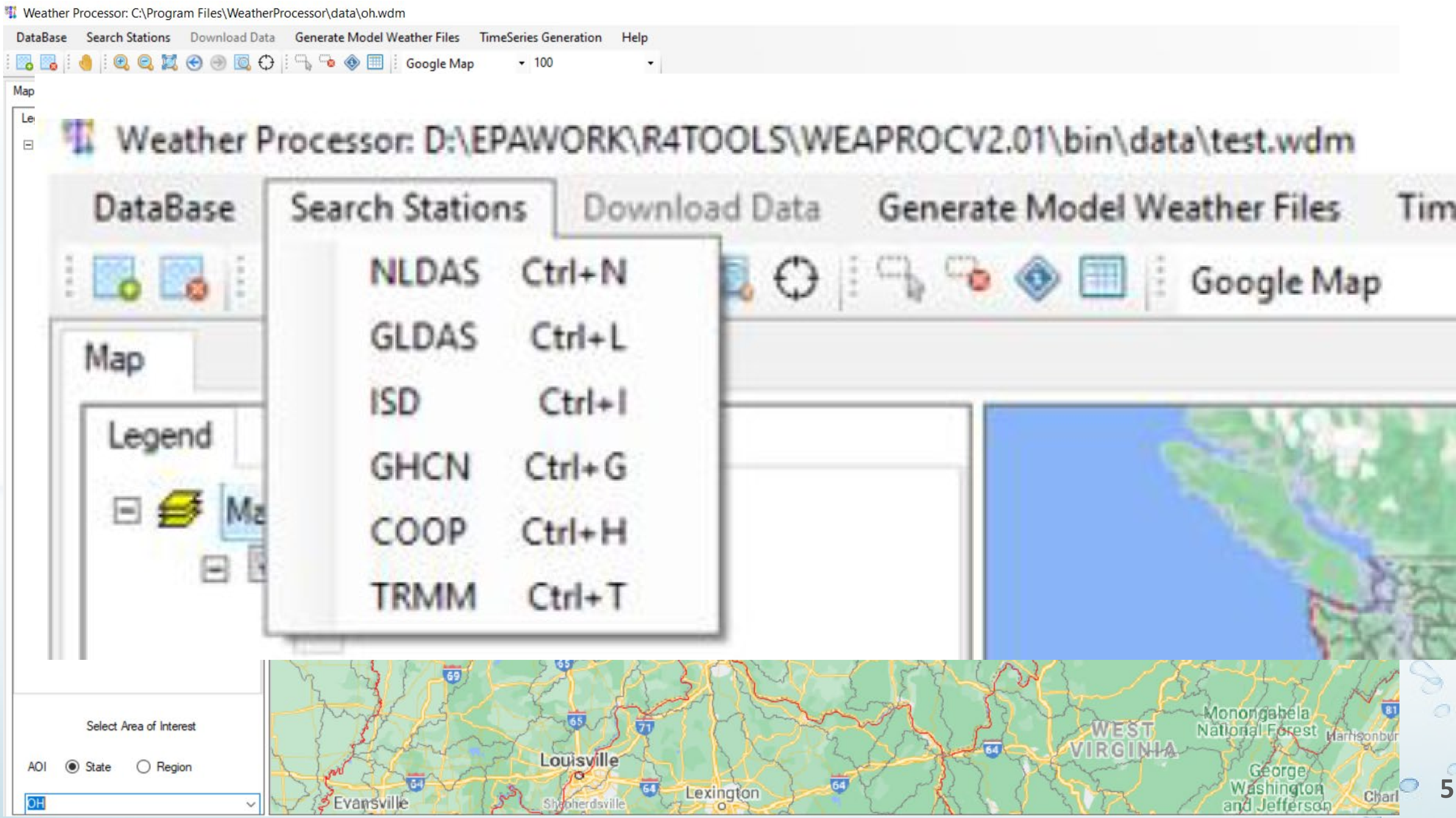
Precipitation
- Measure
- Download from NOAA
- SWC
- BASINS Weather Processor

Evaporation
- Hargreaves
- PET
- SWC

Climate Change
- SWMM-CAT
- SWC-CAT

EPA BASINs Weather Processor Tool

https://www.epa.gov/ceam/basins-download-and-installation

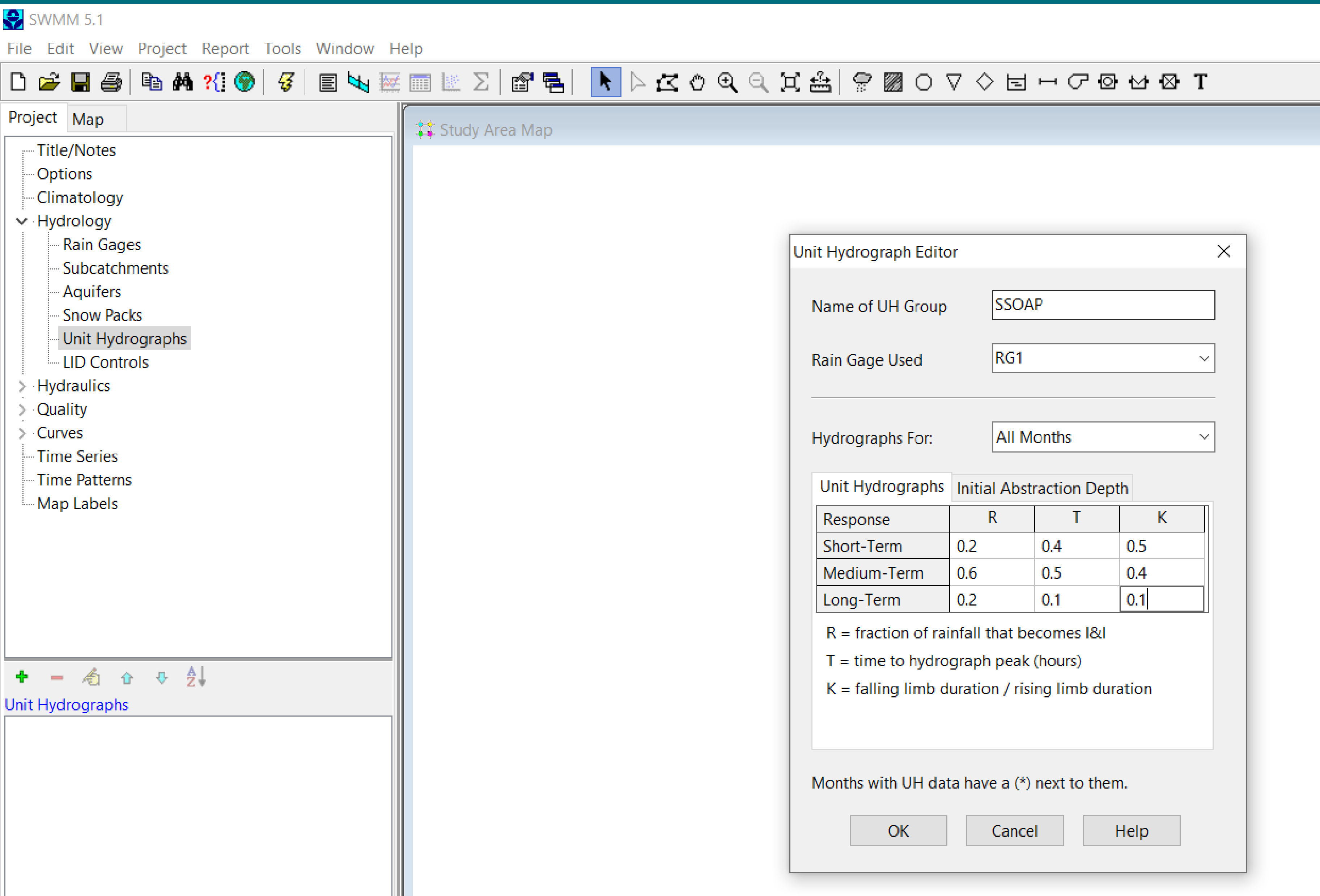


Most Common Format of Precipitation file
See Reference Manual I Chapter 2

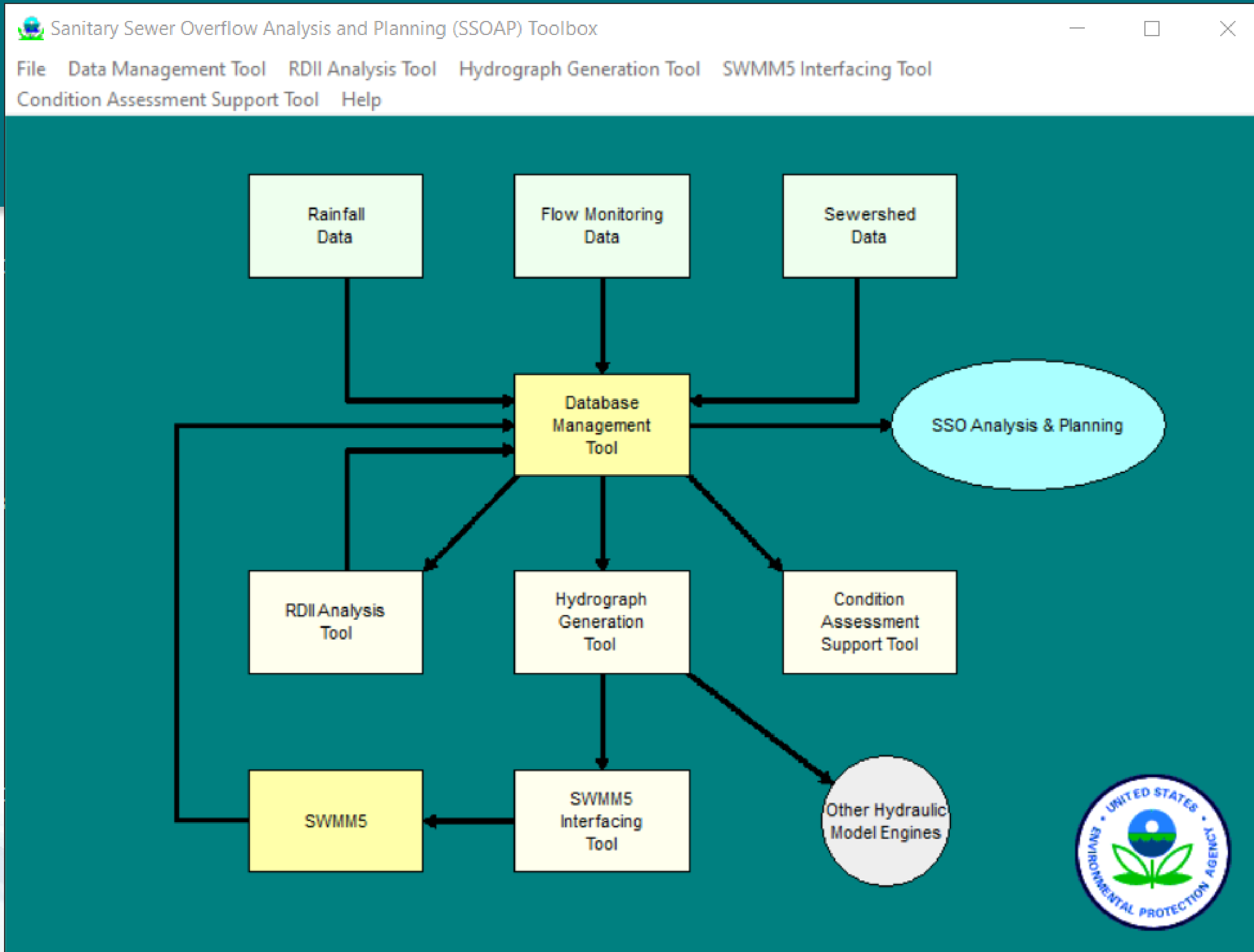
change.log | DryWell.inp | weir20200408.dat | pipe2020408a.inp

```
Weir    2020    4    6    14    15    0.25
Weir    2020    4    6    14    34    0.26
Weir    2020    4    6    18    23    0.25
Weir    2020    4    6    18    34    0.26
Weir    2020    4    6    18    45    0.28
Weir    2020    4    6    19    6     0.25
Weir    2020    4    6    22    41    0.27
Weir    2020    4    6    22    58    0.26
Weir    2020    4    6    23    9     0.27
Weir    2020    4    7    0     5     0.26
Weir    2020    4    7    0     13    0.28
Weir    2020    4    7    0     24    0.26
Weir    2020    4    7    1     18    0.26
Weir    2020    4    7    1     49    0.27
Weir    2020    4    7    2     5     0.30
Weir    2020    4    7    2     13    0.28
Weir    2020    4    7    2     23    0.29
Weir    2020    4    7    2     33    0.27
```

Unit Hydrograph



SSOAP



https://www.epa.gov/water-research/sanitary-sewer-overflow-analysis-and-planning-ssoap-toolbox

How SSOAP works

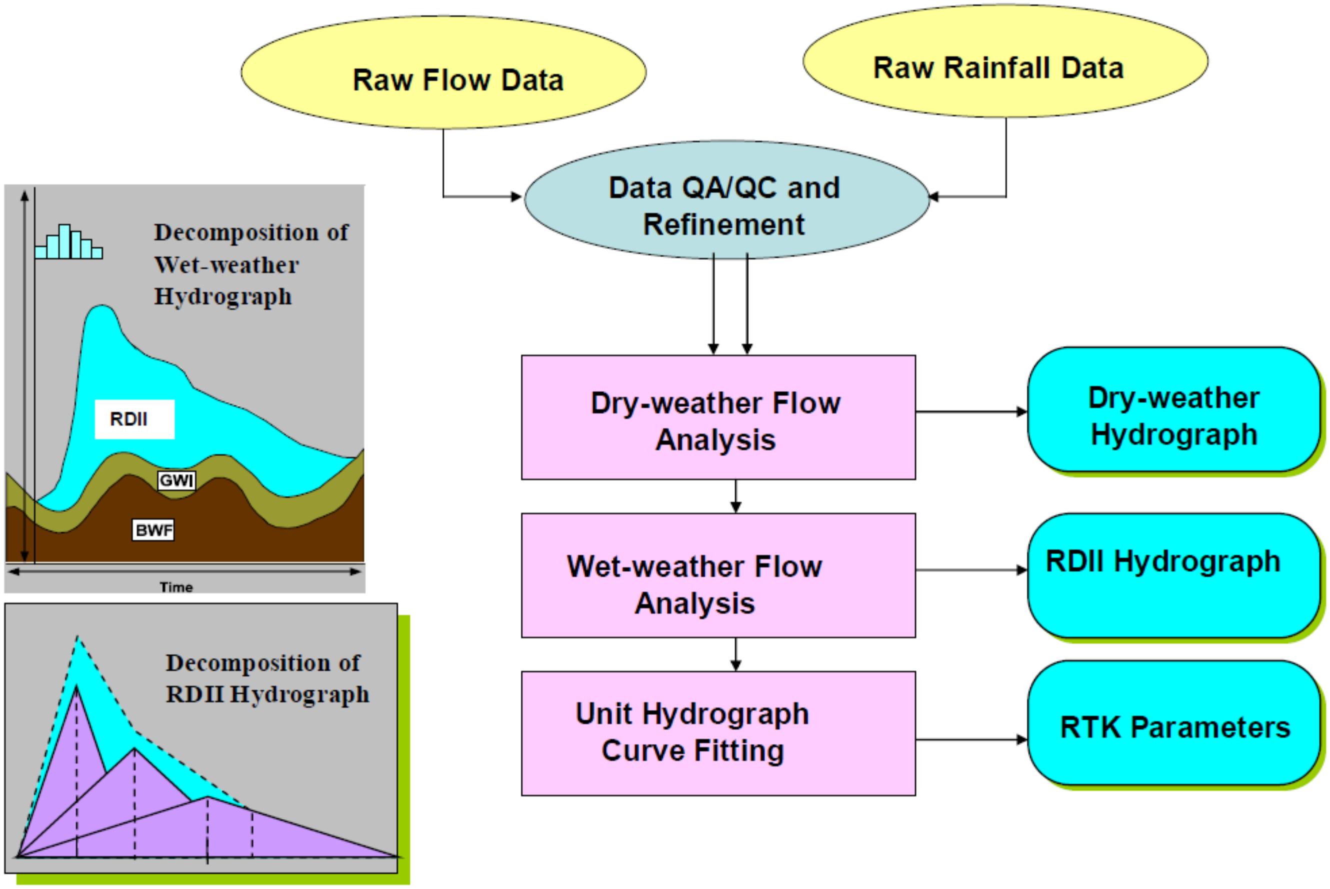
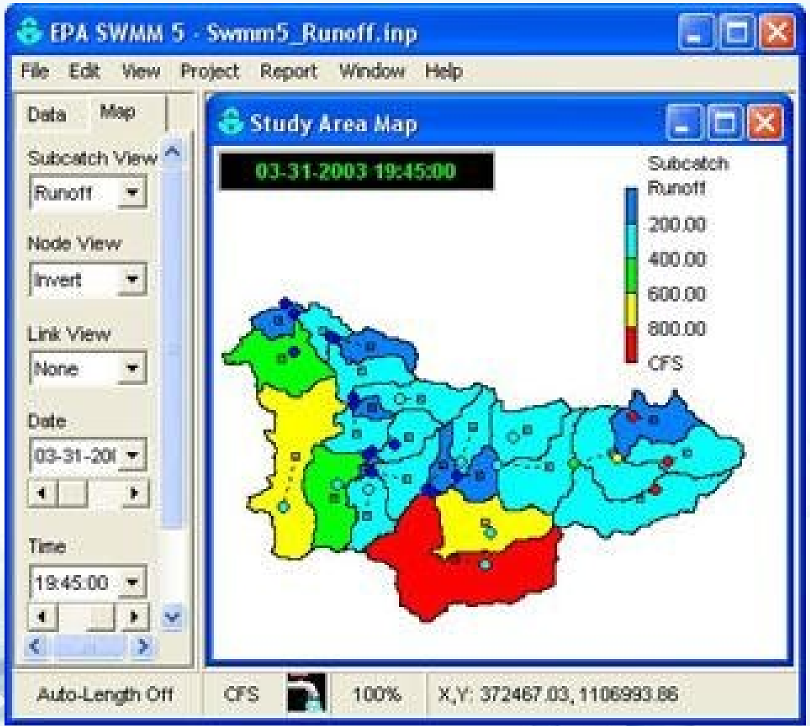


Figure 4. Flow Chart of the Analyses Performed by the RDII Analysis Tool

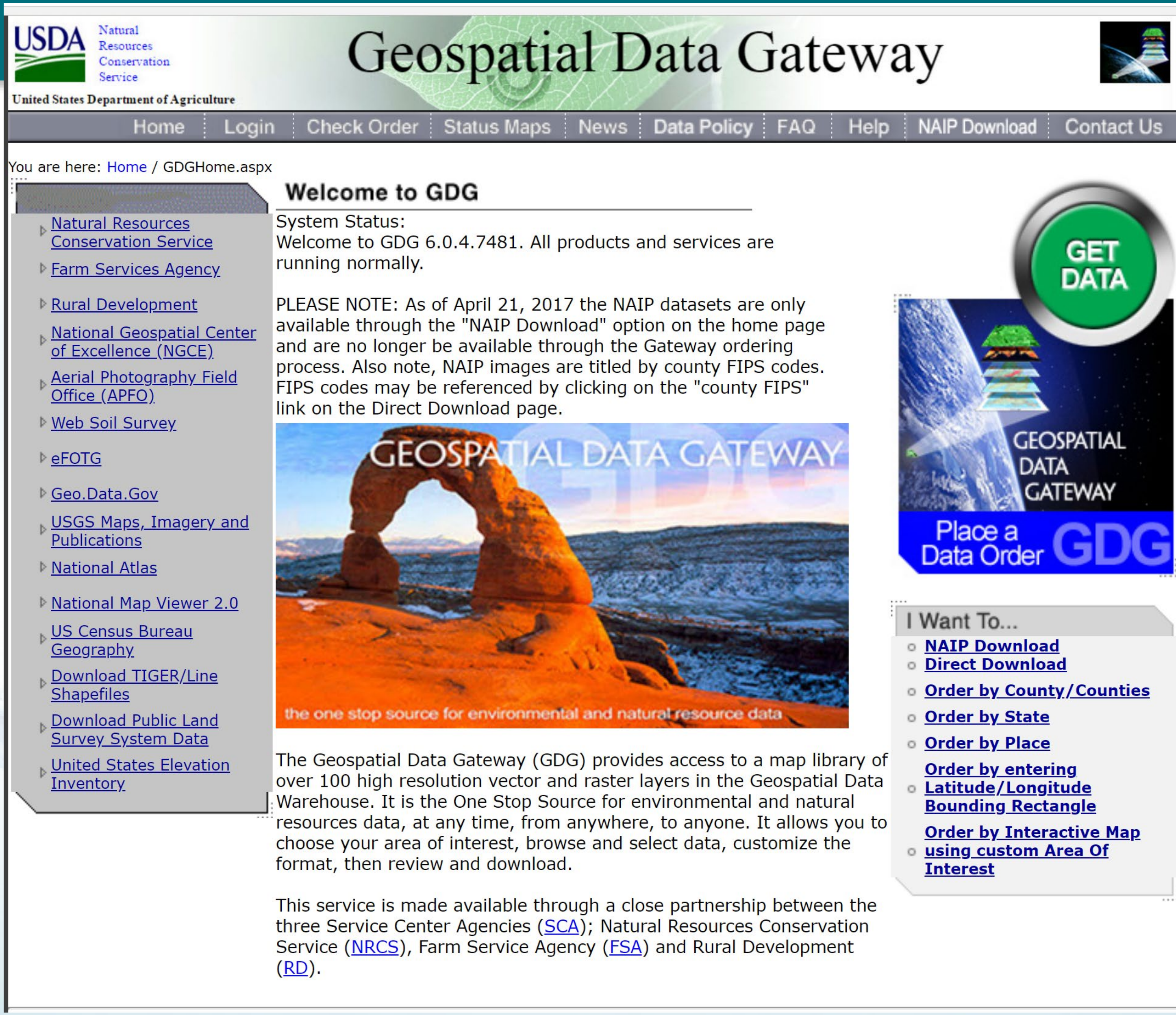
Data that you need for SWMM

Either you measure it or

- Soil Infiltration from a Soil database (SSURGO or STATSGO)
- Land Use – Land Cover (National Land Cover Dataset – NLCD)
- Climatic Data – find closest NOAA station
  - use Stormwater Calculator
  - BASINS Weather Processor Tool
- Site Configuration
  - Subcatchment area
  - Drainage flow
- Hydraulic Configuration
  - Conduit geometry, length, material
  - Network schematic



https://datagateway.nrcs.usda.gov/



Technical Support - Open SWMM

OPEN SWMM

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View and share research.

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KNOWLEDGE CODE RESEARCH RESOURCES

18162	5851	2064	27
POSTS	THREADS	CONTRIBUTORS	YEARS

About OPEN SWMM

Collapse all

— Mission and Intent

The SWMM Knowledge Base is intended to function as an online learning resource for users of the public domain EPA SWMM program. It consists of digitally curated content from the SWMM-USERS list server, organized in an easily readable format. Fully searchable, the SWMM Knowledge Base provides a high signal-to-noise ratio, and promotes content discoverability through related topic suggestions.

Together with the open access Journal of Water Management Modeling, the annual International Conference on Water Management Modeling, and the SWMM-USERS list server, the SWMM Knowledge Base rounds out a group of high quality resources that supports, promotes and encourages development of SWMM by the EPA and the user community.

The SWMM Knowledge Base continuously solicits feedback from the community in making the presentation and content as accessible and useful as possible. Please send any comments and questions to staff at info@openswmm.org. The SWMM Knowledge Base is hosted and moderated by the staff of CHI.

- Mission and Intent
- SWMM-USERS list server
- Conditions for subscribing
- Guidelines for posting
- Digital curation
- Disclaimer
- Terms of use

SWMM Applications Manual
https://www.epa.gov/water-research/storm-water-management-model-swmm

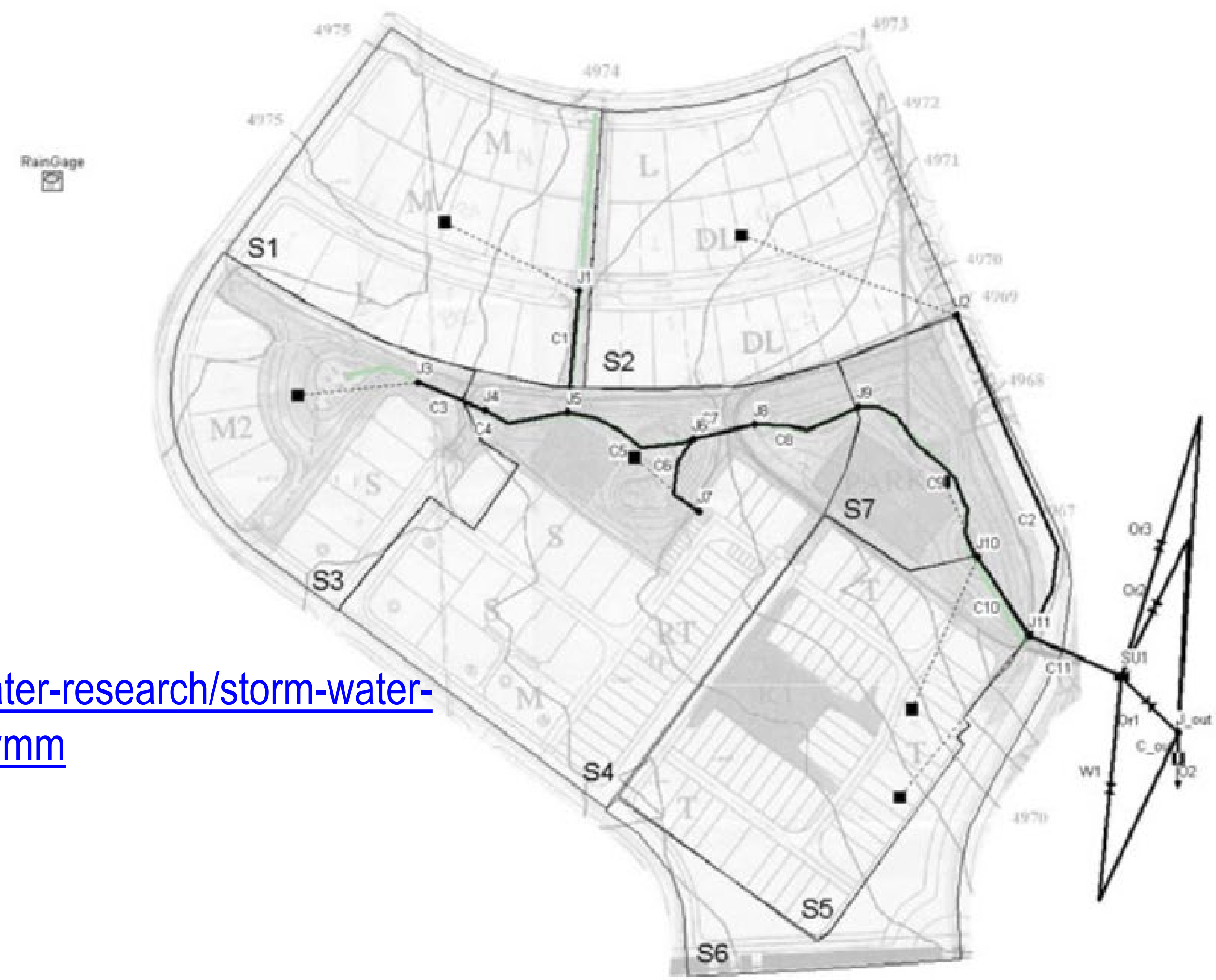

Figure 9-1. Drainage system and detention pond (*SU1*) designed in Example 3

https://www.epa.gov/water-research/storm-water-management-model-swmm

EPA Water Modeling Workgroup Webpage:

https://www.epa.gov/waterdata/surface-water-quality-modeling-training

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Thank You!

Michelle Simon
U.S. EPA Office of Research and Development (ORD)
513-720-2970 Simon.michelle@epa.gov

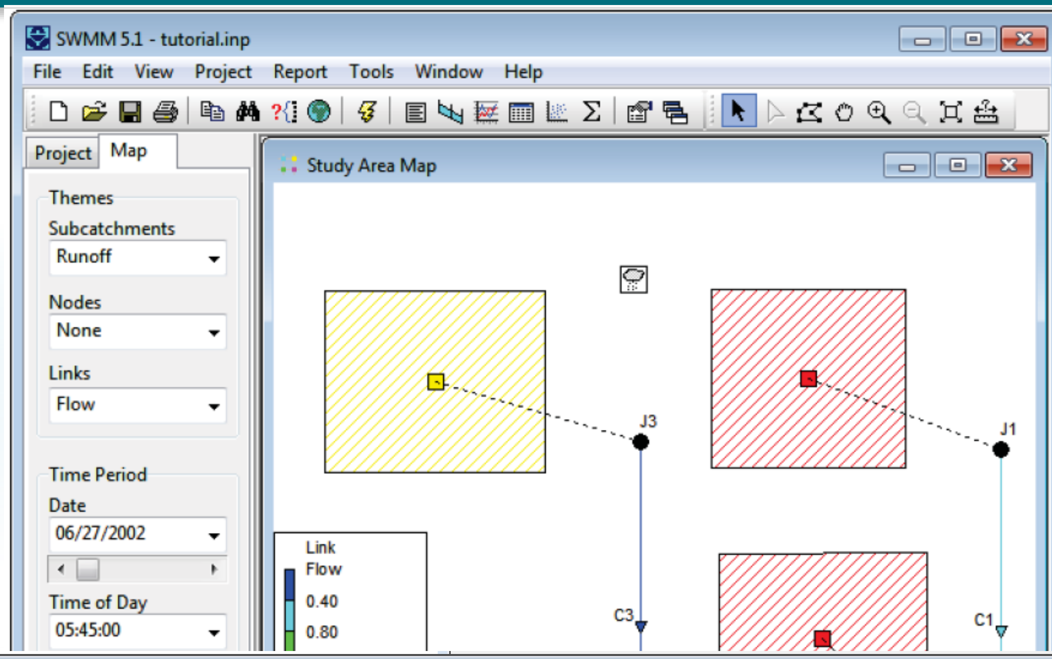
Getting Started with EPA's Storm Water Management Model (SWMM)

Michelle Simon

October 6, 2021

University of Cincinnati

SWMM Hydrology Results – from SWMM User's Manual Tutorial

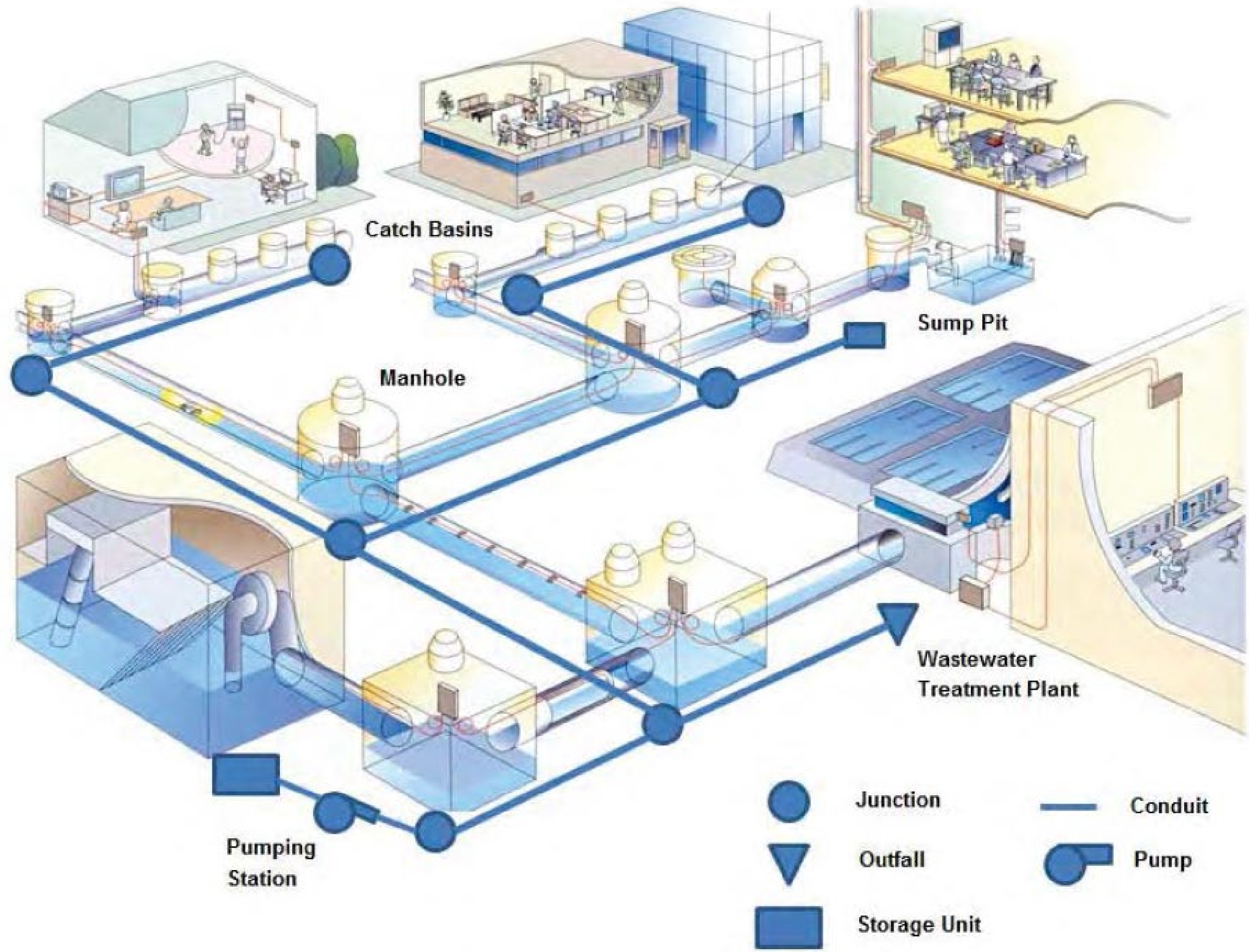


Summary Results

Topic: Subcatchment Runoff   Click a column header to sort the column.

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Imperv Runoff in	Perv Runoff in	Total Runoff in	Total Runoff 10^6 gal	Peak Runoff CFS
Sub3	3.00	0.00	0.00	1.50	1.48	0.00	1.48	0.16	2.02
Sub1	3.00	0.00	0.00	1.50	1.48	0.00	1.48	0.16	2.02
Sub2	3.00	0.00	0.00	1.50	1.48	0.00	1.48	0.16	2.02

Hydraulic Model Reference Manual II



Continuity equation at node

$$H_{t+\Delta t} = H_t + \Sigma Q_t \Delta t / A_{s_t}$$

where

$H_{t+\Delta t}$	=	hydraulic head at next time step (ft)
H_t	=	hydraulic head at beginning of simulation (ft)
Q_t	=	flow rate (ft^3/sec)
Δt	=	time (sec)
A_{st}	=	surface area of node (ft^2)

Governing Equations

Conservation of Momentum in a conduit

$$\frac{\partial Q}{\partial t} + gA\frac{\partial H}{\partial x} + gAS_f + \frac{\partial (Q^2/A)}{\partial x} = 0$$

where

Q_t	=	flow rate (ft^3/sec)
t	=	time (sec)
g	=	gravitational constant (32.2 ft/sec^2)
H	=	hydraulic head (ft)
x	=	length (ft)
A	=	surface area of conduit (ft^2)
Sf	=	slope (ft/ft)

Level of Sophistication

Level of Sophistication

- Steady Flow Routing
- Kinematics Wave Routing
- Dynamic Wave Routing

Kinematic Wave
Reference Manual II Chapter 4

Cannot have

- Looped networks
- Backwater effects
- Pressure-flow conditions

$$\frac{\partial Q}{\partial t} = gA\frac{\partial H}{\partial x} + gAS_f$$

https://www.youtube.com/watch?v=ziWy5qbVIWo

SWMM - Manning Equation Open Channel Flow

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$

Q = flow rate (ft^3/sec)

A = cross sectional area (ft^2)

R = hydraulic radius (ft)

S = slope (ft/ft)

n = Manning roughness coefficient (-)

Dynamic Wave Routing Reference Manual II Chapter 3

Used for

- Branched or looped networks
- Backwater due to tidal or other conditions
- Free-surface flow
- Pressure flow or surcharge
- Flow reversals

$$\frac{\partial Q}{\partial t} = \frac{\partial (Q^2/A)}{\partial x} + gA\frac{\partial H}{\partial x} + gAS_f$$

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Pipes with Circular Force Main Cross sections

Hazen-Williams

$$Q = 1.318\,C\,A\,R^{0.63}\,S^{0.54}$$

Q = flow rate

C = Hazen Williams C-factor

A = cross sectional area

R = hydraulic radius

S = slope

Darcy-Weisbach

$$Q = \sqrt{\frac{8g}{f}}\,A R^{1/2} S^{1/2}$$

Q = flow rate

g = gravity acceleration

f = Darcy-Weisbach friction factor

A = cross sectional area

R = hydraulic radius

S = slope

Hydraulics Nodes

SWMM 5.1 - [Study Area Map]

File Edit View Project Report Tools Window Help

Project | Map

- Title/Notes
- Options
- Climatology
- Hydrology
- Hydraulics
  - Nodes
    - Junctions
    - Outfalls
    - Dividers
    - Storage Units
  - Links
  - Transects
  - Controls
- Quality
- Curves
- Time Series
- Time Patterns
- Map Labels

Auto-Length: Off | Offsets: Elevation | Flow Units: LPS | Zoom Level: 100% | X,Y: 3891.243, 70.621

Junction J1

Property	Value
Name	J1
X-Coordinate	3089.005
Y-Coordinate	5523.560
Description	
Tag	
Inflows	NO
Treatment	NO
Invert El.	0
Max. Depth	0
Initial Depth	0
Surcharge Dept	0
Ponded Area	0

Outfall Out1

Property	Value
Name	Out1
X-Coordinate	4502.618
Y-Coordinate	5261.780
Description	
Tag	
Inflows	NO
Treatment	NO
Invert El.	0
Tide Gate	NO
Route To	
Type	FREE
Fixed Outfall	
Fixed Stage	0
Tidal Outfall	
Curve Name	*
Time Series Out	
Series Name	*

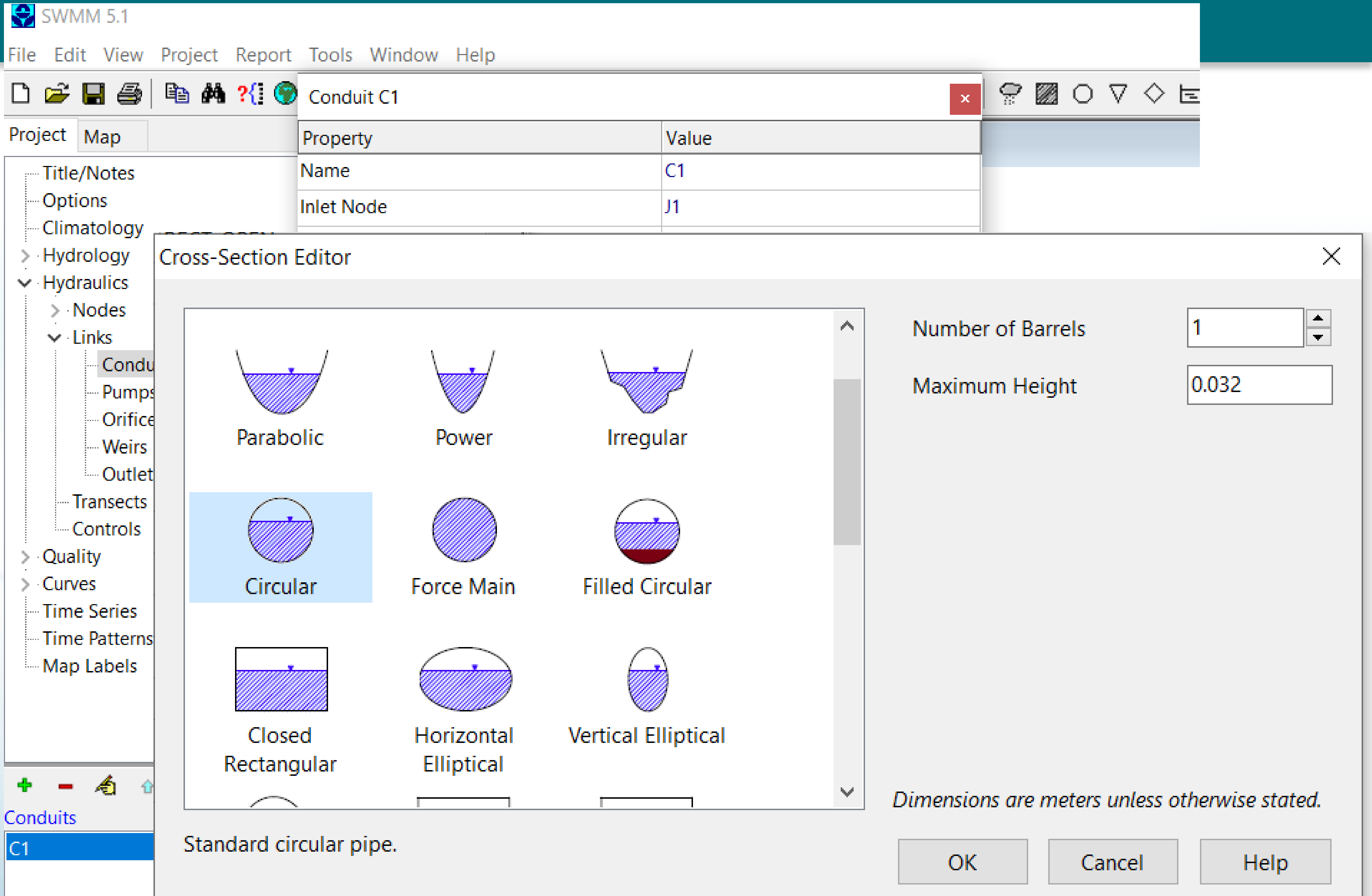
Divider 1

Property	Value
Name	1
X-Coordinate	4816.754
Y-Coordinate	7329.843
Description	
Tag	
Inflows	NO
Treatment	NO
Invert El.	0
Max. Depth	0
Initial Depth	0
Surcharge Dept	0
Ponded Area	0
Diverted Link	*
Type	CUTOFF
Cutoff Divider	
Cutoff Flow	0
Tabular Divider	
Curve Name	*
Weir Divider	
Min. Flow	0
Max. Depth	0
Coefficient	0

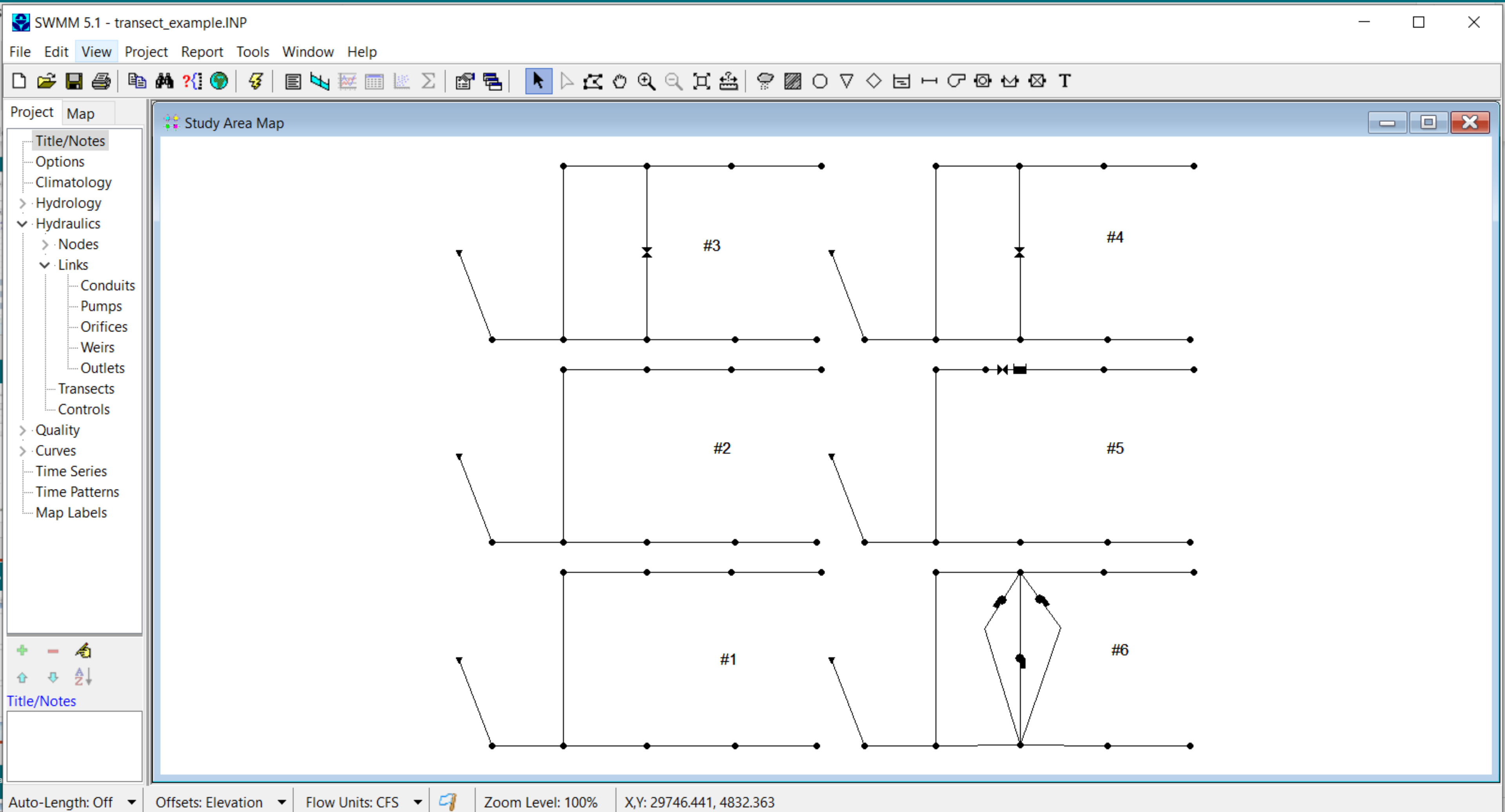
Storage Unit Stor1

Property	Value
Name	Stor1
X-Coordinate	1649.215
Y-Coordinate	3298.429
Description	
Tag	
Inflows	NO
Treatment	NO
Invert El.	0
Max. Depth	0
Initial Depth	0
Surcharge Dept	0
Evap. Factor	0
Seepage Loss	NO
Storage Curve	FUNCTIONAL
Functional Curv	
Coefficient	1000
Exponent	0
Constant	0
Tabular Curve	
Curve Name	*

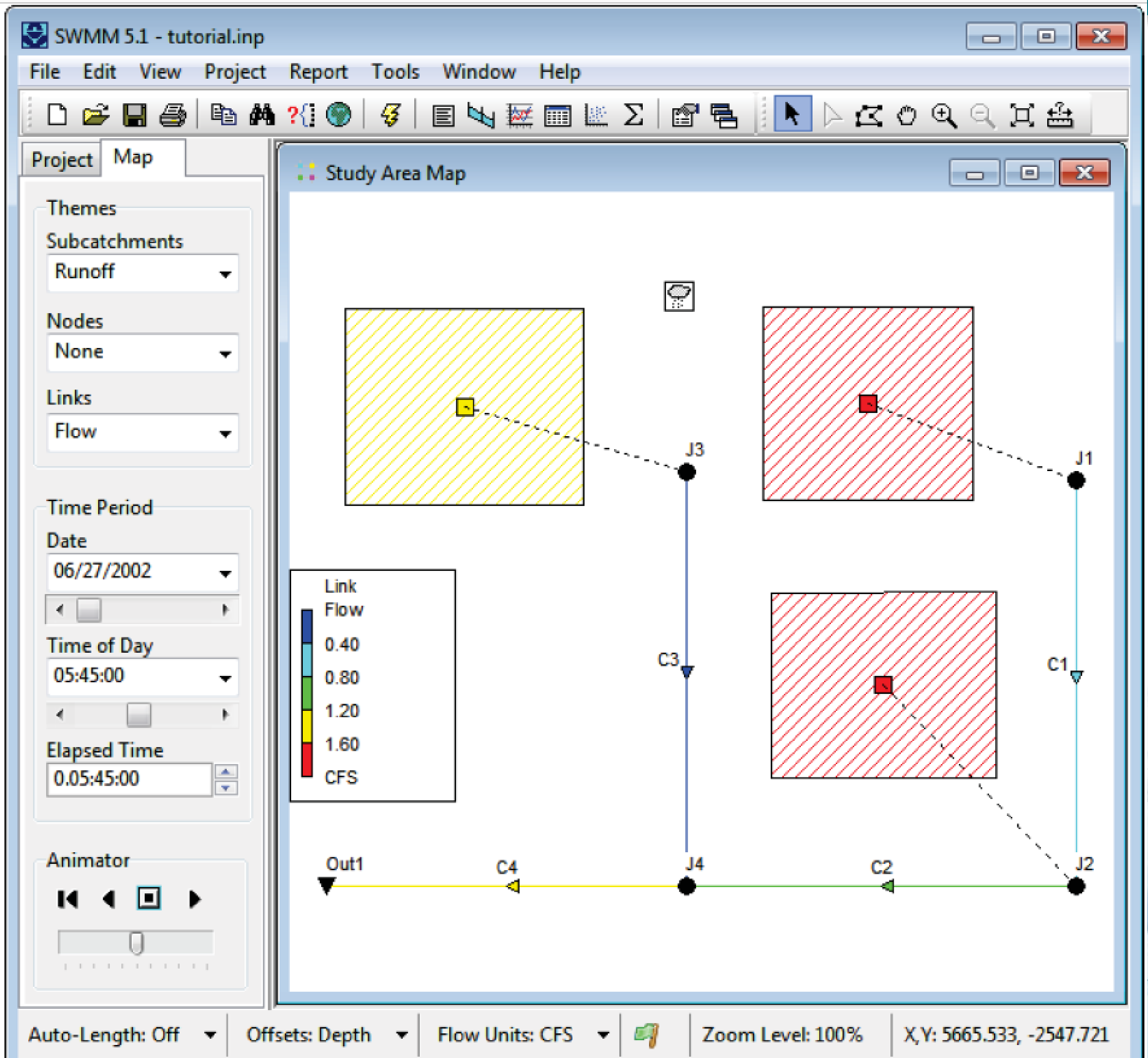
Hydraulics - Links



Hydraulic Link – Reference Manual II
Pumps, Orifices, Weirs, Outlets



SWMM User's Manual
Tutorial Example



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Results – from SWMM User's Manual Tutorial Example

Summary Results

Topic: Conduit Surcharge — Click a column header to sort the column.

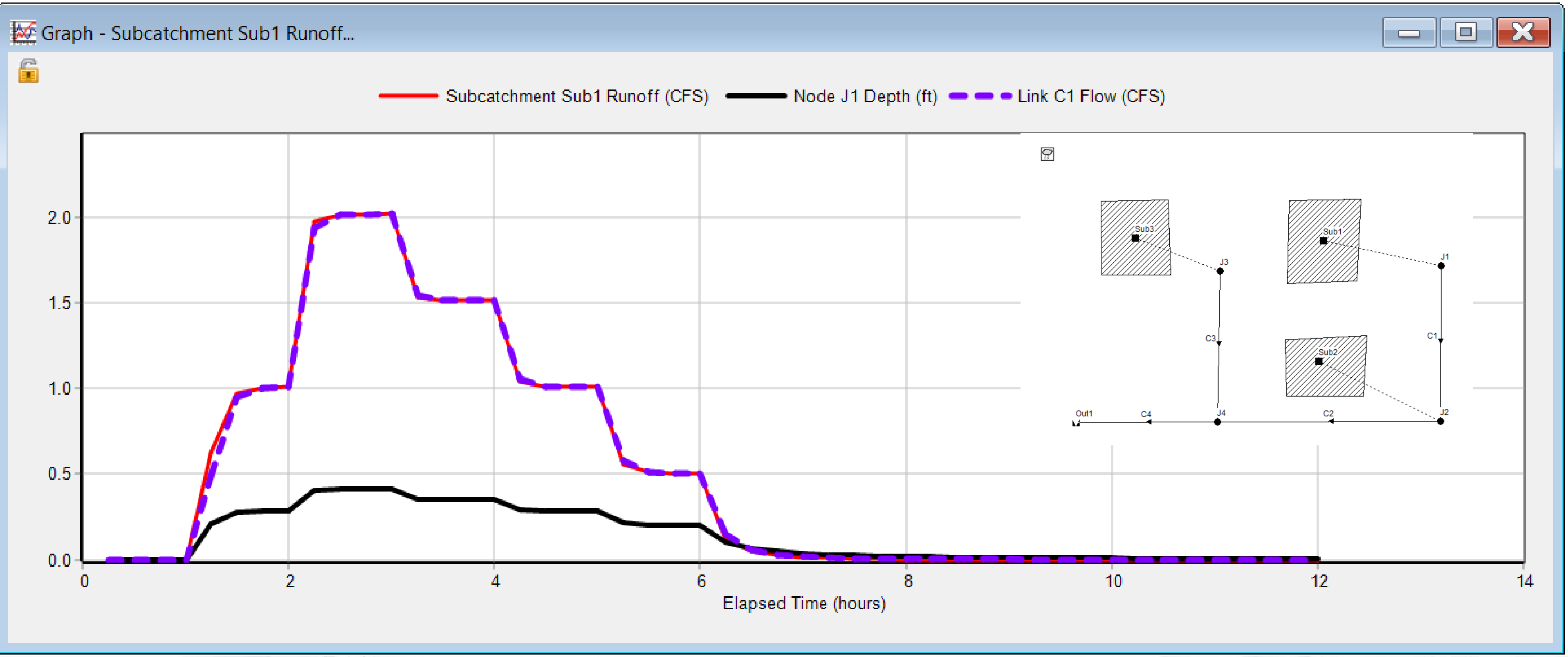
Conduit	Hours Both Ends Full	Hours Upstream Full	Hours Dnstream Full	Hours Above Normal Flow	Hours Capacity Limited
C2	1.03	1.03	1.03	1.03	1.03

Summary Results

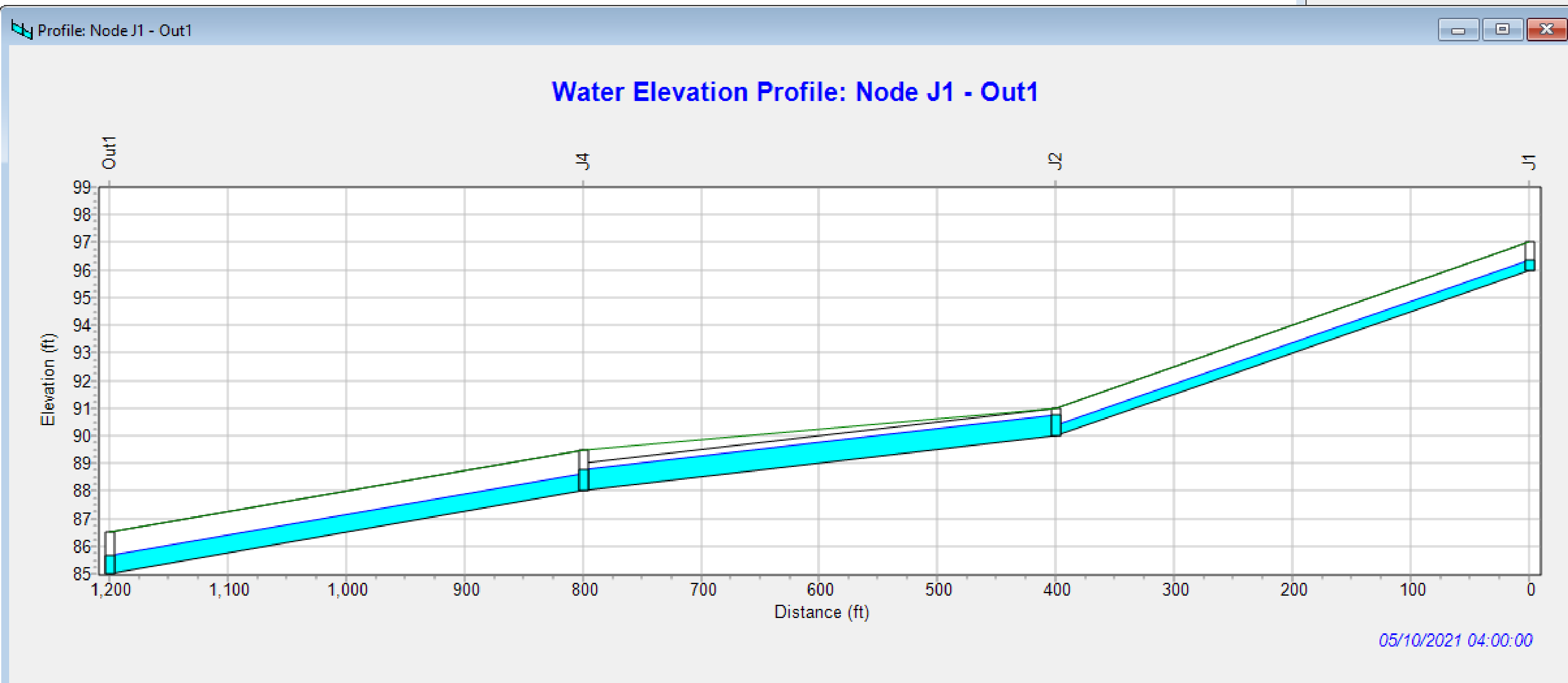
Topic: Outfall Loading — Click a column header to sort the column.

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
Out1	90.97	1.58	5.34	0.465

Graph – from SWMM User's Manual Tutorial Example



Profile – from SWMM User's Manual Tutorial Example



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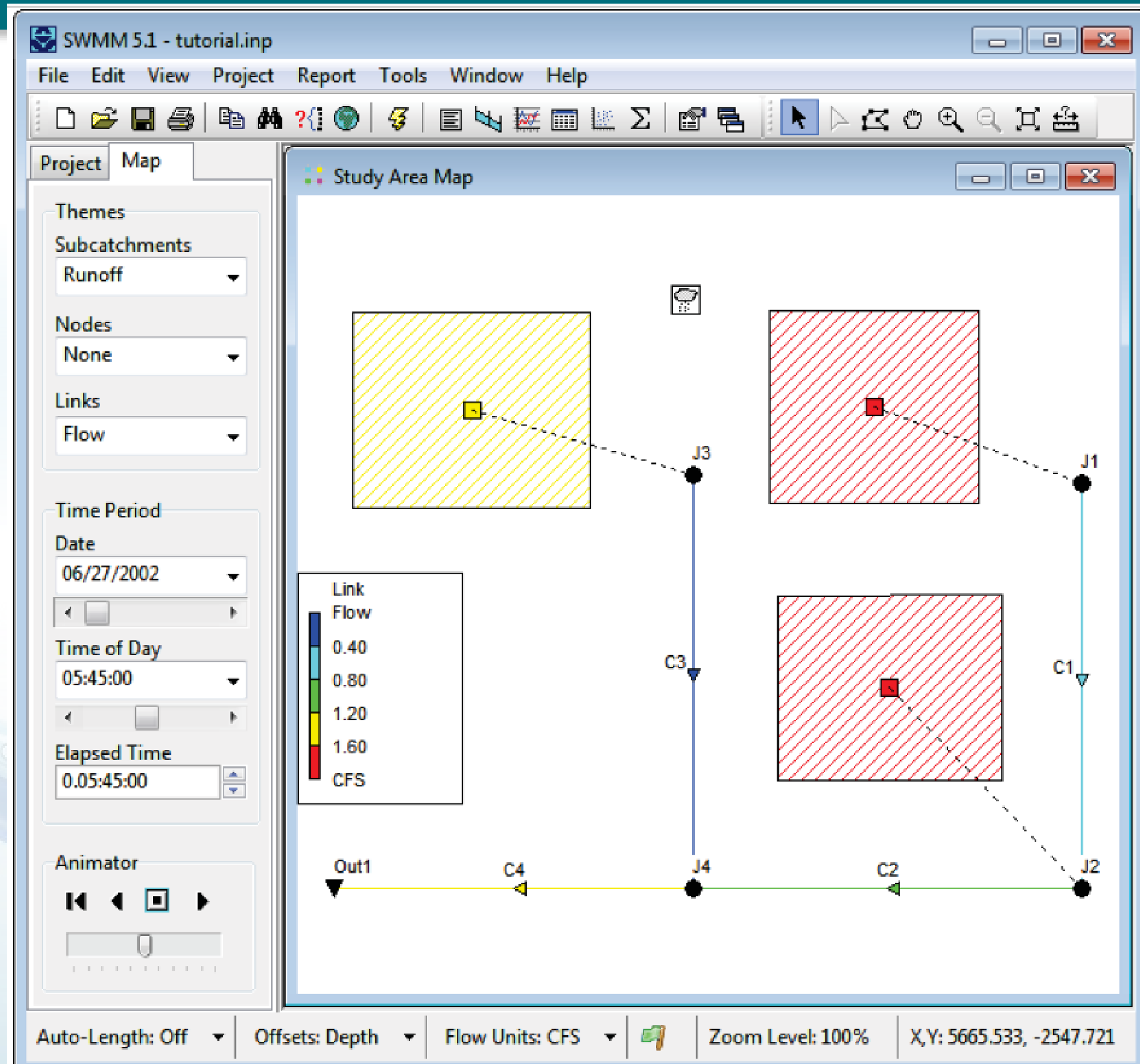
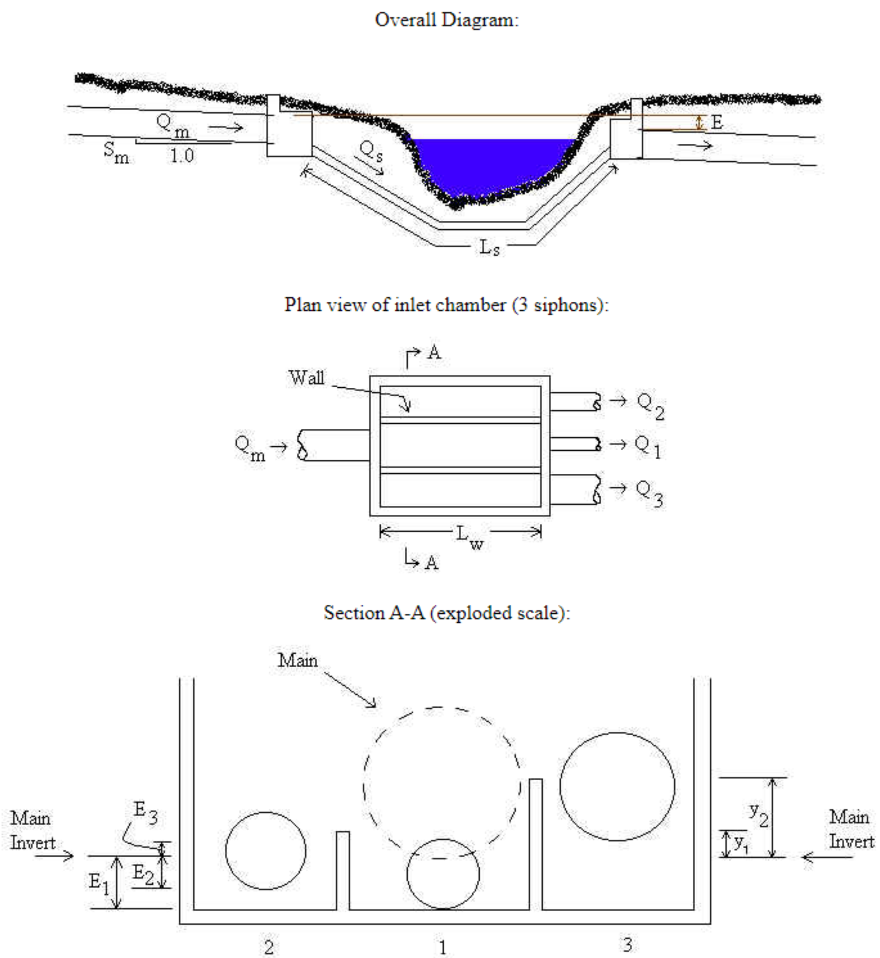
Viewing Results on a Map – SWMM Tutorial Example



Question – Inverted Siphon



https://www.lmnoeng.com/Channels/InvertedSiphon.php - diagram

Questions?

Summary

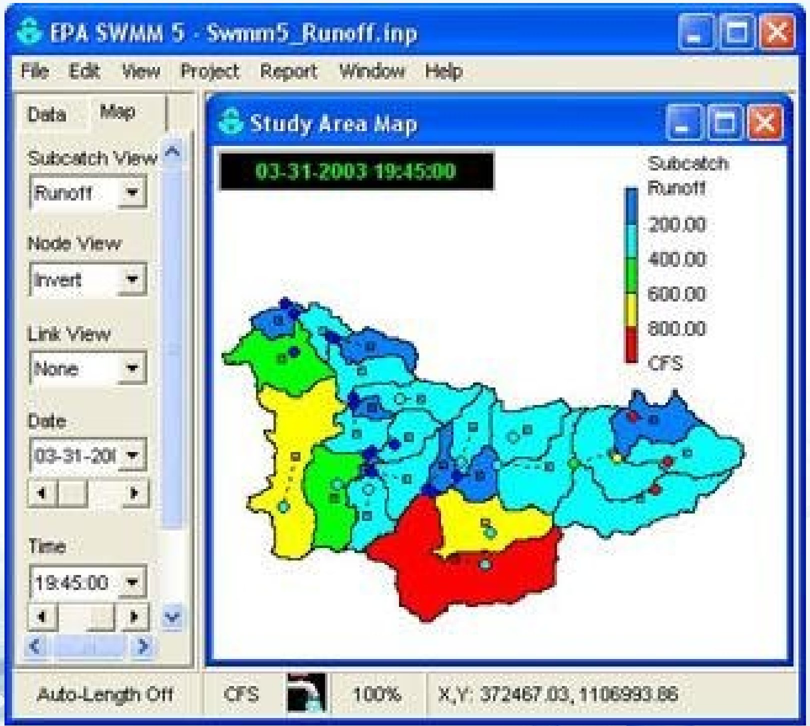
Storm Water Management Model

- Basics of SWMM
- Processes Modeled by SWMM
- Demonstration of SWMM
- National Stormwater Calculator
- Location of Data
- Technical Support
- Discussion & Questions

Data you need for SWMM

Either you measure it or

- Soil Infiltration from a Soil database (SSURGO or STATSGO)
- Land Use – Land Cover (National Land Cover Dataset – NLCD)
- Climatic Data – find closest NOAA station
  - use Stormwater Calculator
  - BASINS Weather Processor Tool
- Site Configuration
  - Subcatchment area
  - Drainage flow
- Hydraulic Configuration
  - Conduit geometry, length, material
  - Network schematic



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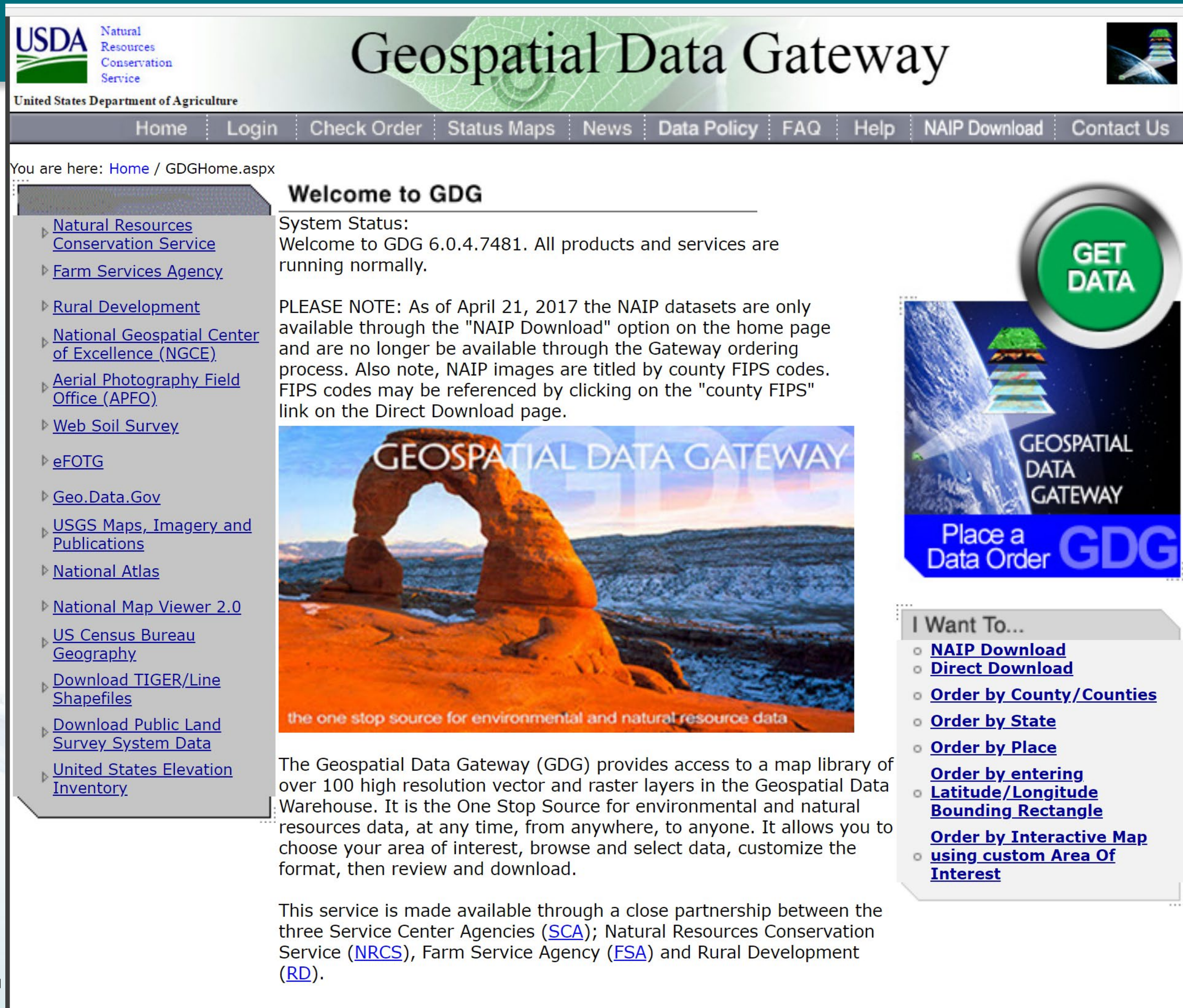
https://datagateway.nrcs.usda.gov/



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About OPEN SWMM

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— Mission and Intent

The SWMM Knowledge Base is intended to function as an online learning resource for users of the public domain EPA SWMM program. It consists of digitally curated content from the SWMM-USERS list server, organized in an easily readable format. Fully searchable, the SWMM Knowledge Base provides a high signal-to-noise ratio, and promotes content discoverability through related topic suggestions.

Together with the open access Journal of Water Management Modeling, the annual International Conference on Water Management Modeling, and the SWMM-USERS list server, the SWMM Knowledge Base rounds out a group of high quality resources that supports, promotes and encourages development of SWMM by the EPA and the user community.

The SWMM Knowledge Base continuously solicits feedback from the community in making the presentation and content as accessible and useful as possible. Please send any comments and questions to staff at info@openswmm.org. The SWMM Knowledge Base is hosted and moderated by the staff of CHI.

- Mission and Intent
- SWMM-USERS list server
- Conditions for subscribing
- Guidelines for posting
- Digital curation
- Disclaimer
- Terms of use

Key Websites discussed

Storm Water Management Model:
https://www.epa.gov/water-research/storm-water-management-model-swmm

National Stormwater Calculator Website:
https://www.epa.gov/water-research/national-stormwater-calculator

Water Research Program Webinar Series Website:
https://www.epa.gov/water-research/water-research-program-webinar-series

USGS's online Seamless Data Warehouse:
https://datagateway.nrcs.usda.gov

YouTube Tutorials:
https://www.youtube.com

Openswmm:
https://www.openswmm.org/

Thank You!

Michelle Simon
U.S. EPA Office of Research and Development (ORD)
513-720-2970 Simon.michelle@epa.gov

EPA Water Modeling Workgroup Webpage:

https://www.epa.gov/waterdata/surface-water-quality-modeling-training

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