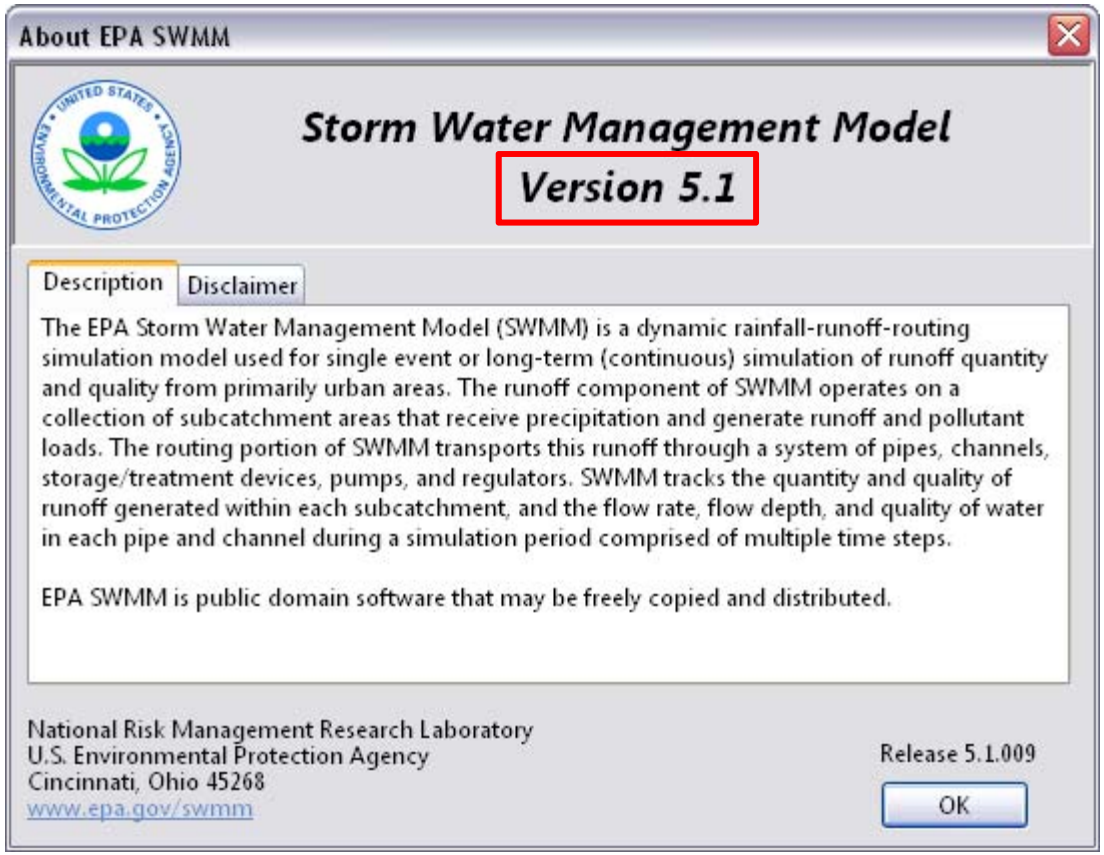
SWMM MODEL BASICS

SWMM 5.1.009


About EPA SWMM
Storm Water Management Model
Version 5.1
Description
Disclaimer
The EPA Storm Water Management Model (SWMM) is a dynamic rainfall-runoff-routing simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas. The runoff component of SWMM operates on a collection of subcatchment areas that receive precipitation and generate runoff and pollutant loads. The routing portion of SWMM transports this runoff through a system of pipes, channels, storage/treatment devices, pumps, and regulators. SWMM tracks the quantity and quality of runoff generated within each subcatchment, and the flow rate, flow depth, and quality of water in each pipe and channel during a simulation period comprised of multiple time steps.
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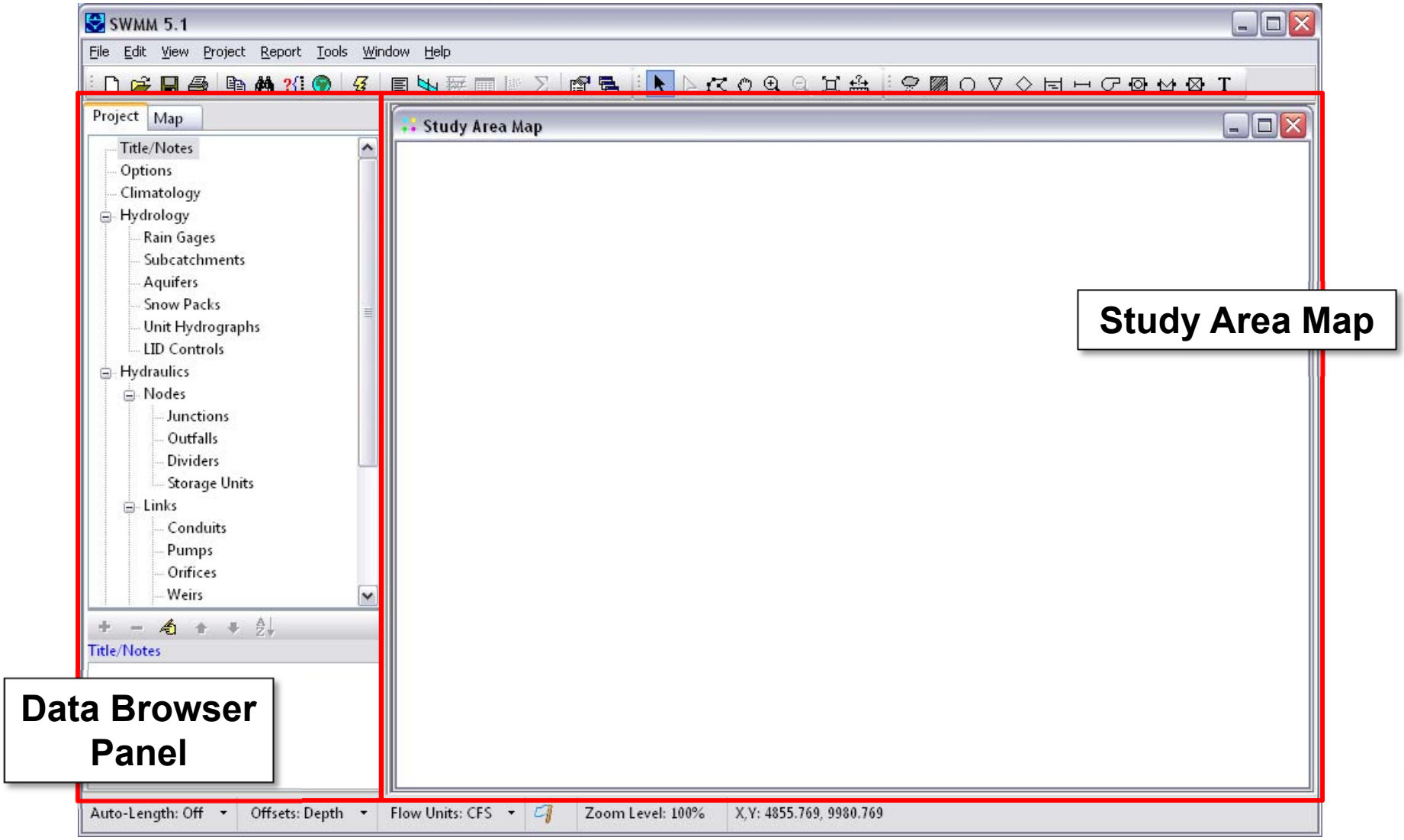
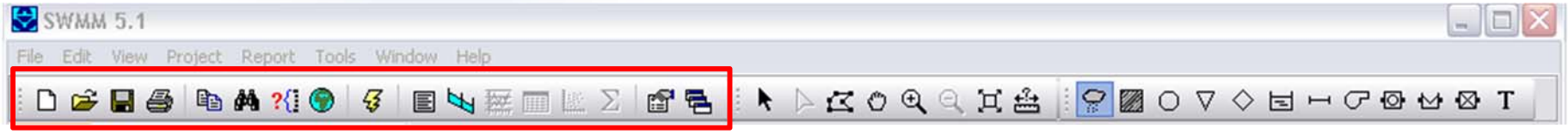
National Risk Management Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268
www.epa.gov/swmm
Release 5.1.009
OK

New File


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
Nodes
Junctions
Outfalls
Dividers
Storage Units
Links
Conduits
Pumps
Orifices
Weirs
Title/Notes
Study Area Map
Study Area Map
Data Browser Panel
Auto-Length: Off
Offsets: Depth
Flow Units: CFS
Zoom Level: 100%
X,Y: 4855.769, 9980.769

Standard Toolbar

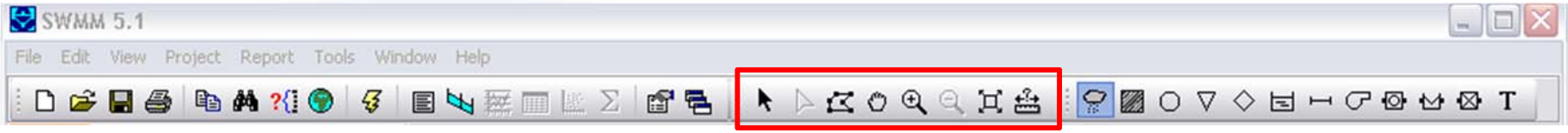


Standard Toolbar

The Standard Toolbar contains buttons for the following commonly used commands:

- Creates a new project (**File >> New**)
- Opens an existing project (**File >> Open**)
- Saves the current project (**File >> Save**)
- Prints the currently active window (**File >> Print**)
- Copies selection to the clipboard or to a file (**Edit >> Copy To**)
- Finds a specific object on the Study Area Map (**Edit >> Find Object**) or specific text in the Status Report (**Edit >> Find Text**)
- Runs a simulation (**Project >> Run Simulation**)
- Makes a visual query of the study area map (**View >> Query**)
- Creates a profile plot of simulation results (**Report >> Graph >> Profile**)
- Creates a time series plot of simulation results (**Report >> Graph >> Time Series**)
- Creates a scatter plot of simulation results (**Report >> Graph >> Scatter**)
- Creates a table of simulation results (**Report >> Table**)
- Performs a statistical analysis of simulation results (**Report >> Statistics**)
- Modifies display options for the currently active view (**Tools >> Map Display Options** or **Report >> Customize**)
- Arranges windows in cascaded style, with the study area map filling the entire display area (**Window >> Cascade**)

Map Toolbar



Map Toolbar

The Map Toolbar contains the following buttons for viewing the study area map:

- Selects an object on the map (**Edit >> Select Object**)
- Selects link or subcatchment vertex points (**Edit >> Select Vertex**)
- Selects a region on the map (**Edit >> Select Region**)
- Pans across the map (**View >> Pan**)
- Zooms in on the map (**View >> Zoom In**)
- Zooms out on the map (**View >> Zoom Out**)
- Draws map at full extent (**View >> Full Extent**)
- Measures a length or area on the map

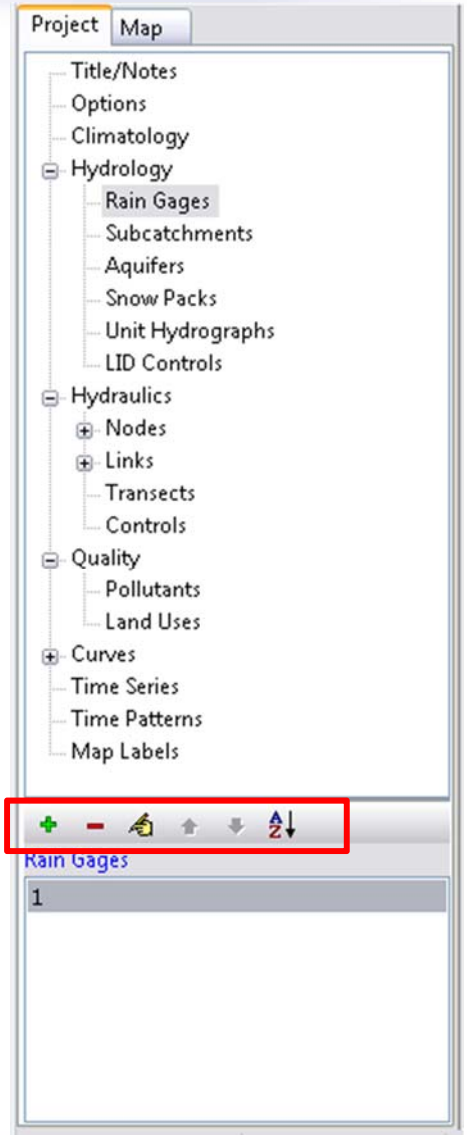
Object Toolbar

Object Toolbar

The Object Toolbar contains buttons for adding objects to the study area map:

- Adds a rain gage to the map
- Adds a subcatchment to the map
- Adds a junction node to the map
- Adds an outfall node to the map
- Adds a flow divider node to the map
- Adds a storage unit node to the map
- Adds a conduit link to the map
- Adds a pump link to the map
- Adds an orifice link to the map
- Adds a weir link to the map
- Adds an outlet link to the map
- T Adds a label to the map

Data Browser Panel

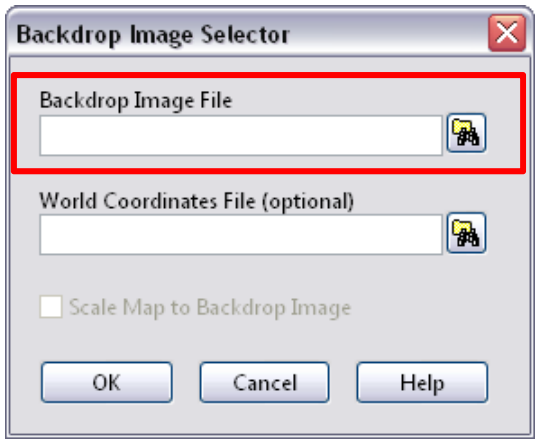


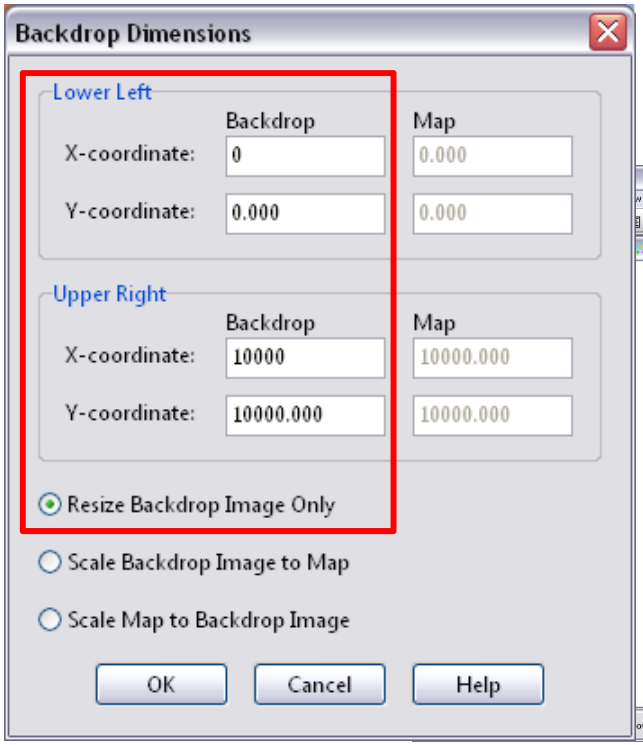
The buttons between the two list boxes of the Data Browser are used as follows:

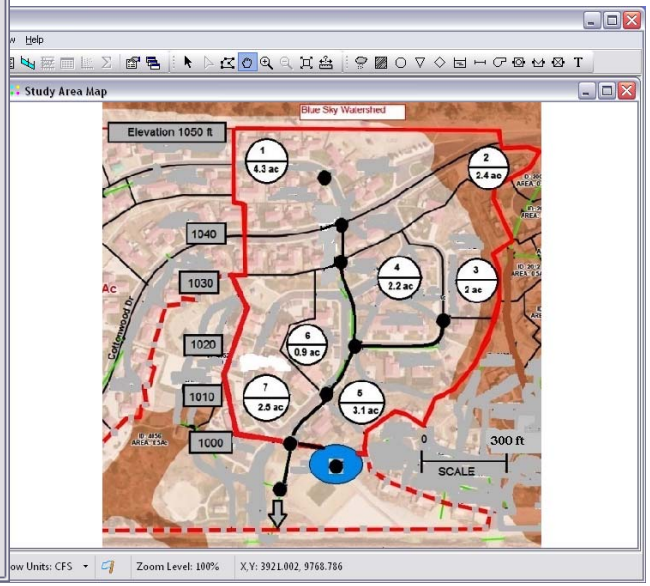
- adds a new object
- deletes the selected object
- edits the selected object
- moves the selected object up one position
- moves the selected object down one position
- sorts the objects in ascending order

Add a Backdrop Image

- Open the “Backdrop Image Selector” and import an image (if available). This setting is optional.
  - View - > Backdrop -> Load… - > “Browse for image”
- Open the “Backdrop Dimensions” editor and enter in the desired coordinates.
  - View - > Backdrop - > Resize…
- The Backdrop image can also be moved in the Study Area Map
  - View - > Backdrop - > Align



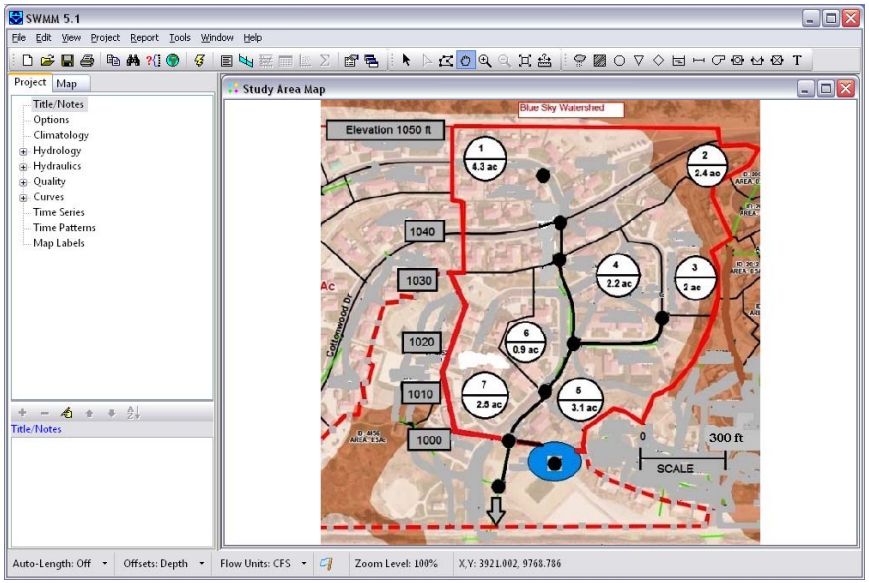




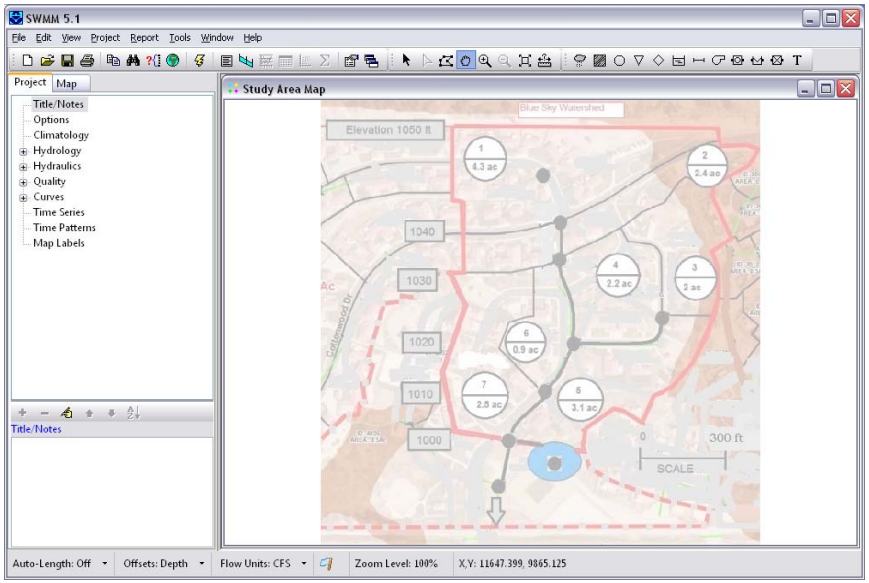
Backdrop Watermark

- To screen back the image, there is an optional “Watermark” setting.
- View - > Backdrop - > “Watermark”

w/o Watermark



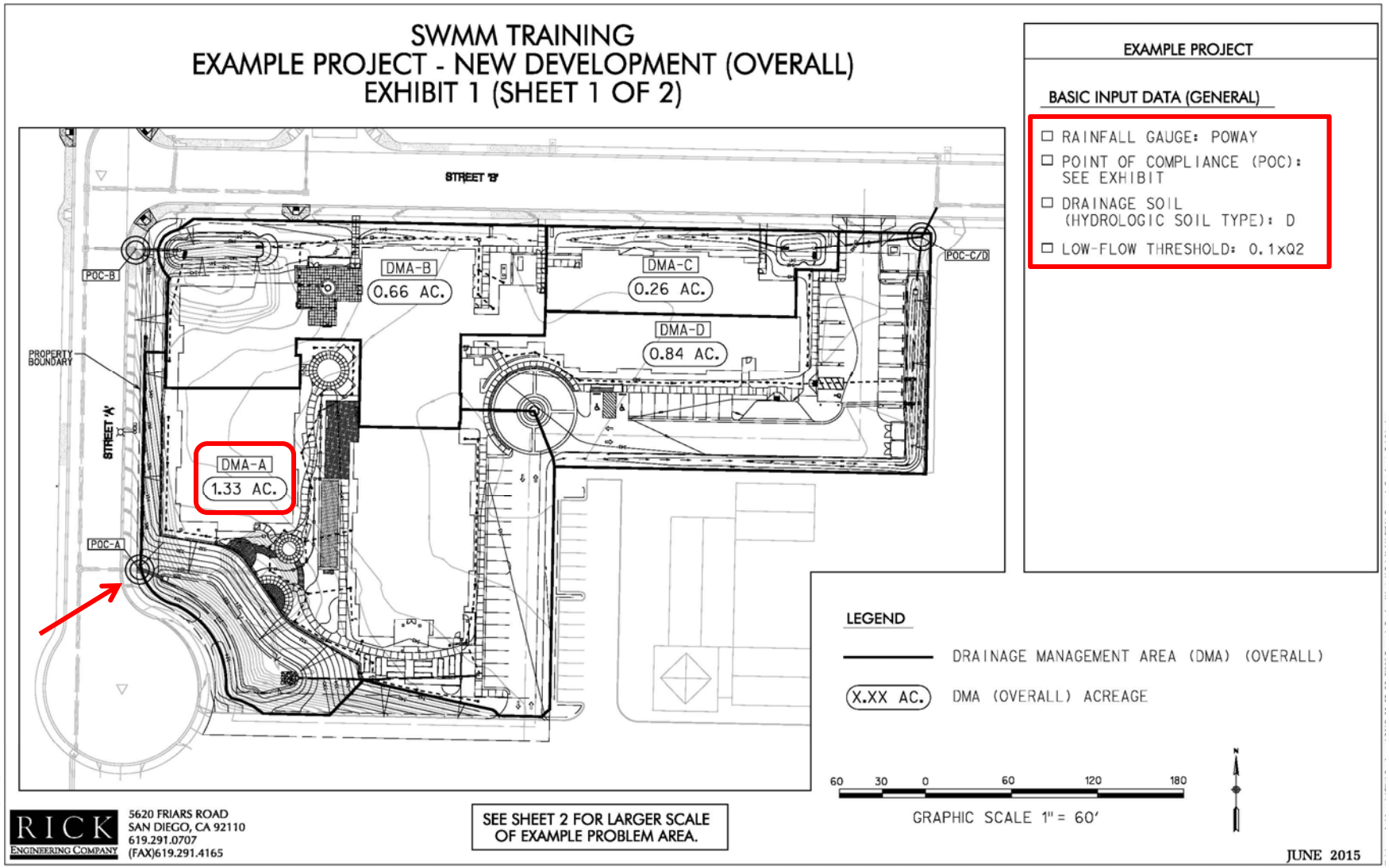
w/ Watermark



Example Project – Institutional Living

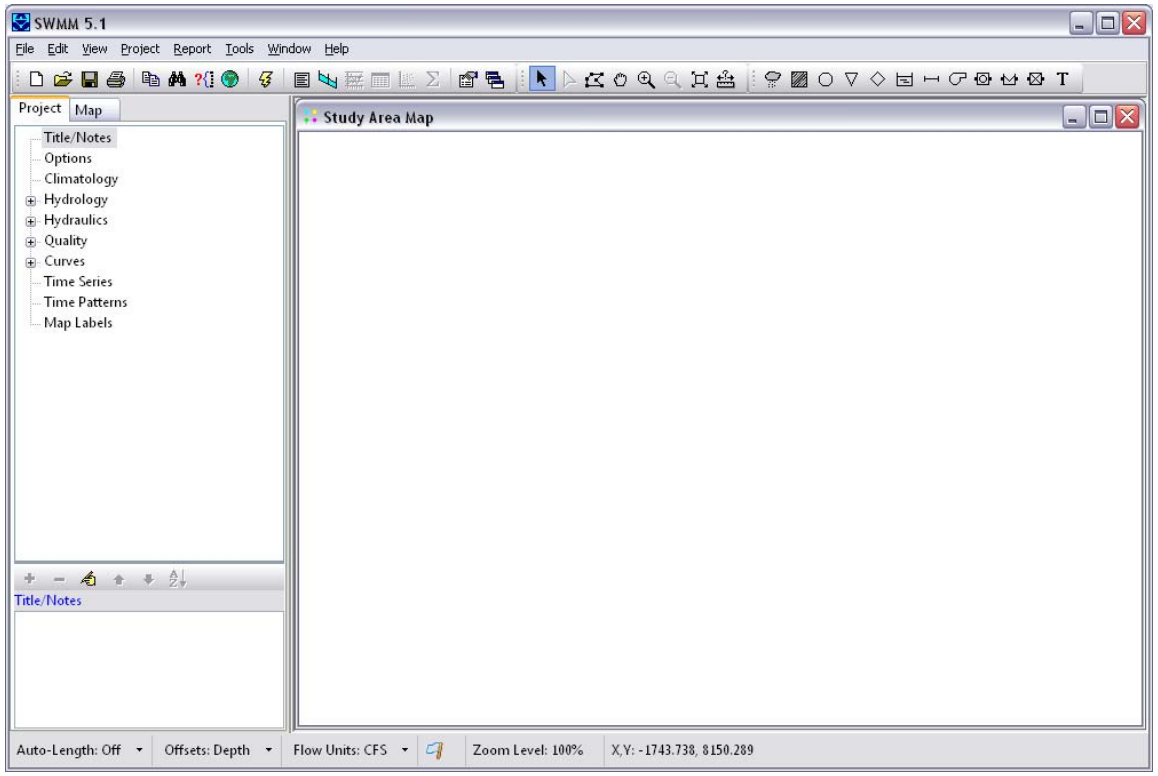
PRE-PROJECT MODEL SETUP

Example Project Site



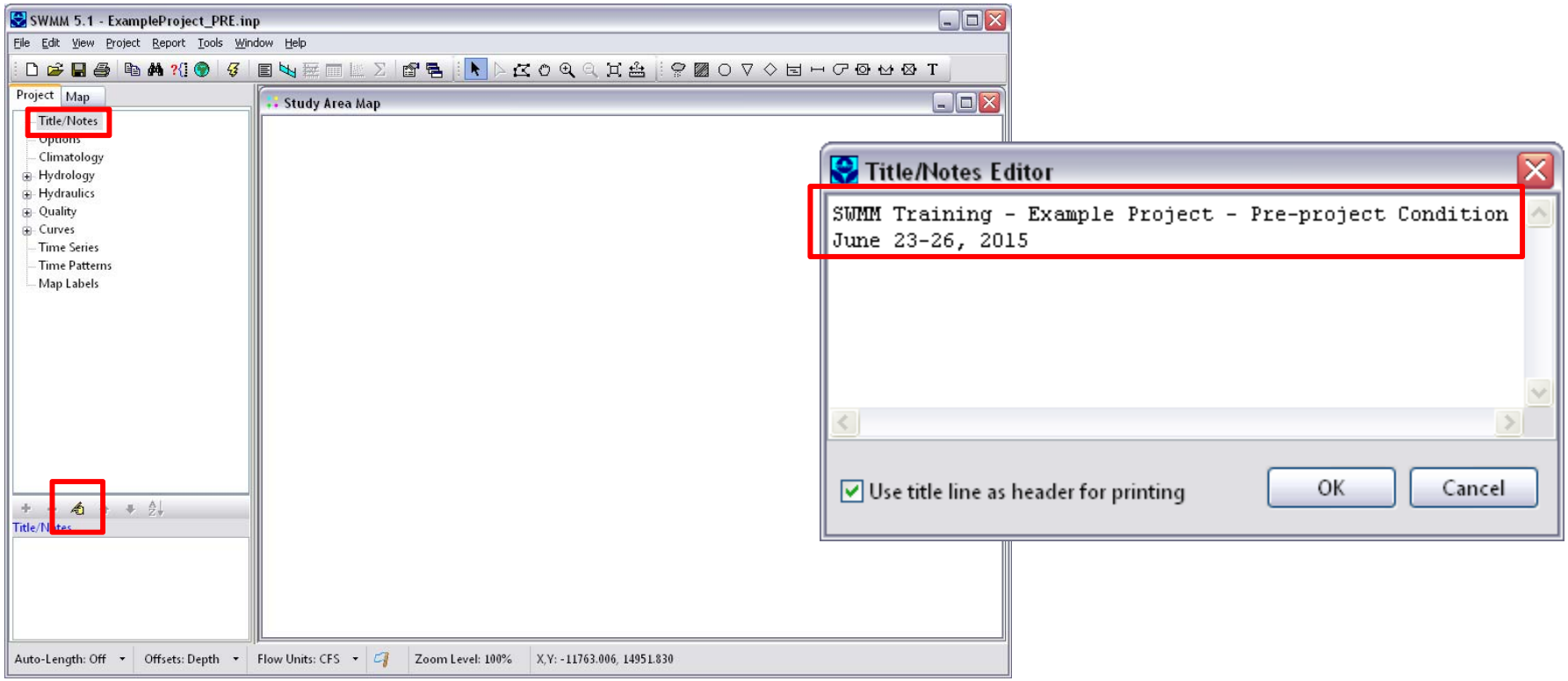
New File

- Open a new SWMM file
- File - > Save As -> “ExampleProject_PRE.inp” in the folder “…\MyModel\”
  - Note: The “.inp” file path corresponds to the model’s **input** file.



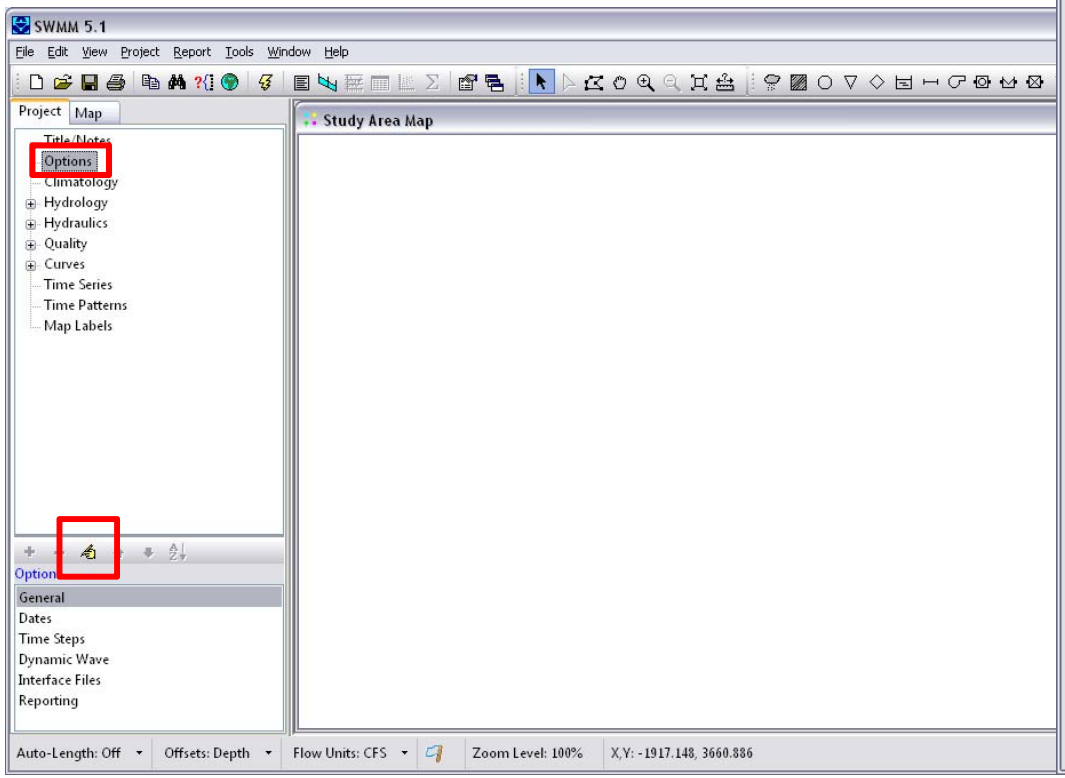
Title/Notes Editor

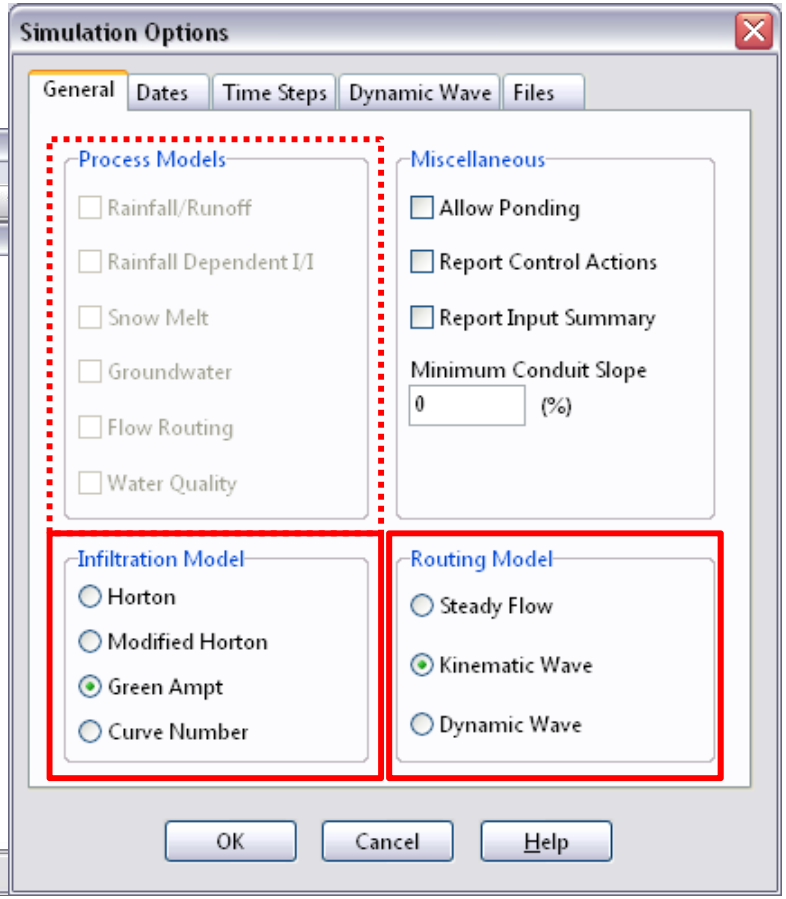
- Select “Title/Notes” in the Data Browser Panel
- Click on the edit button to open the “Title/Notes Editor”
- Insert text to identify the project name, modeled condition, etc.



Simulation Options

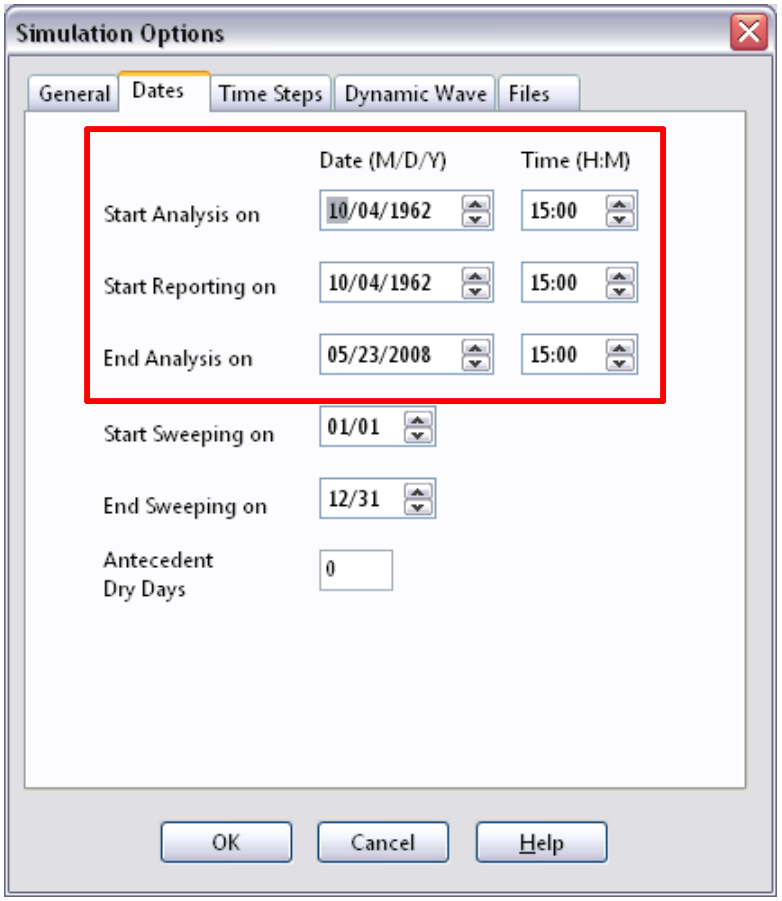
- Select “Options” in the Data Browser Panel
- Click on the edit button to open the “Simulation Options” window
- Select Green Ampt
- Select Kinematic Wave

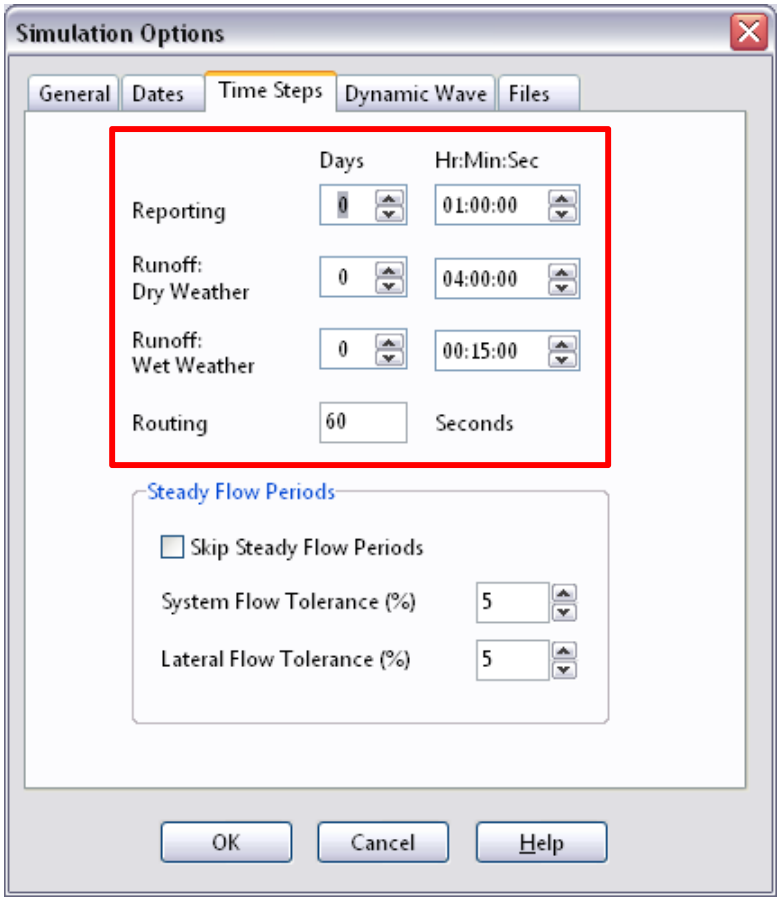




Simulation Options (Cont.)

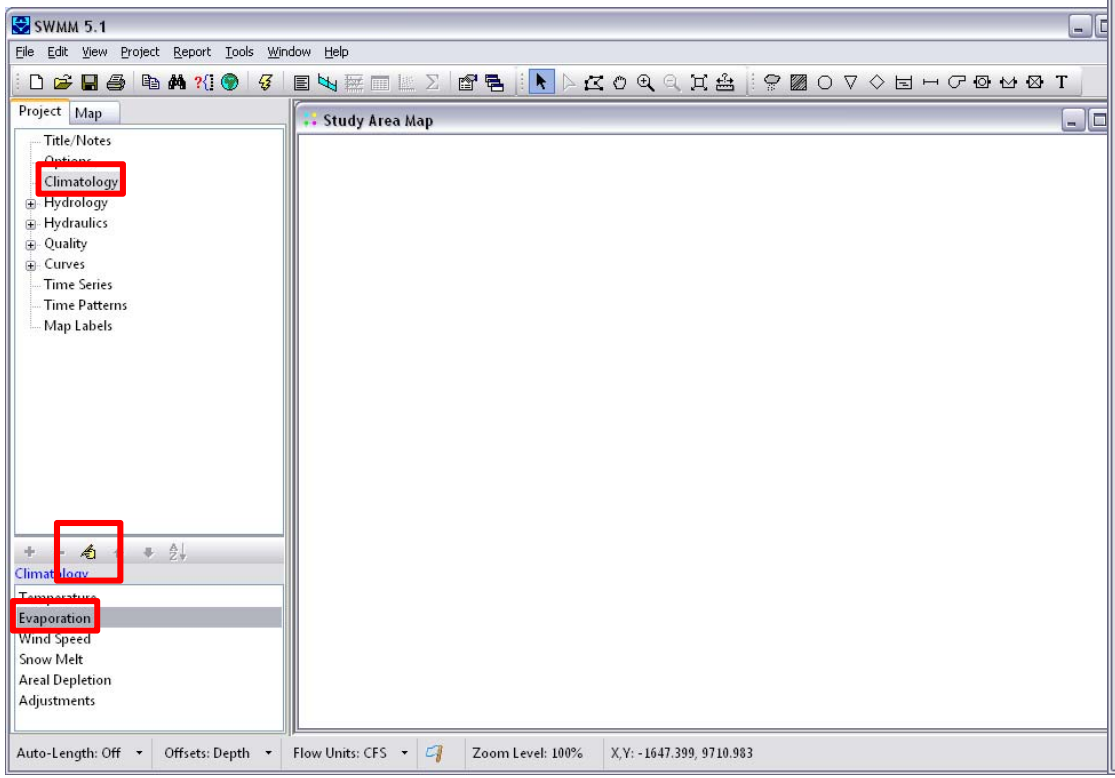
- In the “Dates” tab, insert the “start” and “end” analysis dates based on the available time-series.
  - Note: The dates shown below are only applicable to the Poway gage.
- In the “Time Steps” tab, insert the analysis and routing time steps below.

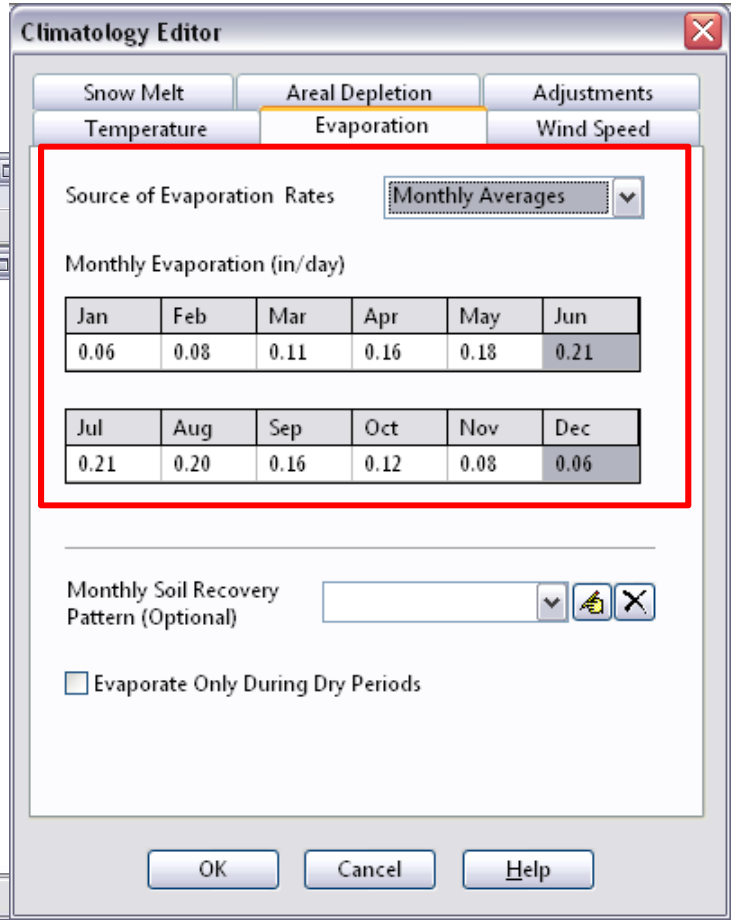




Climatology: Evaporation

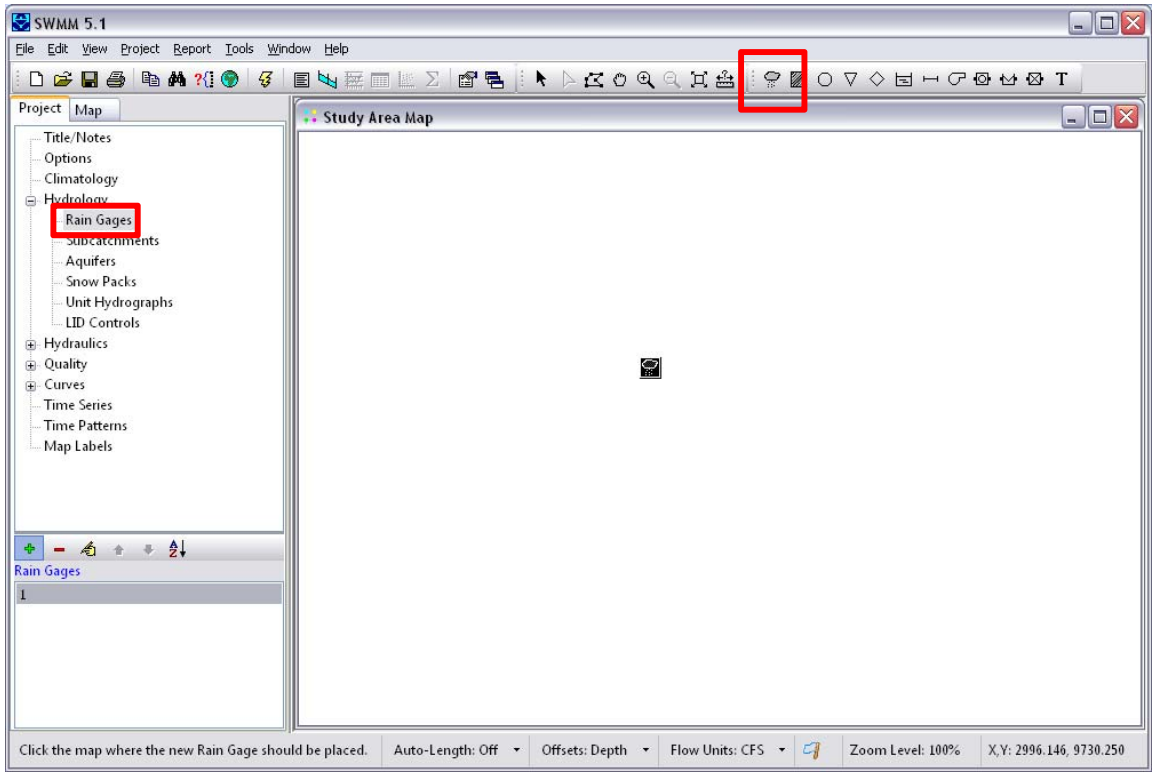
- Select “Climatology” and “Evaporation” in the Data Browser Panel
- Click on the edit button to open the “Climatology Editor”
- Under “Source of Evaporation Rates,” select “Monthly Averages”
- Input the CIMIS Reference Evapotranspiration (ETo) rates in inches/day.
- Note: This example shows CIMIS Zone 6 rates.





Add Rain Gage

- Click the “Add a Rain Gage” icon, then insert a rain gage on the “Study Area Map”
  - Note: The X- and Y-Coordinates do not need to match.
- Click the selector arrow, then double-click on the icon to edit the properties
- Next, double-click on the “ * ” under TIME SERIES: “Series Name” to open the “Time Series Editor”



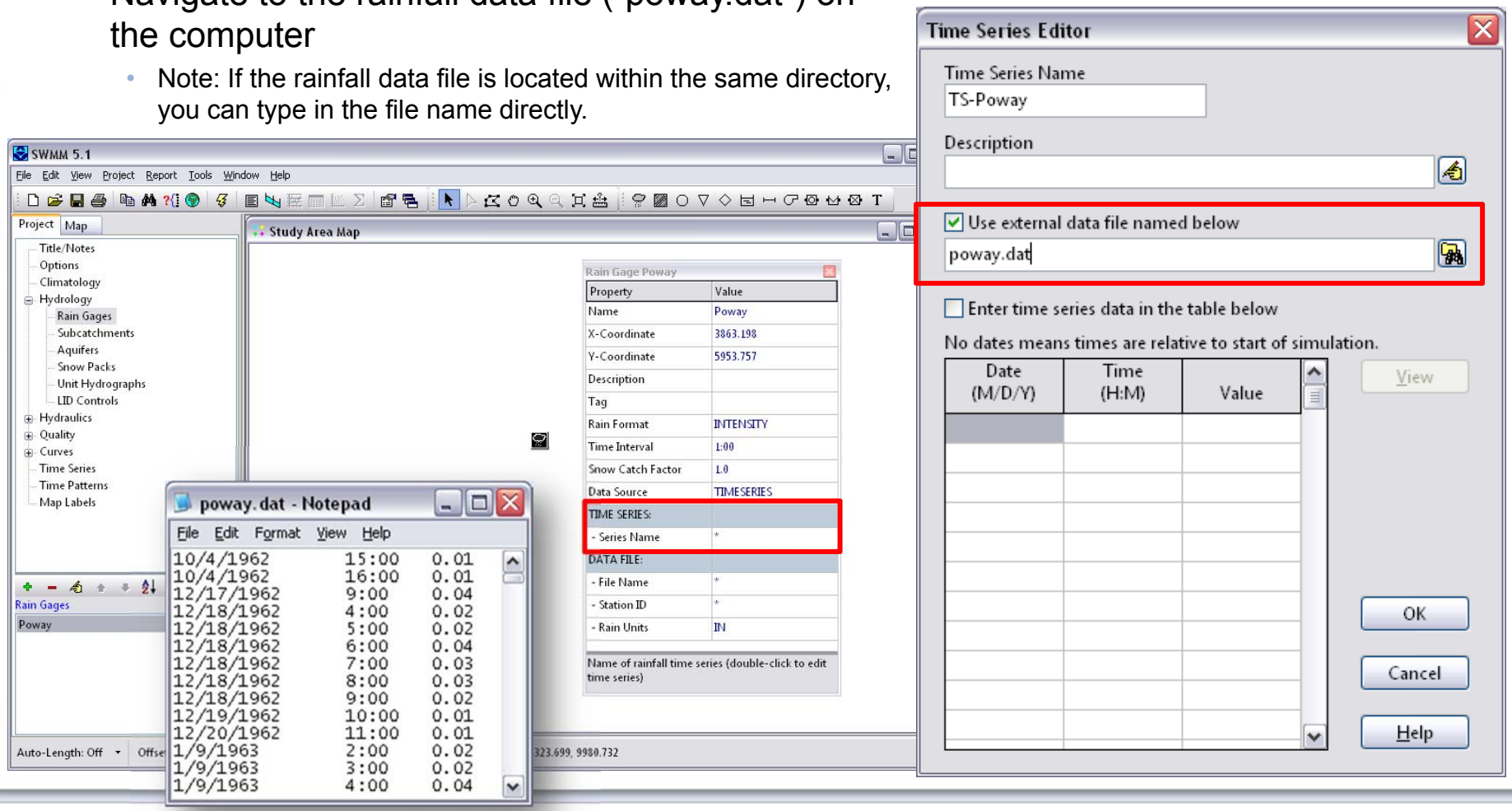
Rain Gage Poway

Property	Value
Name	Poway
X-Coordinate	3863.198
Y-Coordinate	5953.757
Description	
Tag	
Rain Format	INTENSITY
Time Interval	1:00
Snow Catch Factor	1.0
Data Source	TIMESERIES
TIME SERIES:	
- Series Name	*
DATA FILE:	
- File Name	*
- Station ID	*
- Rain Units	IN

User-assigned name of rain gage

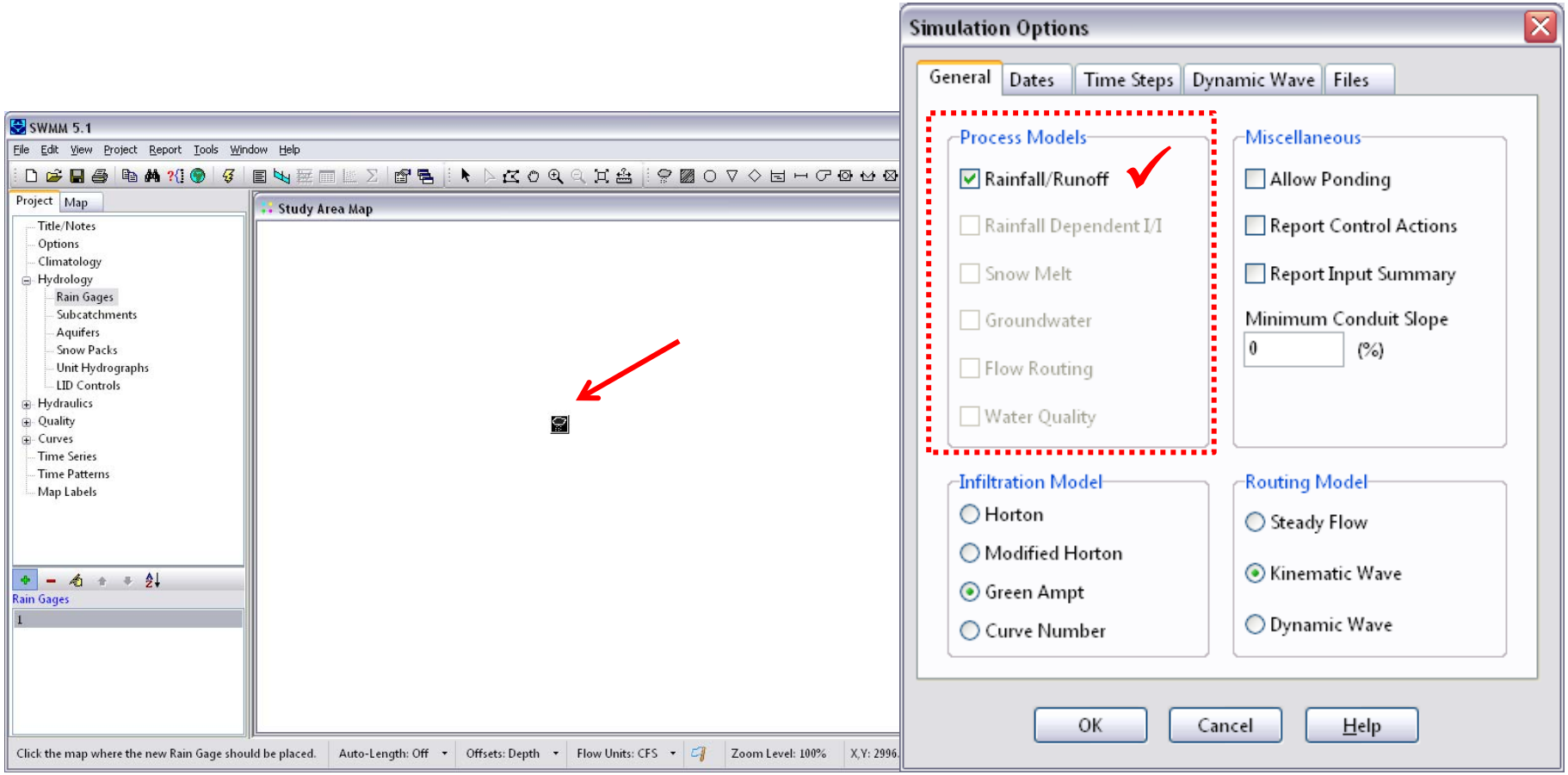
Add Time Series

- Insert a “Time Series Name”
- Select “Use external data file…”
- Navigate to the rainfall data file (“poway.dat”) on the computer
  - Note: If the rainfall data file is located within the same directory, you can type in the file name directly.



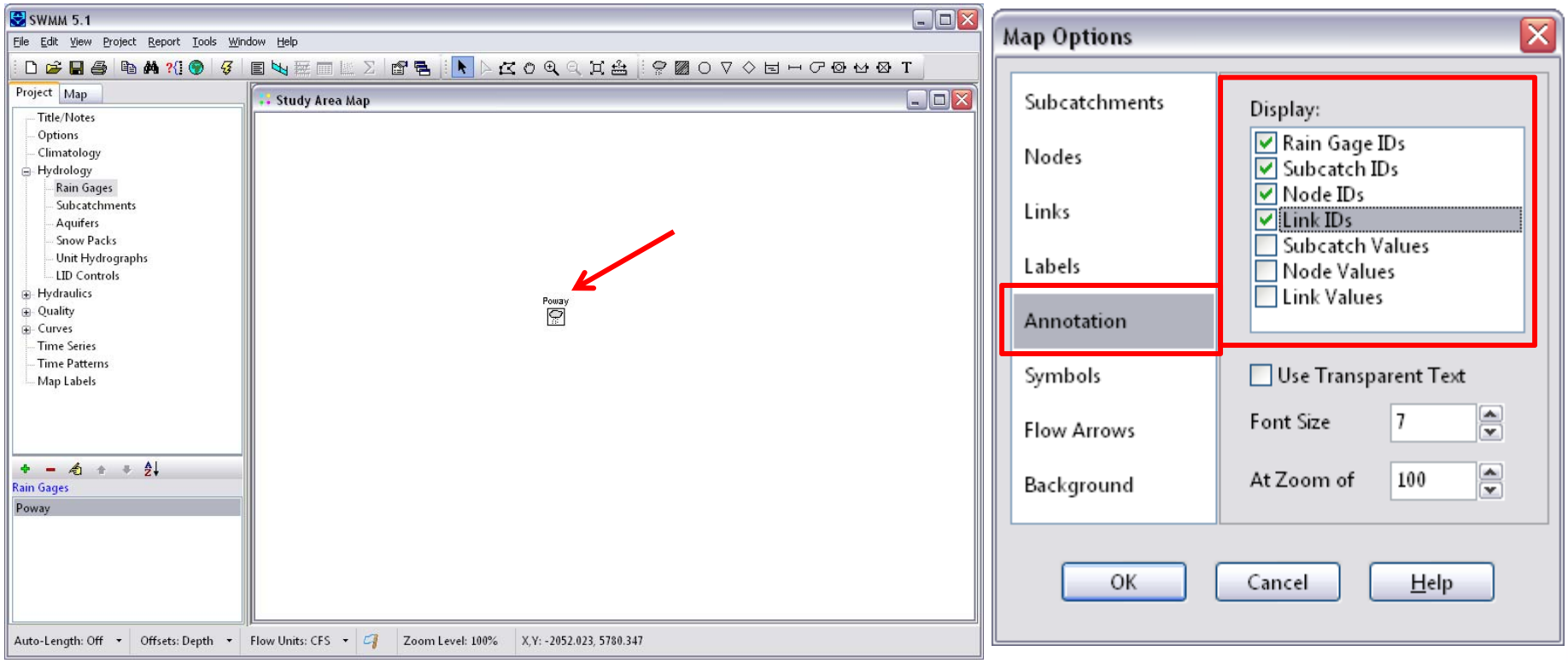
Check Process Models

- Let's check the "Process Model"
- After adding a Rain Gage, the "Rainfall/Runoff" Process is now checked.



Map Options: Annotation

- Right-click on Study Area Map and select “Options…”
- Select Annotation
- Check boxes as shown below to display object IDs for Rain Gage, Subcatchment, Node, and Link objects.



Project Defaults

- Before adding objects to the model, define the object naming convention ("ID Labels") and default parameter values for subcatchments/nodes/links.
  - Note: The example Green-Ampt infiltration soil parameters shown are for Type D soils.

Project Defaults

ID Labels | Subcatchments | Nodes/Links

Object	ID Prefix
Rain Gages	
Subcatchments	DMA
Junctions	J
Outfalls	POC
Dividers	DIV
Storage Units	STOR
Conduits	
Pumps	
Regulators	
ID Increment	1

☐ Save as defaults for all new projects

OK | Cancel | Help

Project Defaults

ID Labels | Subcatchments | Nodes/Links

Property	Default Value
Area	99
Width	99
% Slope	99
% Imperv	99
N-Imperv	0.012
N-Perv	0.15
Dstore-Imperv	0.05
Dstore-Perv	0.1
%Zero-Imperv	25
Infiltration Model	GREEN_AMPT

☐ Save as defaults for all new projects

OK | Cancel | Help

Infiltration Editor

Infiltration Method: GREEN_AMPT

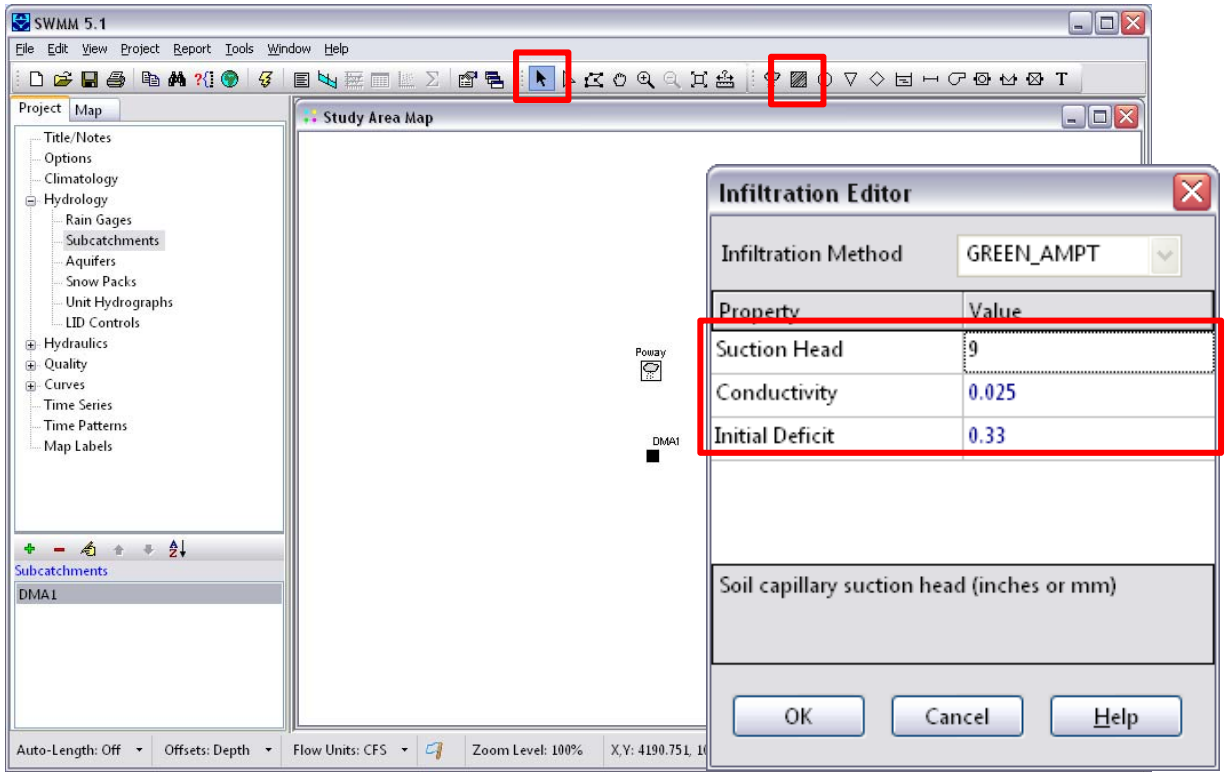
Property	Value
Suction Head	9
Conductivity	0.025
Initial Deficit	0.33

Soil capillary suction head (inches or mm)

OK | Cancel | Help

Add Subcatchment

- Click the “Add a Subcatchment” icon, then insert the object on the “Study Area Map”
  - Note: The Subcatchment ID is automatically named “DMA1” based on the project defaults previously defined.
- Click the selector arrow, then double-click on the Subcatchment icon to edit the properties
  - Note: Average Width (of Sheet Flow) = Area ÷ Average Maximum Overland Flow Length



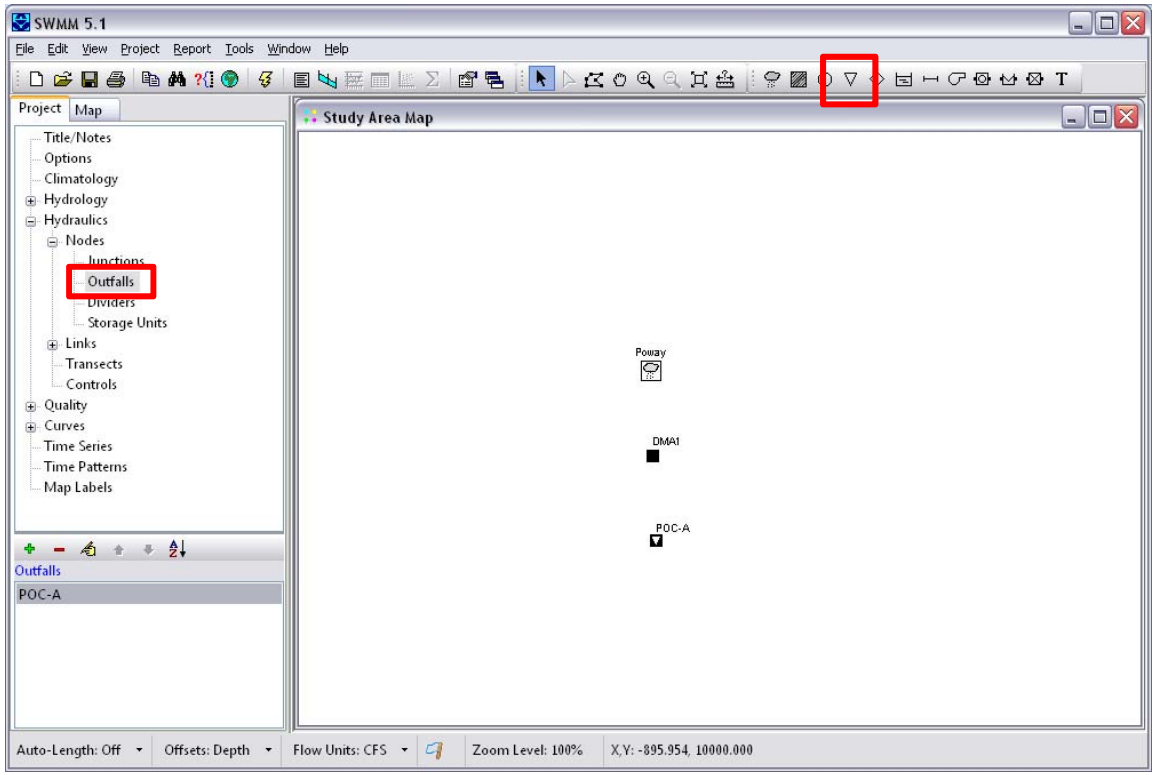
Subcatchment DMA-A

Property	Value
Name	DMA-A
X-Coordinate	3000.000
Y-Coordinate	7000.000
Description	
Tag	
Rain Gage	Poway
Outlet	POC-A
Area	1.33
Width	245
% Slope	3
% Imperv	0
N-Imperv	0.012
N-Perv	0.05
Dstore-Imperv	0.05
Dstore-Perv	0.1
%Zero-Imperv	25
Subarea Routing	OUTLET
Percent Routed	100
Infiltration	GREEN_AMPT ...
Groundwater	NO
Snow Pack	
LID Controls	0
Land Uses	0
Initial Buildup	NONE
Curb Length	0

Infiltration parameters (click to edit)

Add Outfall

- In the Subcatchment Properties, click "…" to open the "Infiltration Editor"
- Select the "Add an outfall node" icon, then insert the object on the "Study Area Map"
- The Outfall object is the HMP Point of Compliance (POC).



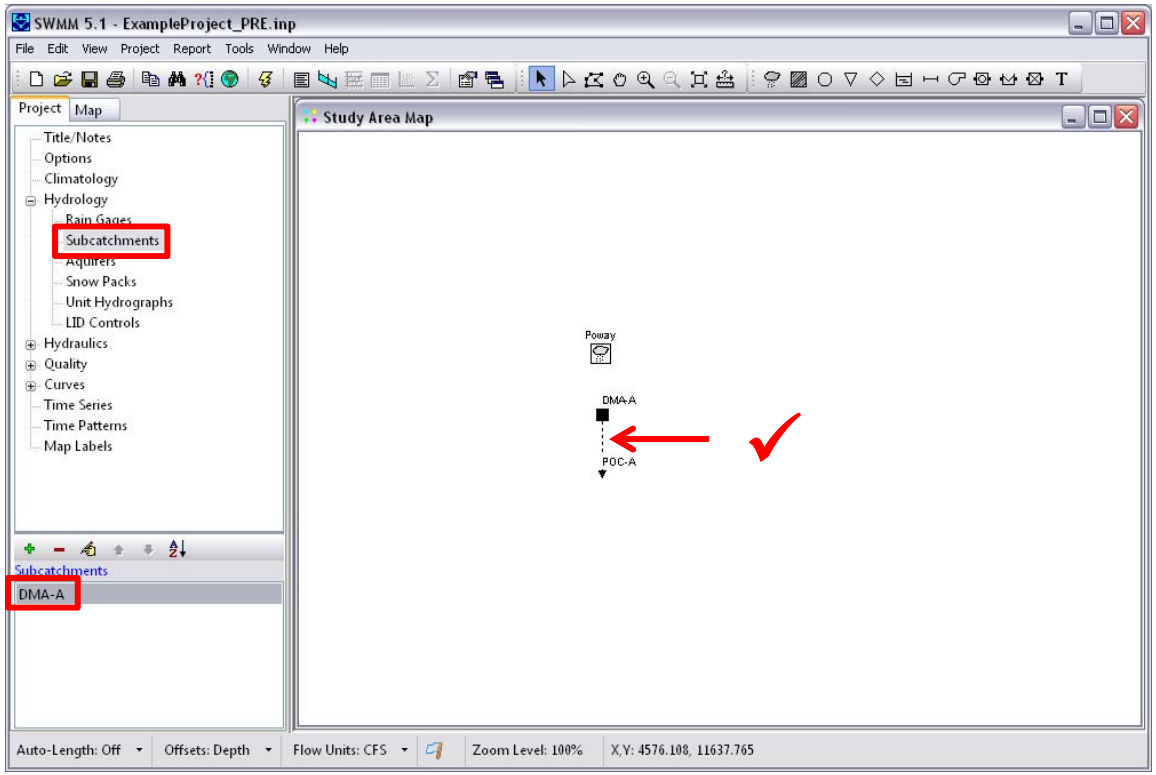
Outfall POC-A

Property	Value
Name	POC-A
X-Coordinate	3921.002
Y-Coordinate	3121.387
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 Outfall	
Series Name	*

User-assigned name of outfall

Connect Subcatchment to Outfall

- Open the Subcatchment Properties for “DMA-A” and insert the outlet name “POC-A”



Subcatchment DMA-A

Property	Value
Name	DMA-A
X-Coordinate	3000.000
Y-Coordinate	7000.000
Description	
Tag	
Rain Gage	Poway
Outlet	POC-A
Area	1.33
Width	245
% Slope	3
% Imperv	0
N-Imperv	0.012
N-Perv	0.05
Dstore-Imperv	0.05
Dstore-Perv	0.1
%Zero-Imperv	25
Subarea Routing	OUTLET
Percent Routed	100
Infiltration	GREEN_AMPT ...
Groundwater	NO
Snow Pack	
LID Controls	0
Land Uses	0
Initial Buildup	NONE
Curb Length	0

Infiltration parameters (click to edit)

Model Complete!

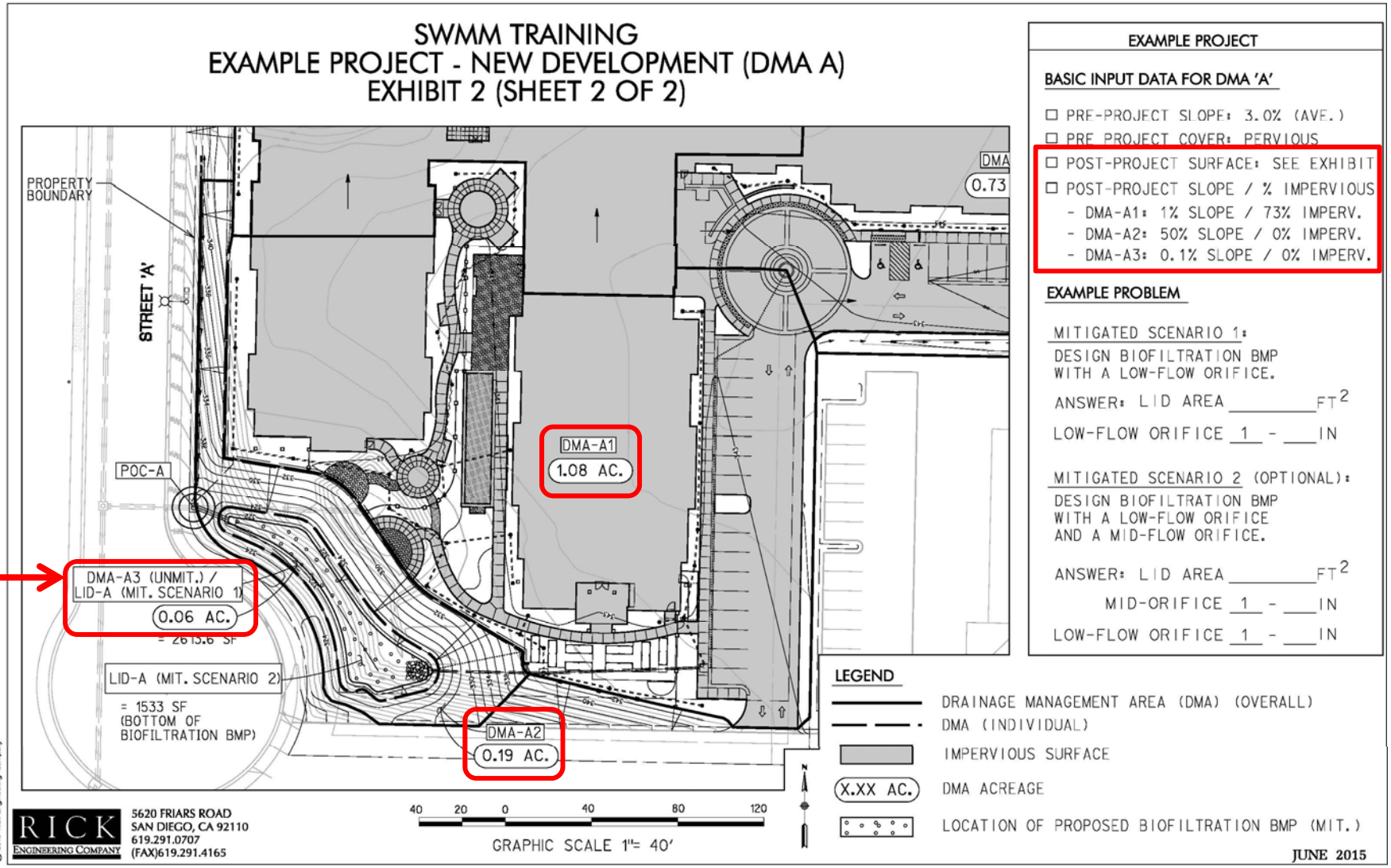
The *Pre-project Condition* model
is now complete!

Next, let's set-up a **Post-project (Unmitigated) Condition** model
to quantify the hydrologic impacts
of the proposed development.

Example Project – Institutional Living

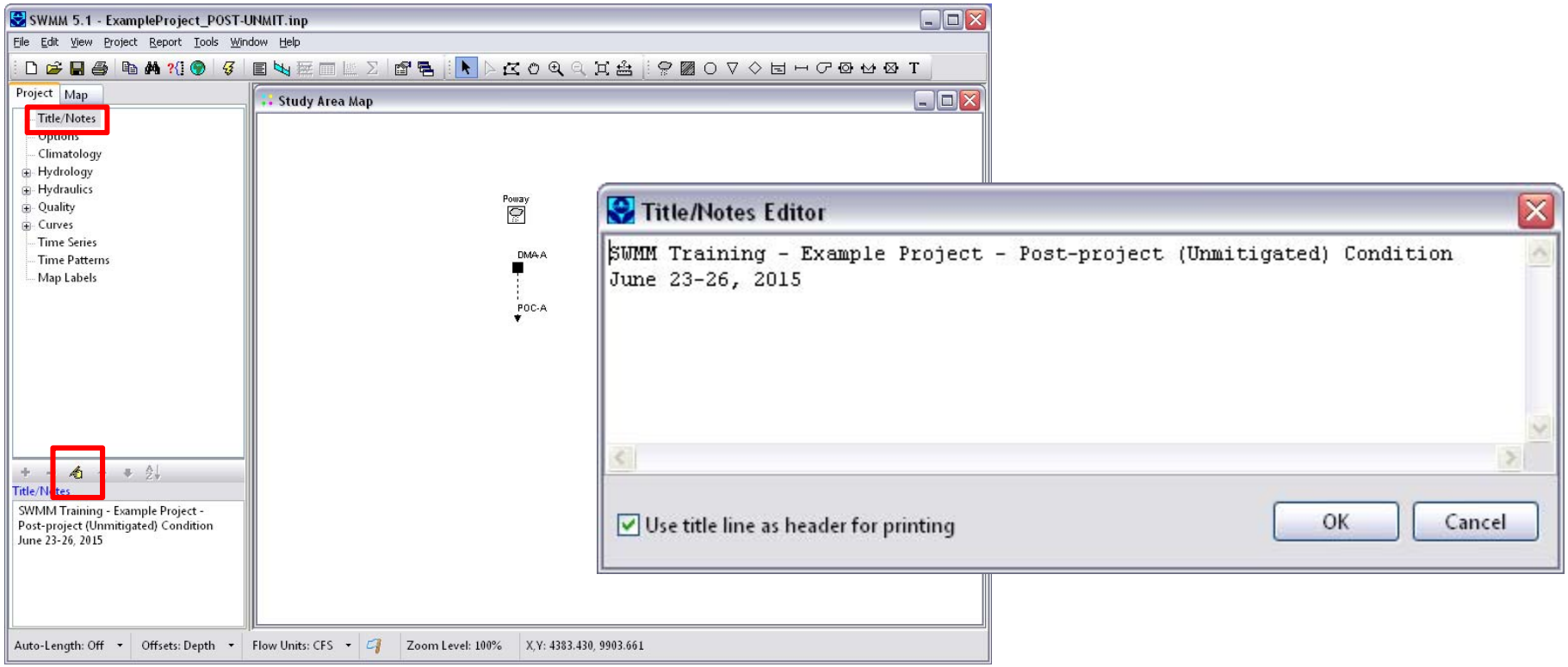
POST-PROJECT (UNMITIGATED) MODEL SETUP

Drainage Management Area "A"



New File

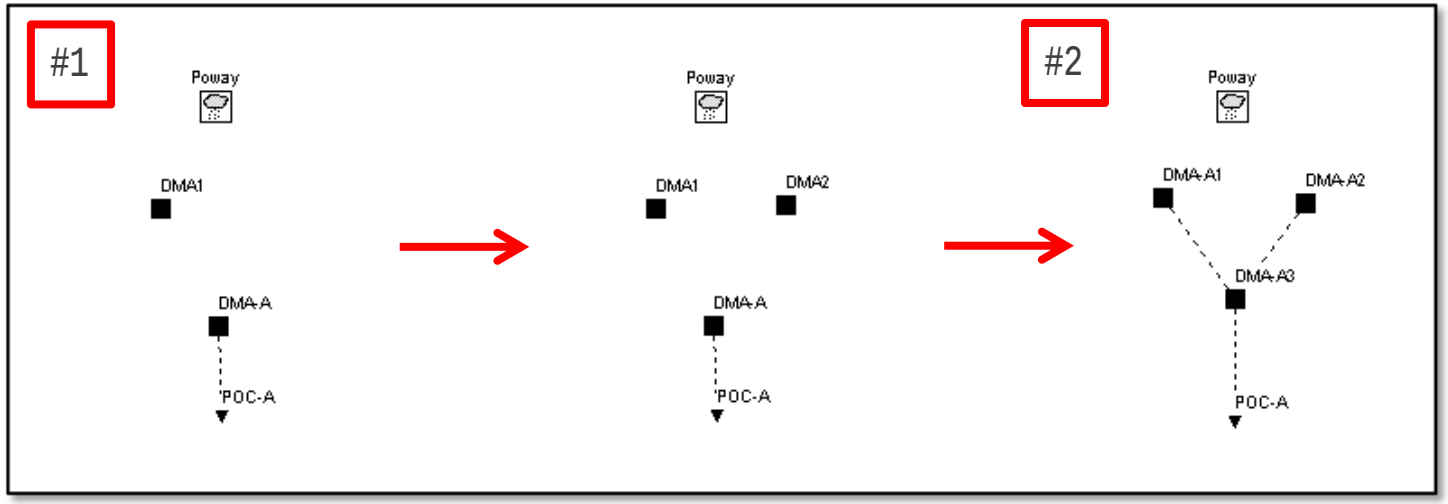
- Open “ExampleProject_Pre.inp”
- Save As “ExampleProject_Post-Unmit.inp” in the folder “…\MyModel\” to create the Post-project (Unmitigated) model.
- Update the “Title/Notes Editor” as shown below.



Subcatchments

- Under the post-project condition, we will split the Drainage Basin A area into three (3) subcatchments
  - "DMA-A1" – the building roof, courtyard, and parking lot
  - "DMA-A2" – the 2:1 graded slope
  - "DMA-A3" – a mostly flat swale area (future location of Biofiltration Basin)

- First, let's add two (2) subcatchment objects to the Study Area Map.
- Second, let's double-click on each subcatchment object to edit its properties



Edit Subcatchment Properties

Subcatchment DMA-A1

Property	Value
Name	DMA-A1
X-Coordinate	2000.000
Y-Coordinate	7000.000
Description	
Tag	
Rain Gage	Poway
Outlet	DMA-A3
Area	1.08
Width	230
% Slope	1
% Imperv	73
N-Imperv	0.012
N-Perv	0.15
Dstore-Imperv	0.05
Dstore-Perv	0.1
%Zero-Imperv	25
Subarea Routing	OUTLET
Percent Routed	100
Infiltration	GREEN_AMPT
Groundwater	NO
Snow Pack	
LID Controls	0
Land Uses	0
Initial Buildup	NONE
Curb Length	0

User-assigned name of subcatchment

Subcatchment DMA-A2

Property	Value
Name	DMA-A2
X-Coordinate	3747.592
Y-Coordinate	6994.220
Description	
Tag	
Rain Gage	Poway
Outlet	DMA-A3
Area	0.19
Width	185
% Slope	50
% Imperv	0
N-Imperv	0.012
N-Perv	0.15
Dstore-Imperv	0.05
Dstore-Perv	0.1
%Zero-Imperv	25
Subarea Routing	OUTLET
Percent Routed	100
Infiltration	GREEN_AMPT
Groundwater	NO
Snow Pack	
LID Controls	0
Land Uses	0
Initial Buildup	NONE
Curb Length	0

User-assigned name of subcatchment

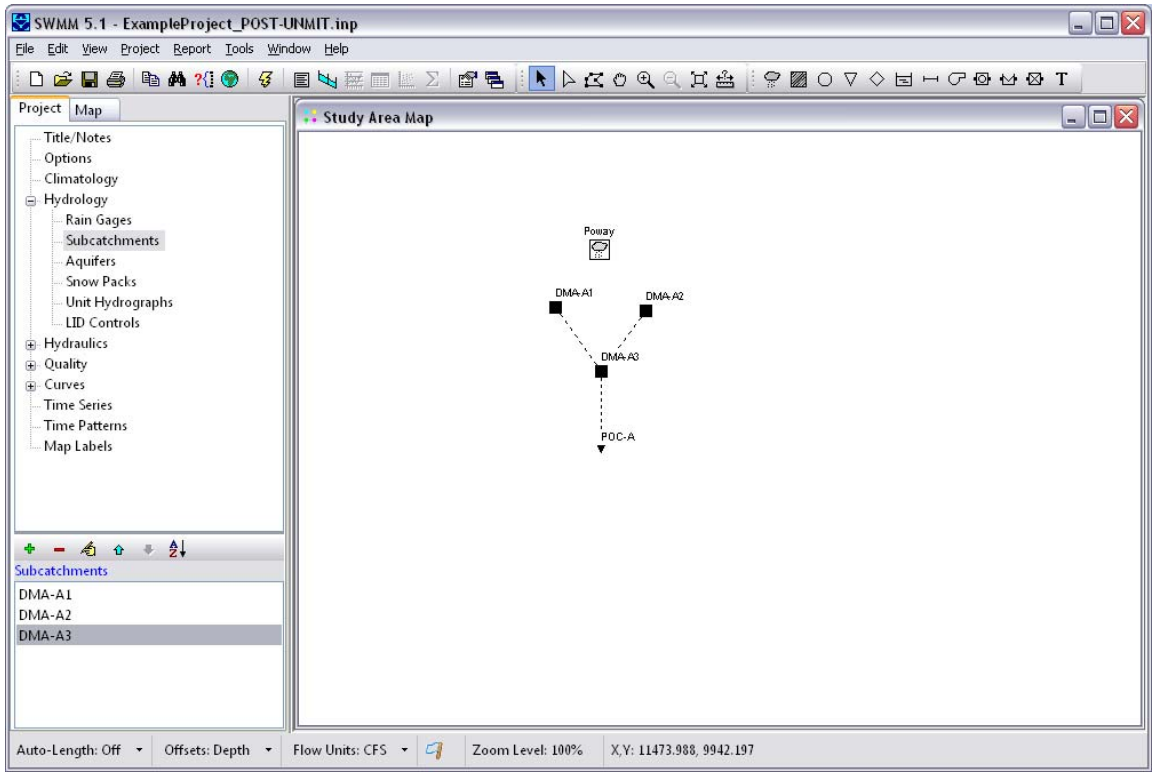
Subcatchment DMA-A3

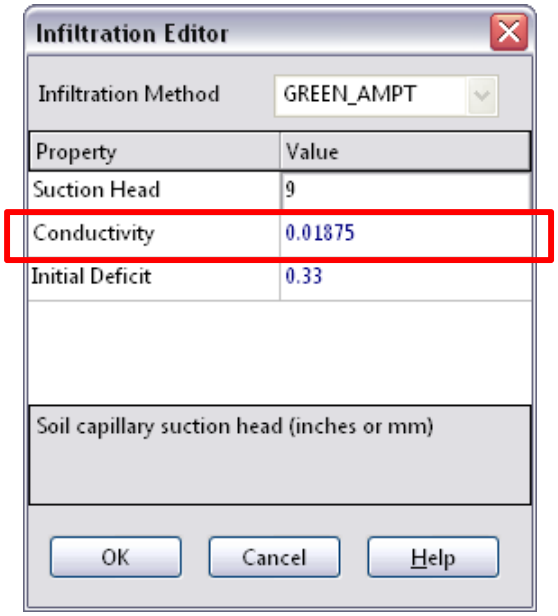
Property	Value
Name	DMA-A3
X-Coordinate	2996.146
Y-Coordinate	5973.025
Description	
Tag	
Rain Gage	Poway
Outlet	POC-A
Area	0.06
Width	25
% Slope	0.1
% Imperv	0
N-Imperv	0.012
N-Perv	0.15
Dstore-Imperv	0.05
Dstore-Perv	0.1
%Zero-Imperv	25
Subarea Routing	OUTLET
Percent Routed	100
Infiltration	GREEN_AMPT
Groundwater	NO
Snow Pack	
LID Controls	0
Land Uses	0
Initial Buildup	NONE
Curb Length	0

User-assigned name of subcatchment

Infiltration Editor

- To account for the compacted condition of the soil, a 25% reduction factor is applied to the “Conductivity” variable for all three (3) subcatchments.
  - Note: The infiltration parameters shown here are for Type D soils.





Model Complete!

The *Post-project (Unmitigated) Condition* model is now complete!

Next, let's run the **post-processing analysis** to quantify the hydrologic impacts of the proposed development.

Example Project – Institutional Living

POST-PROCESSING
PRE- AND POST-PROJECT UNMITIGATED

HMP Flow Control Performance Standard

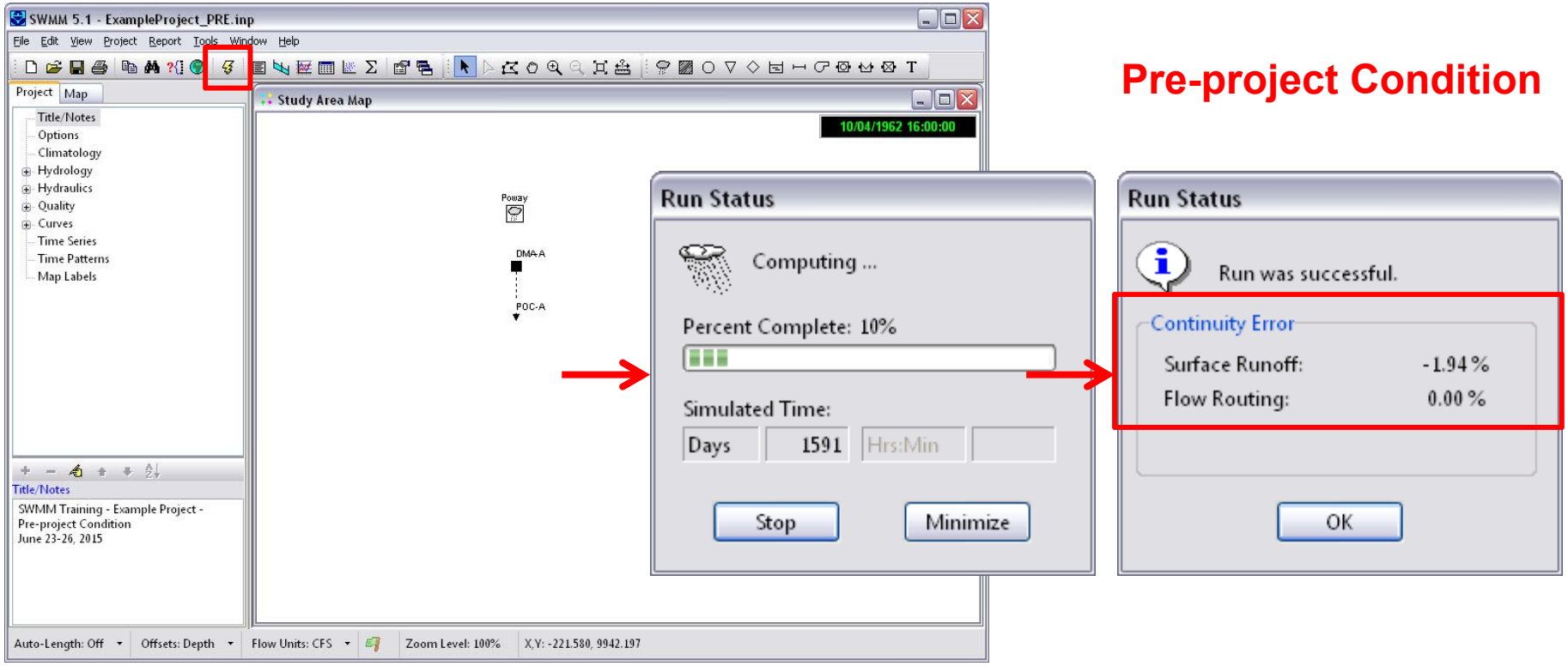
- The following are the ***peak flow*** and ***duration*** control requirements per the DRAFT Model BMP Design Manual, dated January 2015.

Chapter 6: Hydromodification Management Requirements for Priority Development Projects

1. For flow rates ranging from 10 percent, 30 percent or 50 percent of the pre-development 2-year runoff event ($0.1Q_2$, $0.3Q_2$, or $0.5Q_2$) to the pre-development 10-year runoff event (Q_{10}), the post-project discharge rates and durations shall not deviate above the pre-development rates and durations by more than 10 percent over and more than 10 percent of the length of the flow duration curve. The specific lower flow threshold will depend on the erosion susceptibility of the receiving stream for the project site (see Section 6.3.4).
2. For flow rates ranging from the lower flow threshold to Q_5, the post-project peak flows shall not exceed pre-development peak flows. For flow rates from Q_5 to Q_{10}, post-project peak flows may exceed pre-development flows by up to 10 percent for a 1-year frequency interval. For example, post-project flows could exceed pre-development flows by up to 10 percent for the interval from Q_9 to Q_{10} or from $Q_{5.5}$ to $Q_{6.5}$, but not from Q_8 to Q_{10}.

Run Simulation

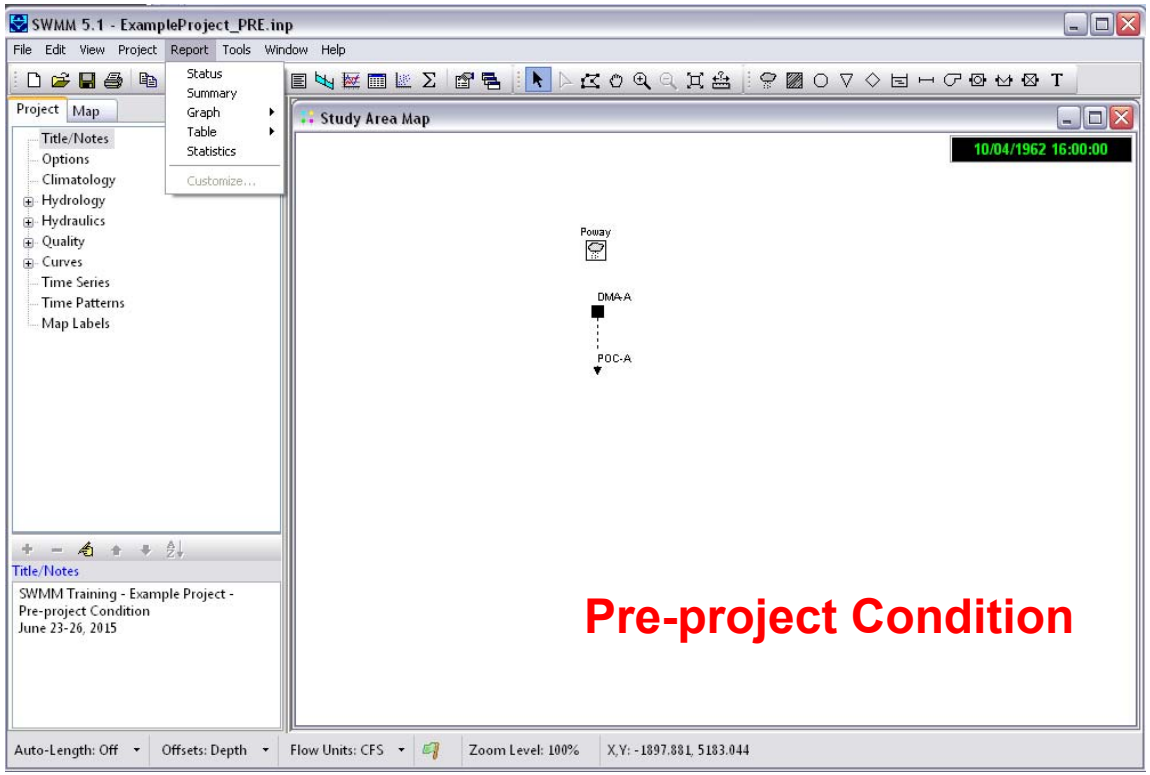
- To define the baseline flow rates for our analysis, let's run the simulations for both Pre-project and Post-project (Unmitigated) Conditions.
- Open the "ExampleProject_PRE.inp" file
- Click the "Run a simulation" icon

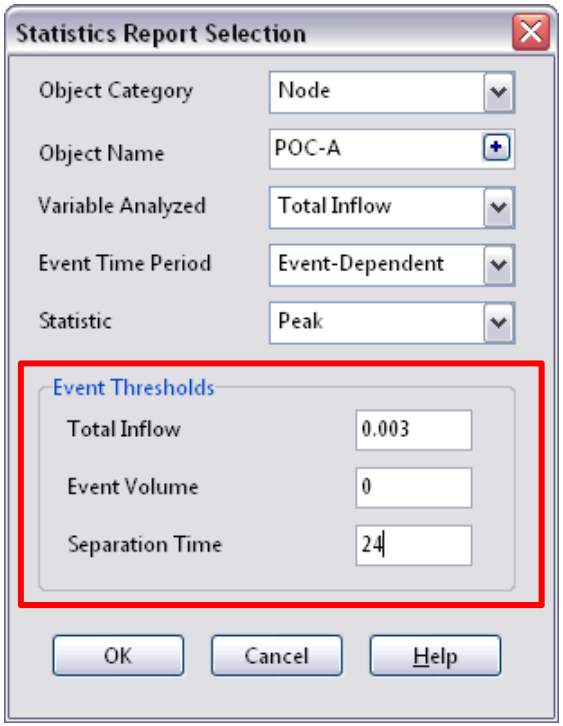


Pre-project Condition

Flow Frequency Statistics

- First, let's determine the Pre-project Condition $0.1xQ_2$ flow rate by generating the flow frequency statistics at the POC location.
- Report -> Statistics -> "Statistics Report Selection"
- Input the selections shown below.
  - Note: The "Total Inflow" Event Threshold is defined as 0.002 cfs/acre x Total Drainage Area





Statistics

Statistics - Node POC-A Total Inflow

Summary | Events | Histogram | Frequency Plot

```
S U M M A R Y   S T A T I S T I C S
===================================
Object ............... Node POC-A
Variable ............. Total Inflow  (CFS)
Event Period ......... Variable
Event Statistic ...... Peak  (CFS)
Event Threshold ...... Total Inflow > 0.0030  (CFS)
Event Threshold ...... Event Volume > 0.0000 (ft3)
Event Threshold ...... Separation Time >= 24.0  (hr)
Period of Record ..... 10/04/1962 to 05/23/2008

Number of Events ..... 292
Event Frequency*...... 0.007
Minimum Value ........ 0.003
Maximum Value ........ 1.019
Mean Value ........... 0.248
Std. Deviation ....... 0.198
Skewness Coeff. ...... 1.356

*Fraction of all reporting periods belonging to an eve
```

- SWMM's built-in statistics are based on the Weibull Plotting Position

Statistics - Node POC-A Total Inflow

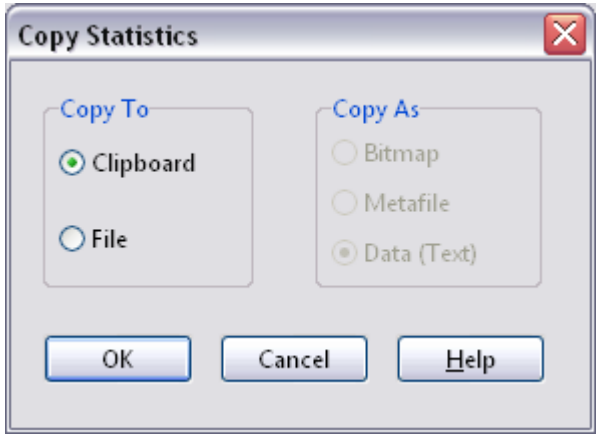
Summary | Events | Histogram | Frequency Plot

Rank	Start Date	Event Duration (hours)	Event Peak (CFS)	Exceedance Frequency (percent)	Return Period (years)
1	03/24/1983	11.0	1.019	0.34	47.00
2	02/18/1980	77.0	1.014	0.68	23.50
3	01/25/1995	11.0	0.908	1.02	15.67
4	01/09/1978	29.0	0.883	1.37	11.75
5	03/17/1982	21.0	0.883	1.71	9.40
6	12/28/2004	19.0	0.839	2.05	7.83
7	11/05/1987	2.0	0.804	2.39	6.71
8	02/08/1998	16.0	0.752	2.73	5.88
9	12/28/1978	37.0	0.735	3.07	5.22
10	11/29/1982	22.0	0.733	3.41	4.70
11	02/03/1998	7.0	0.727	3.75	4.27
12	12/18/1978	3.0	0.710	4.10	3.92
13	11/12/1976	2.0	0.693	4.44	3.62

Pre-project Condition

Copy Statistics

- On the Statistics tab, click the top left corner of the table to highlight the entire table.
- Edit - > Copy to… -> “Copy Statistics”



External Post-processing Spreadsheet

- Open “SWMM_PostProcessing.xlsx”
- Click on the “Pre-Q” tab and paste Pre-project Condition statistics in the highlighted cell
- Make adjustments to “Column I” as necessary to determine the Q_2, Q_5, and Q_{10} values.

Pre-project

10-year Q:	0.883	cfs
5-year Q:	0.734	cfs
2-year Q:	0.570	cfs

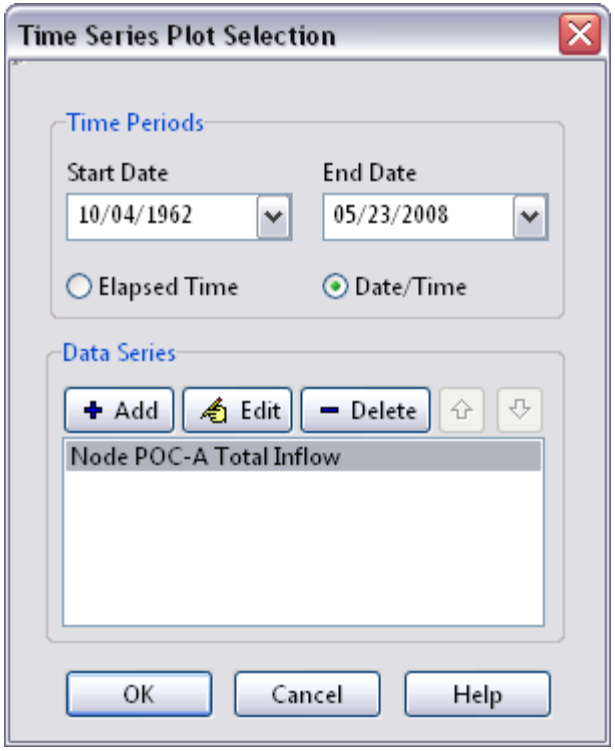
Lower Flow Threshold:	10%
0.1xQ2 (Pre):	0.057 cfs

	A	B	C	D	E	F
1						
2	**Pre-project Flow Frequency - Long-term Simulation**					
3						
4	SWMM Training - Example Project - Pre-project Condition					
5	Statistics - Node POC-A Total Inflow					
6			Event	Event	Exceedance	Return
7			Duration	Peak	Frequency	Period
8	Rank	Start Date	(hours)	(CFS)	(percent)	(years)
9	1	3/24/1983	11	1.019	0.34	47
10	2	2/18/1980	77	1.014	0.68	23.5
11	3	1/25/1995	11	0.908	1.02	15.67
12	4	1/9/1978	29	0.883	1.37	11.75
13	5	3/17/1982	21	0.883	1.71	9.4
14	6	12/28/2004	19	0.839	2.05	7.83
15	7	11/5/1987	2	0.804	2.39	6.71
16	8	2/8/1998	16	0.752	2.73	5.88
17	9	12/28/1978	37	0.735	3.07	5.22
18	10	11/29/1982	22	0.733	3.41	4.7
19	11	2/3/1998	7	0.727	3.75	4.27
20	12	12/18/1978	3	0.71	4.1	3.92
21	13	11/12/1976	2	0.693	4.44	3.62
22	14	2/28/1970	3	0.691	4.78	3.36
23	15	2/14/1998	5	0.652	5.12	3.13
24	16	1/6/1974	33	0.631	5.46	2.94
25	17	3/1/1983	42	0.623	5.8	2.76
26	18	2/8/1983	5	0.617	6.14	2.61
27	19	1/5/1979	21	0.605	6.48	2.47
28	20	1/28/1980	45	0.594	6.83	2.35
29	21	12/9/1965	29	0.587	7.17	2.24
30	22	1/9/2005	22	0.585	7.51	2.14
31	23	3/17/1983	29	0.571	7.85	2.04
32	24	11/16/1972	22	0.568	8.19	1.96
33	25	2/27/2001	10	0.55	8.53	1.88

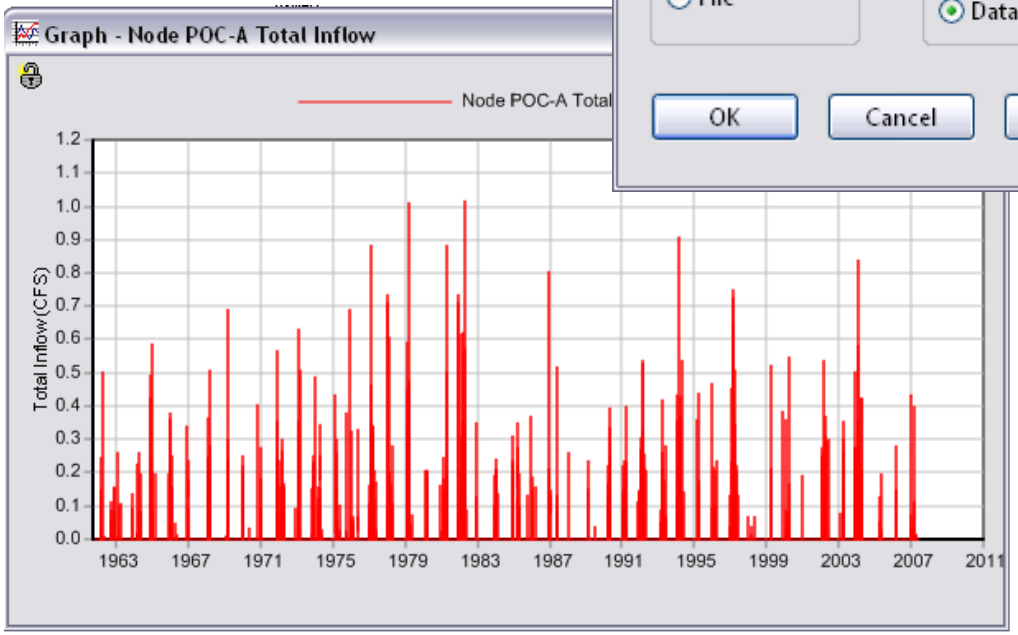
Disclaimer | Pre-Q | Post-Q | PostMit-Q | FF_Summary | FFC

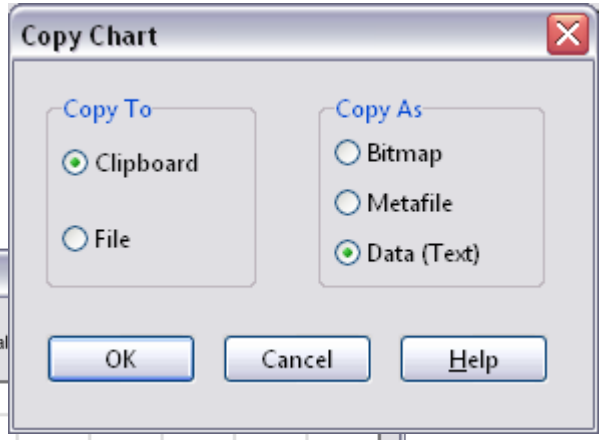
Copy Time-series

- Next, let's extract the runoff hydrograph time-series to calculate the flow durations.
- Report - > Graph - > Time Series - > "Time Series Plot Selection"
- Edit - > Copy to… - > "Copy Chart"

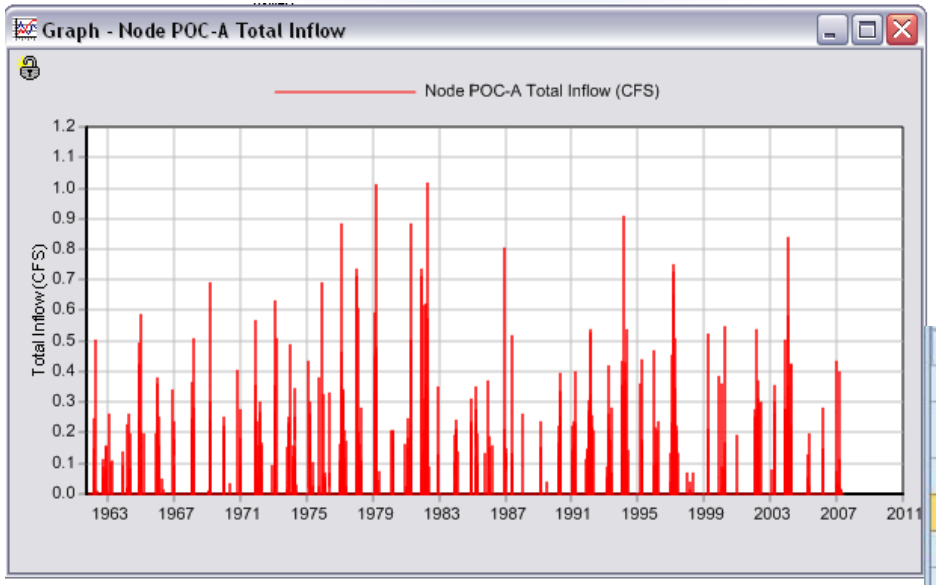


Pre-project Condition





External Post-processing Spreadsheet



Pre-project Condition

- Click on the "Pre-TS" tab and paste Pre-project Condition runoff hydrograph (time-series) in the highlighted cell

	A	B	C	D	E	F
1						
2	Pre-project Time Series - Long-term Simulation					
3						
4	Node POC-A Tota	Inflow (CFS)				
5		Total Inflow (CFS)				
6	10/4/62 16:00	0				
7	10/4/62 17:00	0				
8	10/4/62 18:00	0				
9	10/4/62 19:00	0				
10	10/4/62 20:00	0				
11	10/4/62 21:00	0				
12	10/4/62 22:00	0				
13	10/4/62 23:00	0				
14	10/5/62 0:00	0				
15	10/5/62 1:00	0				
16	10/5/62 2:00	0				
17	10/5/62 3:00	0				
18	10/5/62 4:00	0				
19	10/5/62 5:00	0				

FFC | Pre-TS | Post-TS | PostMit-TS | FD_Summary | F

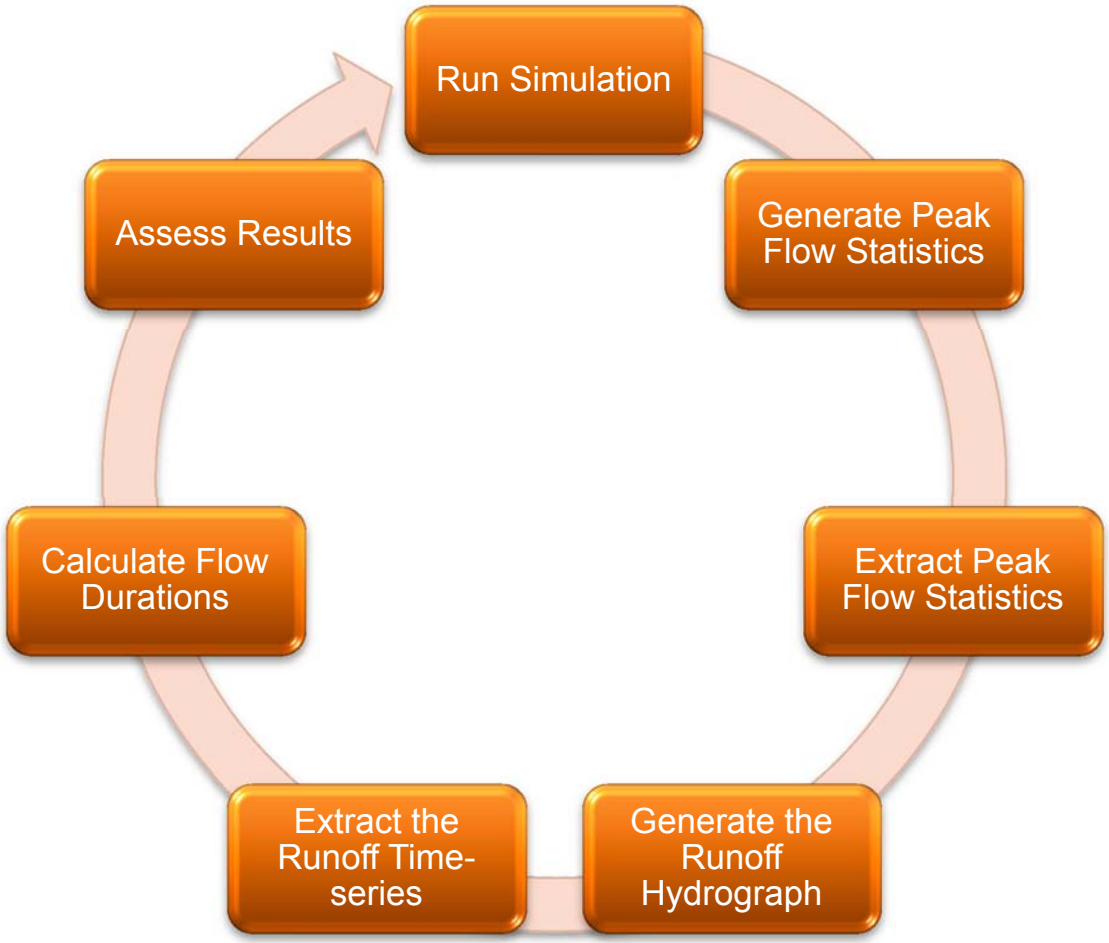
SWMM Files Explained

- If you look in your project directory now, you will find a series of files.

File Extension	Description	How is it created?	Required for Continuous Simulation?
.dat or .txt poway.dat	**Rainfall Data** • Time-series data from PCW	Created by user using external program (e.g. NotePad, Excel, etc.)	Yes
.inp ExampleProject_PRE.inp	**Input File** • Project-specific data	Generated by user in the SWMM program	Yes
.ini ExampleProject_PRE.ini	**Configuration Settings** • Map display options • Object default values	Automatically generated when saving the SWMM program	No
.rpt ExampleProject_PRE.rpt	**Status Report** • Simulation Results • Error Messages • Continuity Errors	Generated by SWMM after a successful simulation	No
.out ExampleProject_PRE.out	**Output File** • Binary file	Generated by SWMM after a successful simulation	No

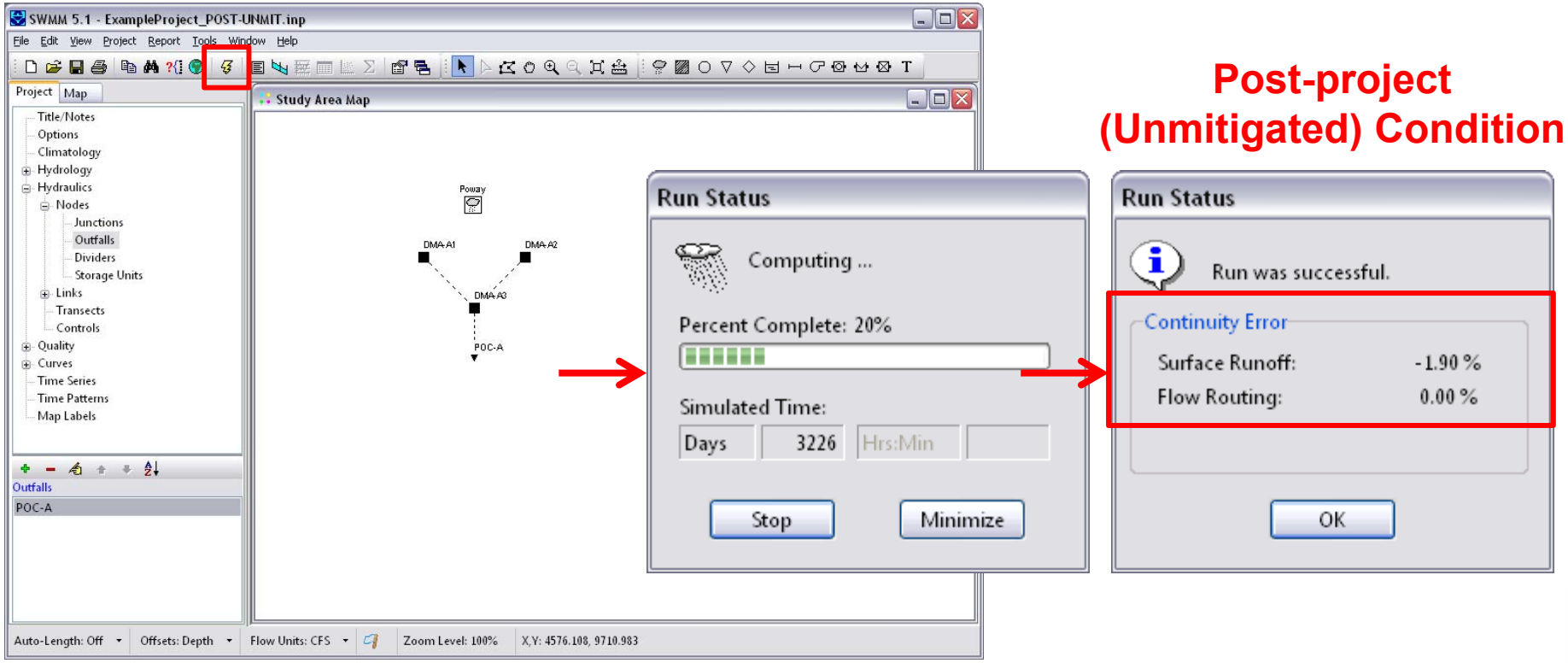
Repeat…

- Let's repeat these steps for the Post-project (Unmitigated) Condition…



Run Simulation

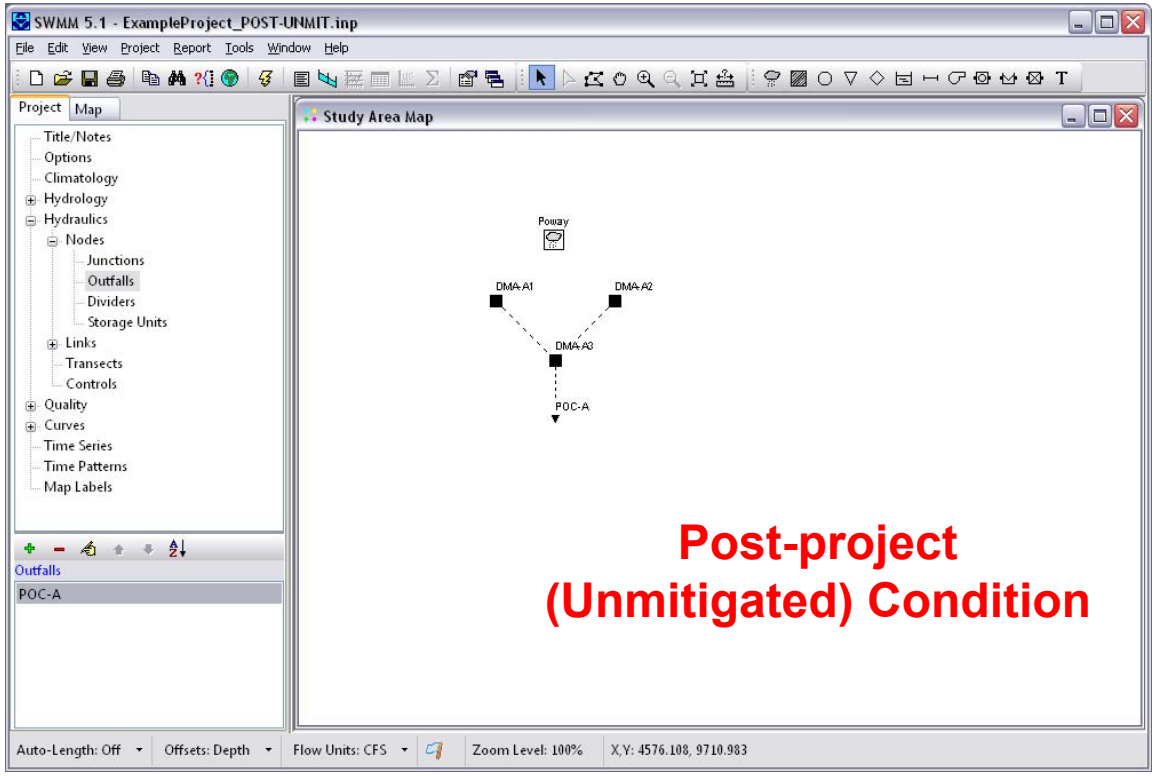
- Open the “ExampleProject_POST-UNMIT.inp” file
- Click the “Run a simulation” icon

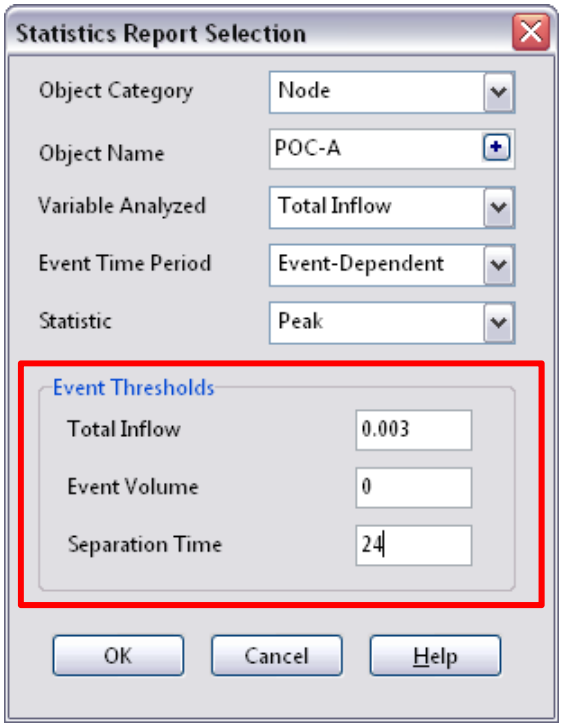


Post-project (Unmitigated) Condition

Flow Frequency Statistics

- Report -> Statistics -> “Statistics Report Selection”
- Input the selections shown below.
  - Note: The “Total Inflow” Event Threshold is defined as 0.002 cfs/acre x Total Drainage Area





Statistics

Σ Statistics - Node POC-A Total Inflow

Summary | Events | Histogram | Frequency Plot

```
S U M M A R Y   S T A T I S T I C S
===================================
Object  ............. Node POC-A
Variable ............ Total Inflow  (CFS)
Event Period ........ Variable
Event Statistic ..... Peak  (CFS)
Event Threshold ..... Total Inflow > 0.0030  (CFS)
Event Threshold ..... Event Volume > 0.0000 (ft3)
Event Threshold ..... Separation Time >= 24.0  (hr)
Period of Record ..... 10/04/1962 to 05/23/2008

Number of Events ..... 742
Event Frequency*...... 0.032
Minimum Value ........ 0.003
Maximum Value ........ 1.053
Mean Value ........... 0.173
Std. Deviation ....... 0.179
Skewness Coeff. ...... 1.843

*Fraction of all reporting periods belonging to an eve
```

- SWMM's built-in statistics are based on the Weibull Plotting Position

Σ Statistics - Node POC-A Total Inflow

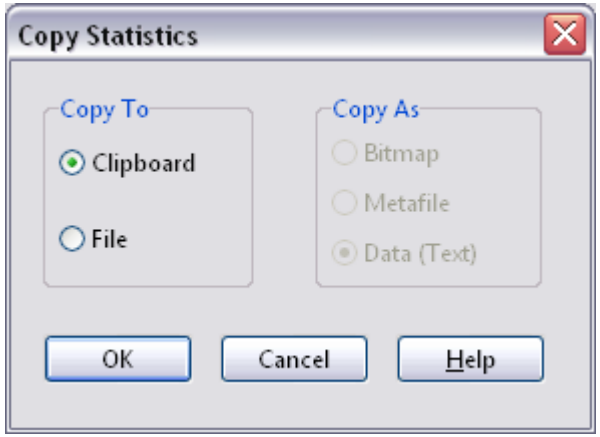
Summary | Events | Histogram | Frequency Plot

Rank	Start Date	Event Duration (hours)	Event Peak (CFS)	Exceedance Frequency (percent)	Return Period (years)
1	03/24/1983	17.0	1.053	0.13	47.00
2	02/13/1980	194.0	1.052	0.27	23.50
3	01/24/1995	51.0	0.946	0.40	15.67
4	12/28/2004	45.0	0.926	0.54	11.75
5	01/09/1978	45.0	0.919	0.67	9.40
6	03/17/1982	52.0	0.918	0.81	7.83
7	11/29/1982	24.0	0.871	0.94	6.71
8	11/04/1987	24.0	0.860	1.08	5.88
9	11/12/1976	11.0	0.824	1.21	5.22
10	02/28/1970	44.0	0.793	1.35	4.70
11	12/27/1978	85.0	0.782	1.48	4.27
12	02/06/1998	70.0	0.774	1.62	3.92

Post-project (Unmitigated) Condition

Copy Statistics

- On the Statistics tab, click the top left corner of the table to highlight the entire table.
- Edit - > Copy to… -> “Copy Statistics”



External Post-processing Spreadsheet

- Open “SWMM_PostProcessing.xlsx”
- Click on the “Post-Q” tab and paste Post-project (Unmitigated) Condition statistics in the highlighted cell
- Make adjustments to “Column I” as necessary to determine the Q_2, Q_5, and Q_{10} values.

Post-project (Unmitigated)

10-year Q:	0.921	cfs
5-year Q:	0.811	cfs
2-year Q:	0.627	cfs

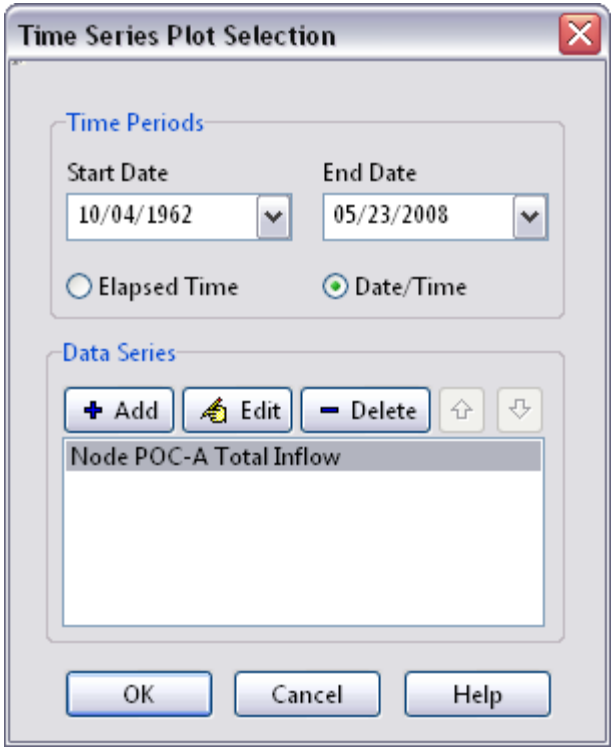
Lower Flow Threshold:	10%	
0.1xQ2 (Pre):	0.063	cfs

	A	B	C	D	E	F
1						
2	Post-project (Unmitigated) Flow Frequency - Long-ter					
3						
4	SWMM Training - Example Project - Post-project (Unmitigated) Condition					
5	Statistics - Node POC-A Total Inflow					
6			Event	Event	Exceedance	Return
7			Duration	Peak	Frequency	Period
8	Rank	Start Date	(hours)	(CFS)	(percent)	(years)
9	1	3/24/1983	17	1.053	0.13	47
10	2	2/13/1980	194	1.052	0.27	23.5
11	3	1/24/1995	51	0.946	0.4	15.67
12	4	12/28/2004	45	0.926	0.54	11.75
13	5	1/9/1978	45	0.919	0.67	9.4
14	6	3/17/1982	52	0.918	0.81	7.83
15	7	11/29/1982	24	0.871	0.94	6.71
16	8	11/4/1987	24	0.86	1.08	5.88
17	9	11/12/1976	11	0.824	1.21	5.22
18	10	2/28/1970	44	0.793	1.35	4.7
19	11	12/27/1978	85	0.782	1.48	4.27
20	12	2/6/1998	70	0.774	1.62	3.92
21	13	12/17/1978	69	0.774	1.75	3.62
22	14	2/3/1998	46	0.769	1.88	3.36
23	15	12/9/1965	31	0.761	2.02	3.13
24	16	2/14/1998	40	0.7	2.15	2.94
25	17	3/1/1983	82	0.652	2.29	2.76
26	18	2/5/1983	64	0.652	2.42	2.61
27	19	1/4/1974	116	0.649	2.56	2.47
28	20	1/5/1979	26	0.648	2.69	2.35
29	21	1/27/1980	70	0.645	2.83	2.24
30	22	3/17/1963	20	0.641	2.96	2.14
31	23	3/17/1983	45	0.639	3.1	2.04
32	24	1/7/2005	115	0.614	3.23	1.96
33	25	4/1/1982	13	0.611	3.36	1.88

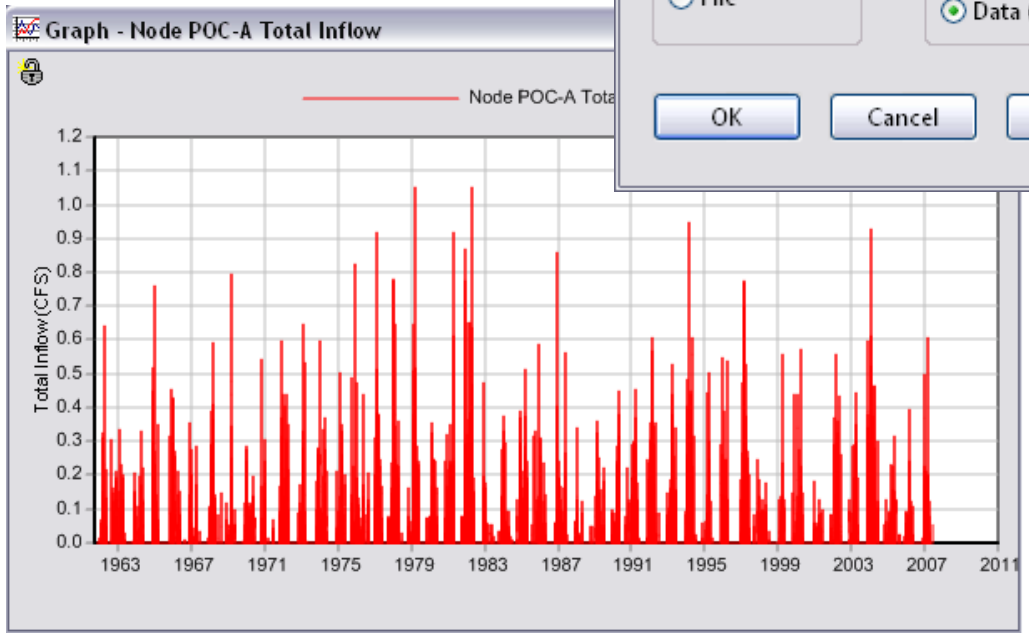
Disclaimer | Pre-Q | Post-Q | PostMit-Q | FF_Summary | FFC

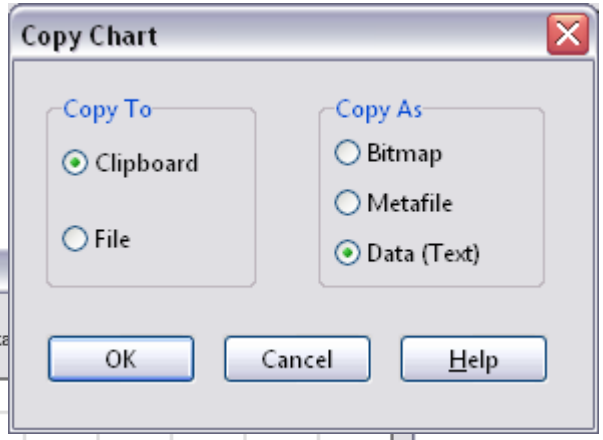
Copy Time-series

- Next, let's extract the runoff hydrograph time-series to calculate the flow durations.
- Report - > Graph - > Time Series - > "Time Series Plot Selection"
- Edit - > Copy to… - > "Copy Chart"

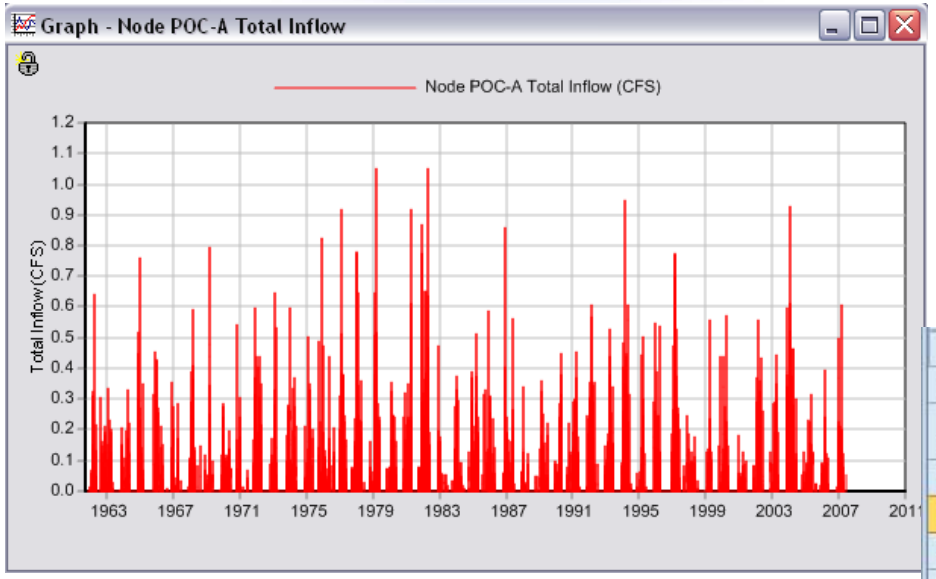


Post-project (Unmitigated) Condition

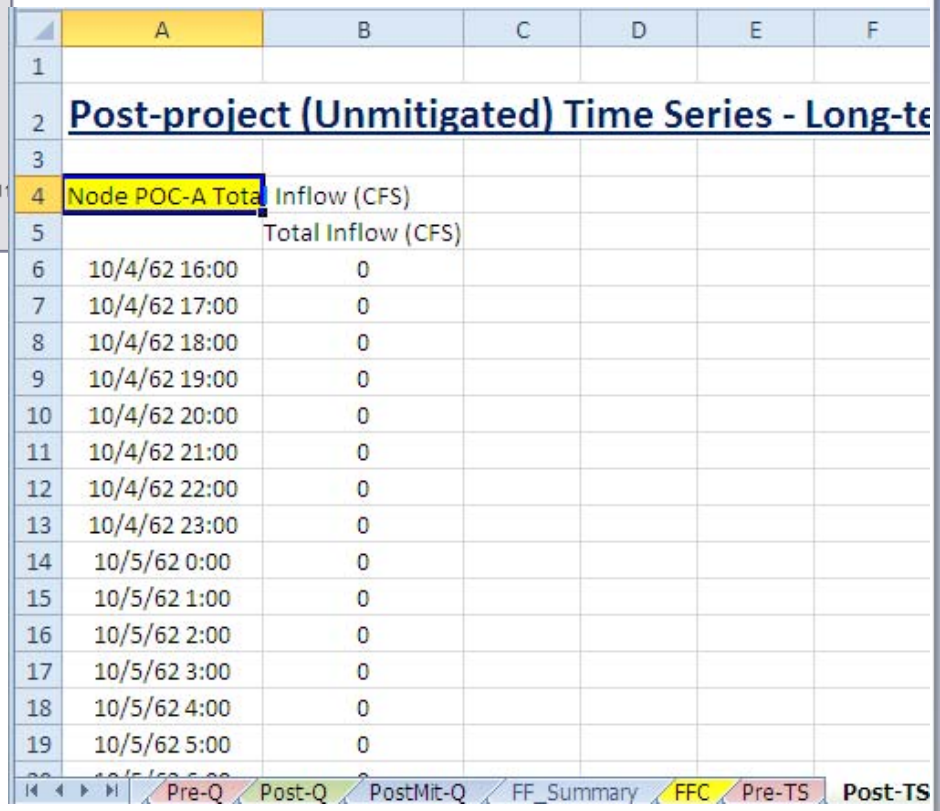




External Post-processing Spreadsheet



Post-project (Unmitigated) Condition



	A	B	C	D	E	F
1						
2	Post-project (Unmitigated) Time Series - Long-te					
3						
4	Node POC-A Tota	Inflow (CFS)				
5		Total Inflow (CFS)				
6	10/4/62 16:00	0				
7	10/4/62 17:00	0				
8	10/4/62 18:00	0				
9	10/4/62 19:00	0				
10	10/4/62 20:00	0				
11	10/4/62 21:00	0				
12	10/4/62 22:00	0				
13	10/4/62 23:00	0				
14	10/5/62 0:00	0				
15	10/5/62 1:00	0				
16	10/5/62 2:00	0				
17	10/5/62 3:00	0				
18	10/5/62 4:00	0				
19	10/5/62 5:00	0				

Pre-Q | Post-Q | PostMit-Q | FF_Summary | FFC | Pre-TS | Post-TS

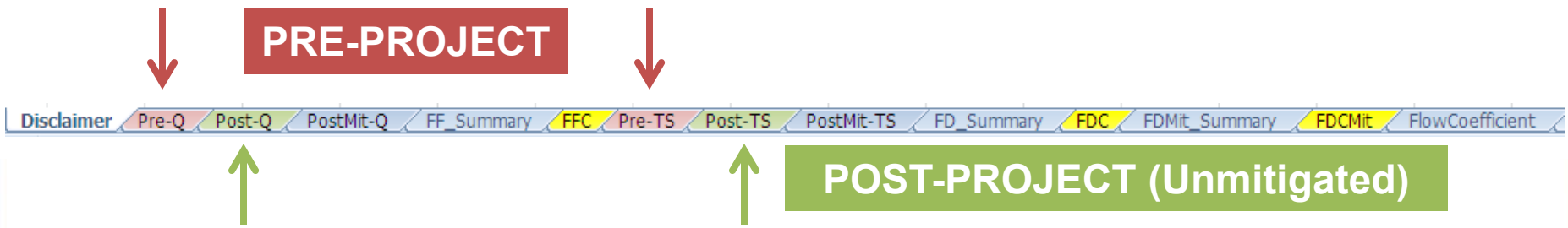
- Click on the “Post-TS” tab and paste Post-project (Unmitigated) Condition runoff hydrograph (time-series) in the highlighted cell

Results?

- Let's take a look at the **post-processing spreadsheet**…

- Flow Frequency
  - Tables: "FF_Summary" tab
  - Curves: "FFC" tab

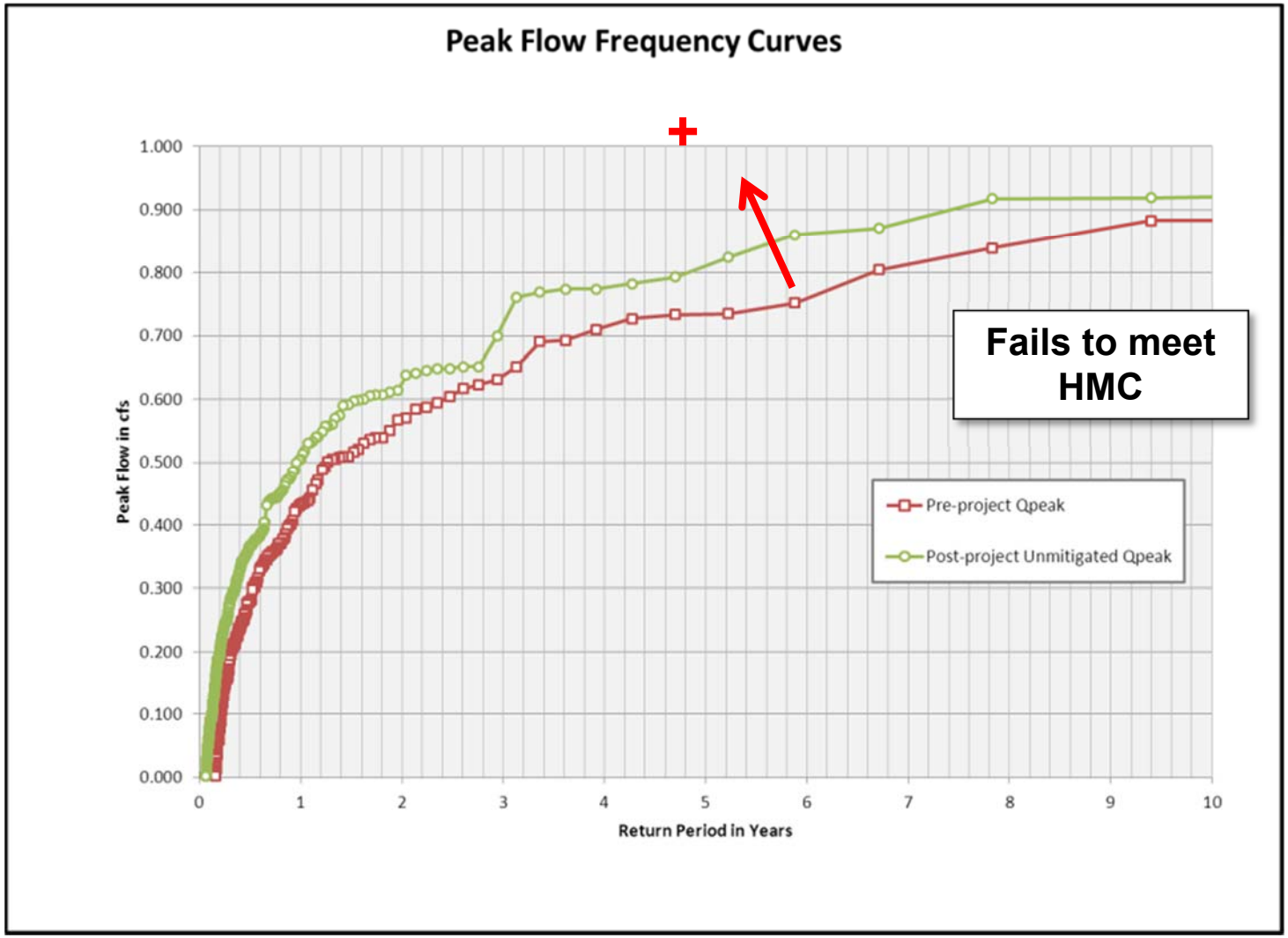
- Flow Duration
  - Tables: "FD_Summary" tab
  - Curves: "FDC" tab



Flow Frequency: Table

Return Period	Pre-project Qpeak (cfs)	Post-project - Unmitigated Q (cfs)
LF = 0.1xQ2	0.057	0.063
2-year	0.570	0.627
5-year	0.734	0.811
10-year	0.883	0.921

Flow Frequency: Curves

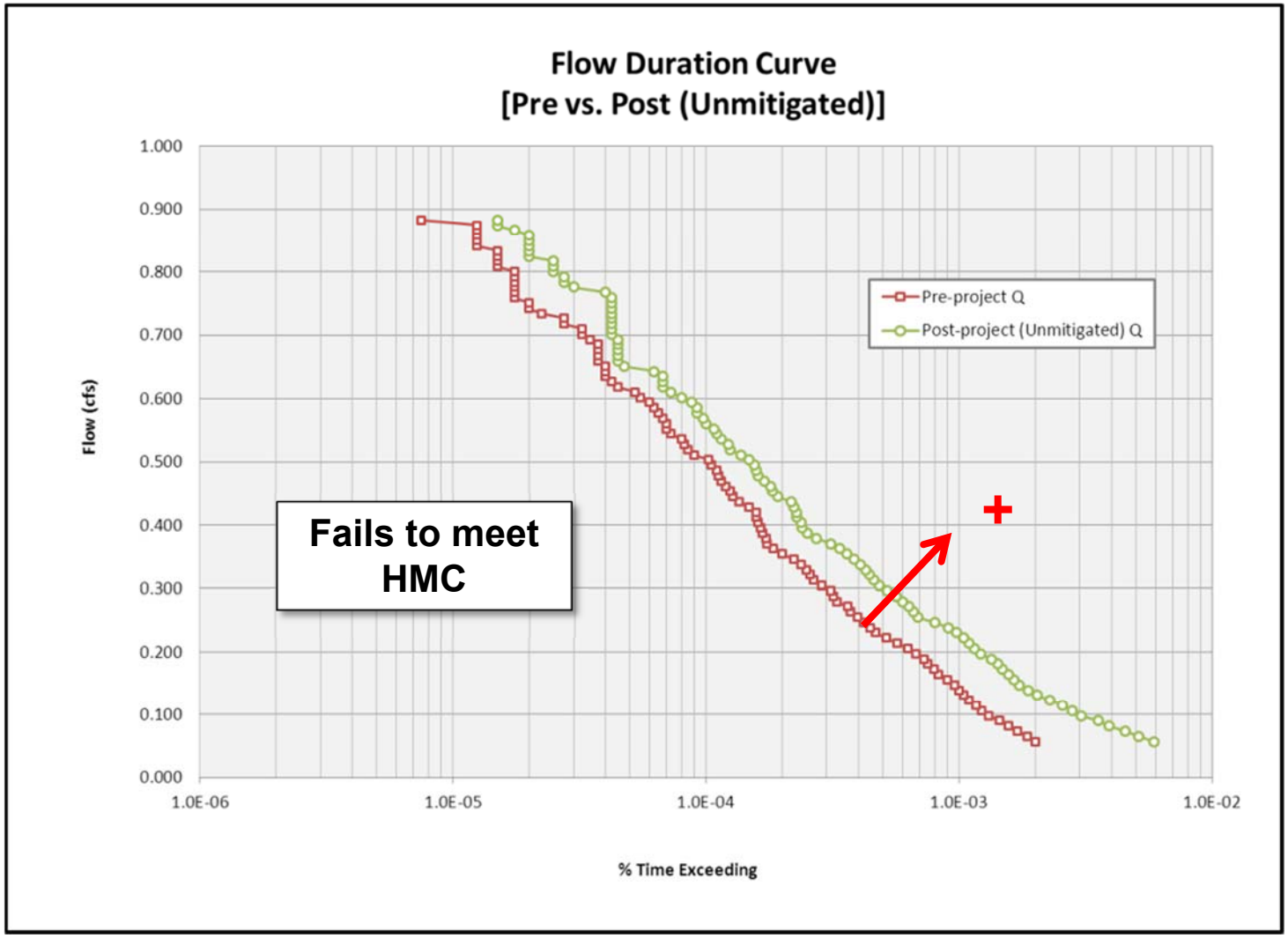


Flow Duration: Table

	A	B	C	D	E	F	G	H
1		Lower Flow Threshold:	10%					
2		0.1xQ2 (Pre):	0.057	cfs				
3		Q10 (Pre):	0.883	cfs				
4		# of Ordinates:	100					
5		Incremental Q (Pre):	0.00826	cfs				
6		Total Hourly Data:	400032	hours			The proposed BMP:	FAILED
7								
8	Interval	Pre-project Flow (cfs)	Pre-project Hours	Pre-project % Time Exceeding	Post-project Hours	Post-project % Time Exceeding	Percentage	Pass/Fail
9	0	0.057	801	2.00E-03	2359	5.90E-03	295%	Fail
10	1	0.065	743	1.86E-03	2056	5.14E-03	277%	Fail
11	2	0.073	680	1.70E-03	1816	4.54E-03	267%	Fail
12	3	0.082	627	1.57E-03	1572	3.93E-03	251%	Fail
13	4	0.090	577	1.44E-03	1421	3.55E-03	246%	Fail
14	5	0.098	524	1.31E-03	1214	3.03E-03	232%	Fail
15	6	0.107	492	1.23E-03	1118	2.79E-03	227%	Fail
16	7	0.115	466	1.16E-03	1023	2.56E-03	220%	Fail
17	8	0.123	437	1.09E-03	915	2.29E-03	209%	Fail
99	90	0.800	7	1.75E-05	10	2.50E-05	143%	Fail
100	91	0.809	6	1.50E-05	10	2.50E-05	167%	Fail
101	92	0.817	6	1.50E-05	10	2.50E-05	167%	Fail
102	93	0.825	6	1.50E-05	8	2.00E-05	133%	Fail
103	94	0.833	6	1.50E-05	8	2.00E-05	133%	Fail
104	95	0.842	5	1.25E-05	8	2.00E-05	160%	Fail
105	96	0.850	5	1.25E-05	8	2.00E-05	160%	Fail
106	97	0.858	5	1.25E-05	8	2.00E-05	160%	Fail
107	98	0.866	5	1.25E-05	7	1.75E-05	140%	Fail
108	99	0.875	5	1.25E-05	6	1.50E-05	120%	Fail
109	100	0.883	3	7.50E-06	6	1.50E-05	200%	Fail
110								

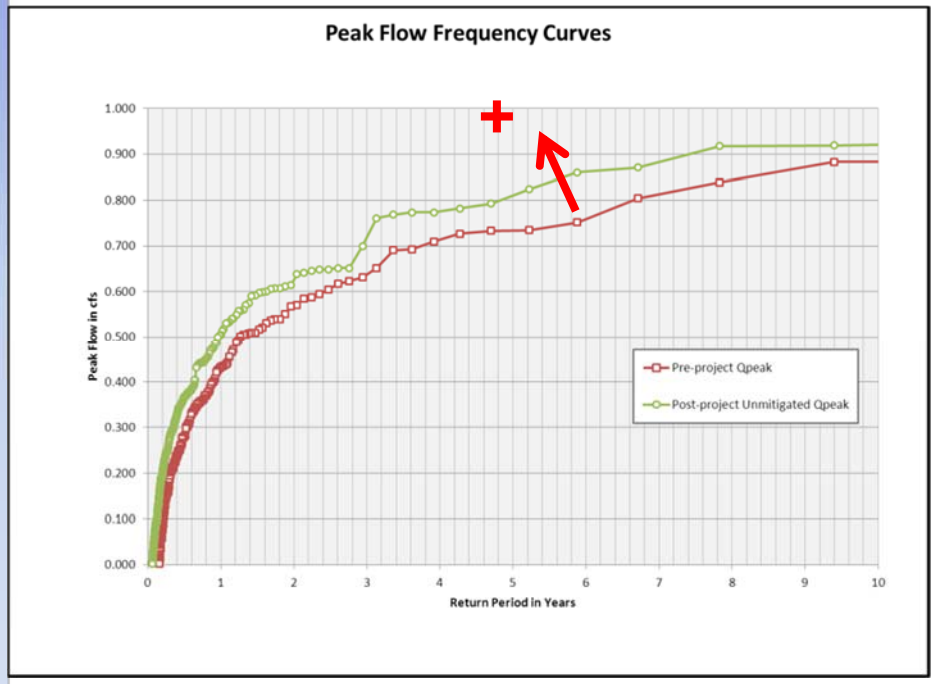
Post-TS | PostMit-TS | FD_Summary | FDC | FDMit_Summary | FDCMit | FlowCoefficient

Flow Frequency: Curves

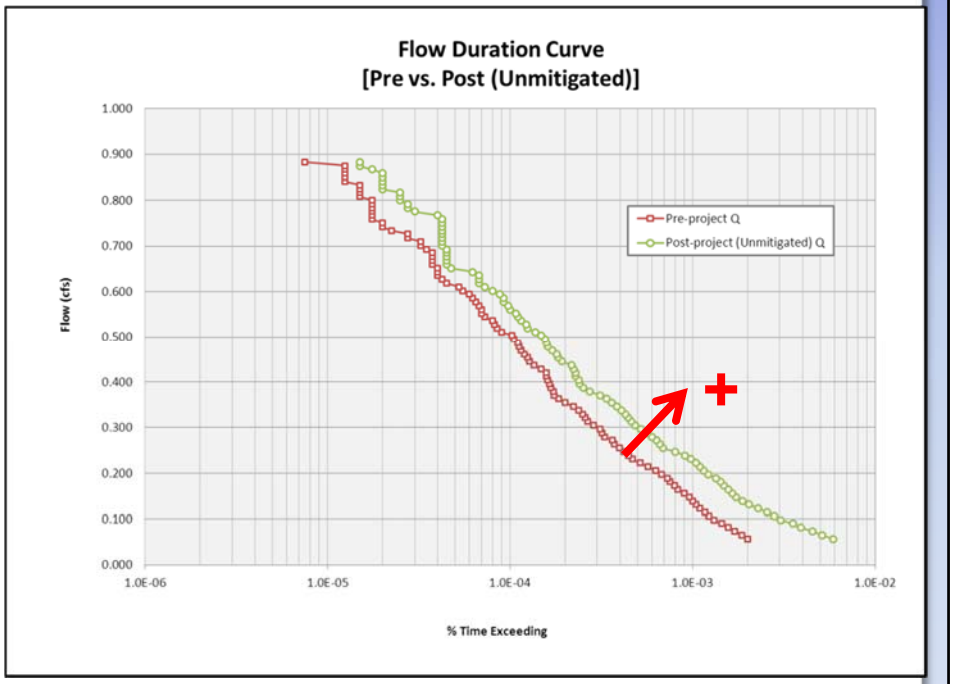


Results Summary

- Now, let's compare the Pre-project and Post-project (Unmitigated) Condition **peak flow frequency statistics** and **flow duration** (time-series) results within our HMP Flow range $0.1xQ_2$ to Q_{10}.



Increase in Peak Flow Frequency



Increase in Flow Durations

Fails to meet the HMP Flow Control Performance Standards

∴ Mitigation is required.

Post-processing Complete!

The **post-processing analysis** for both the *Pre-project Condition* and *Post-project (Unmitigated) Condition* models is now complete!

Next, let's setup a **Post-project (Mitigated) Condition** model, including a Biofiltration Basin.

Example Project – Institutional Living

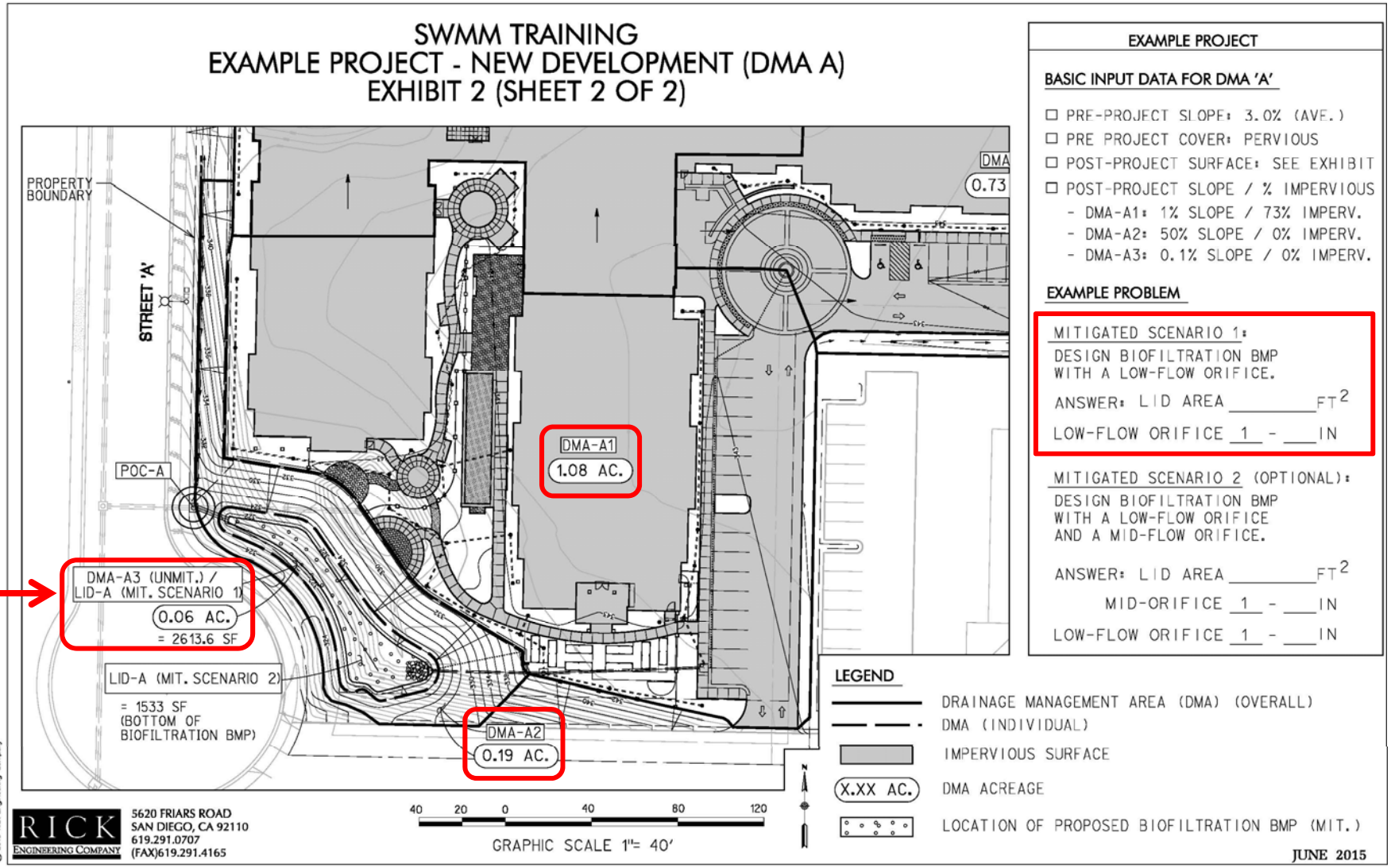
POST-PROJECT (MITIGATED) MODEL SETUP FOR SCENARIO 1

Mitigation Required!

- A biofiltration basin is proposed on the southwest corner of the site at the subcatchment (i.e. formerly “DMA-A3”) to meet both the water quality treatment and hydromodification management criteria.
  - Note: The required Water Quality Volume ~ 1,890 CF

- Subcatchment “DMA-A3” will now be renamed as “LID-A” and we will add the “Bio-Retention Cell” (“LID Control”) component to “LID-A.”

Drainage Management Area "A"



Define Site/Flow Constraints

- Taking into consideration the project's *vertical* and *horizontal* site constraints, we would begin modeling by using an anticipated basin cross-section.

- Anticipated Biofiltration Basin Cross-section

Pre- $0.1xQ_2$ = 0.057 cfs

  - 12-inch Freeboard & Q_{100} Conveyance
  - 12-inch Surface Ponding Depth
  - 24-inch Engineered Soil (η=40%)
  - 12-inch Gravel Layer (η=40% or e=0.67)

H = 4-feet

  - 4-inch Perforated Pipe with Low-Flow Restrictor (Φ = __?__-inches)
    - Both flowlines set at the bottom of the Gravel Layer
  - 3-inch Dead Storage Layer (Gravel)
    - Located longitudinally below the perforated pipe only
    - Does not provided storage volume

- Based on the pressure head acting on the orifice and the pre-project $0.1xQ_2$, the *maximum* low flow restrictor diameter would be 1.0-inches based on the Orifice Equation.

Scenario 1 Working Solution

- There are infinitely many working solutions based on different LID BMP basin configurations, LID surface areas, orifice restrictor sizes, etc.; however, the working solution shown with this example contains the following Biofiltration Basin cross-section.

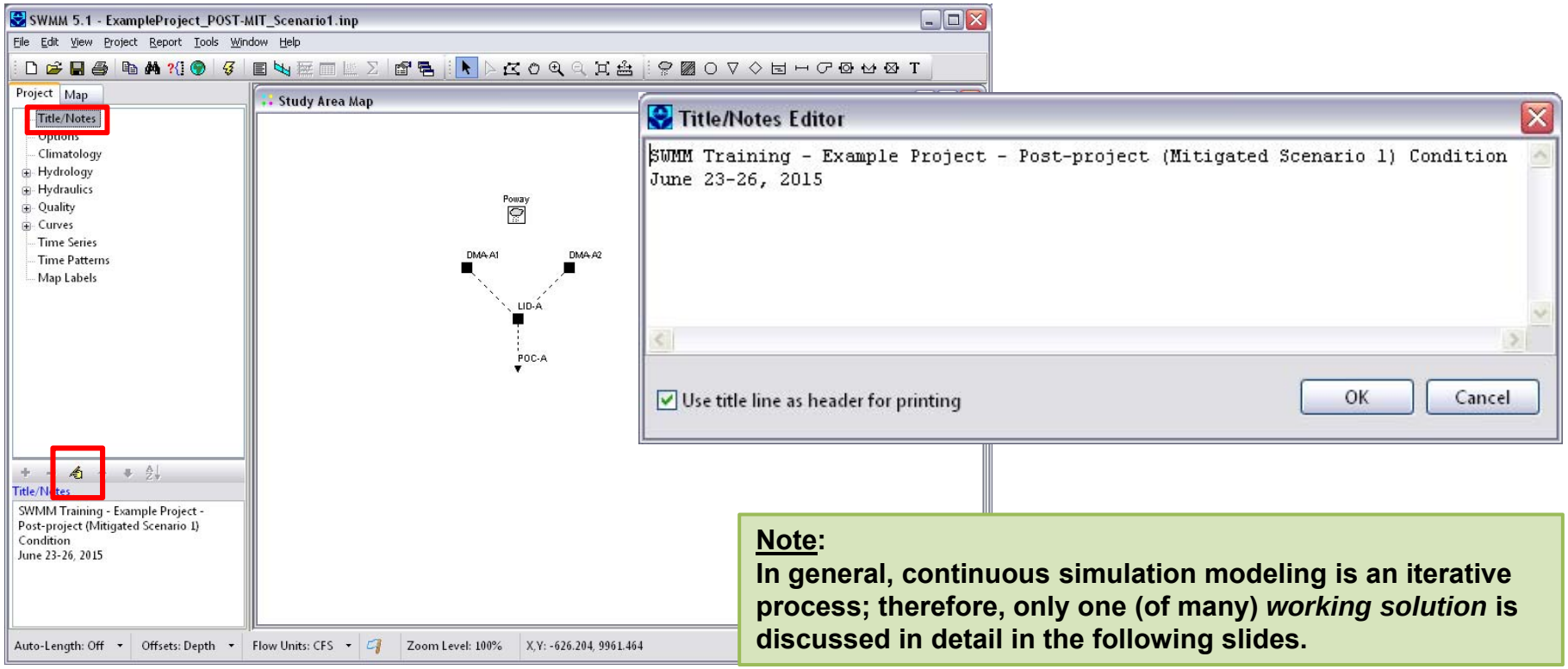
- Working Solution Biofiltration Basin Cross-section
  - 12-inch Freeboard & Q_{100} Conveyance
  - 12-inch Surface Ponding Depth
  - 24-inch Engineered Soil (η=40%)
  - 12-inch Gravel Layer (η =40% or e=0.67)
  - 4-inch Perforated Pipe with Low-Flow Restrictor (Φ = 5/8-inch (or 0.625-inches))
    - Both flowlines set at the bottom of the Gravel Layer
  - 3-inch Dead Storage Layer (Gravel)
    - Located longitudinally below the perforated pipe only
    - Does not provided storage volume

~ diameter of a dime

- How small is 5/8-inch?

New File

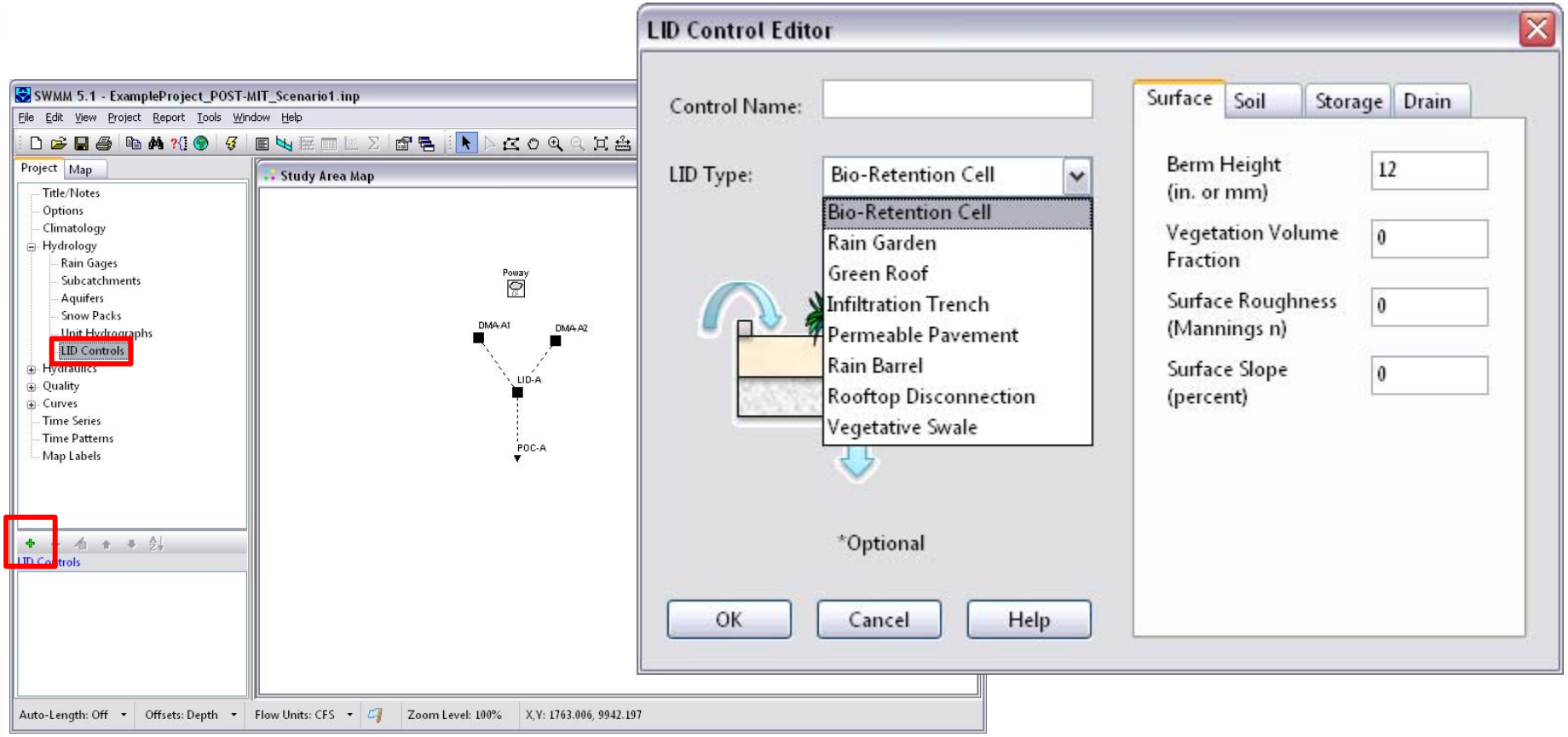
- Open the “ExampleProject_POST-UNMIT.inp”
- Save As “ExampleProject_Post-Mit_Scenario1.inp” in the folder “…\MyModel\” to create Scenario 1 of the Post-project (mitigated) model.
- Rename “DMA-A3” to “LID-A”
- Update the “Title/Notes Editor” as shown below.



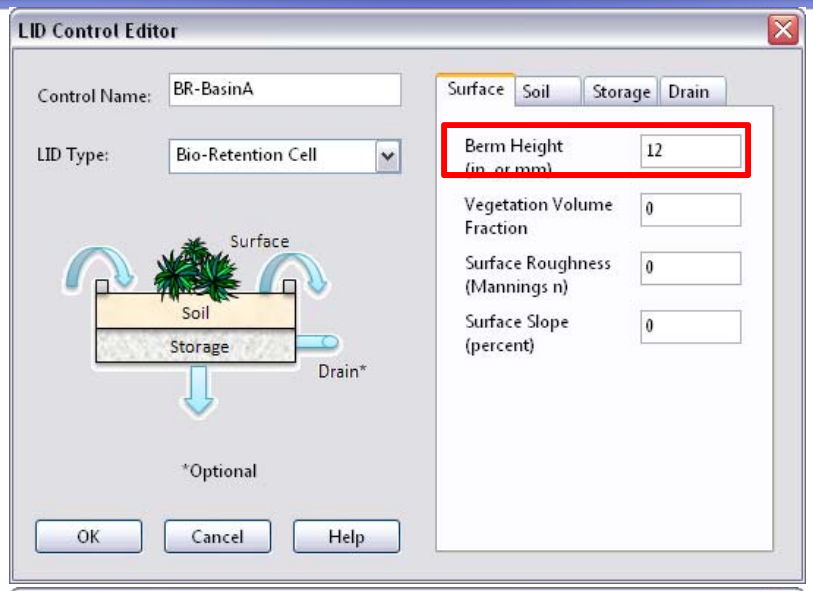
Note:
In general, continuous simulation modeling is an iterative process; therefore, only one (of many) *working solution* is discussed in detail in the following slides.

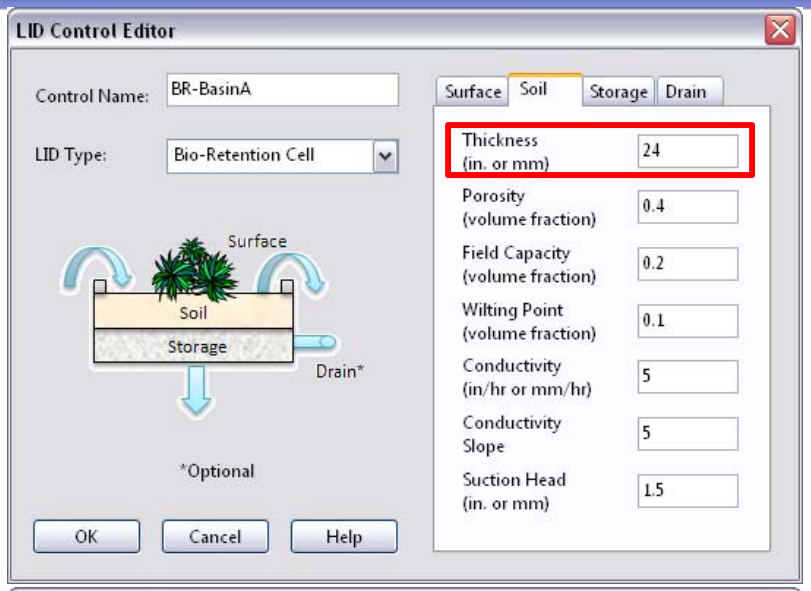
Add LID Control

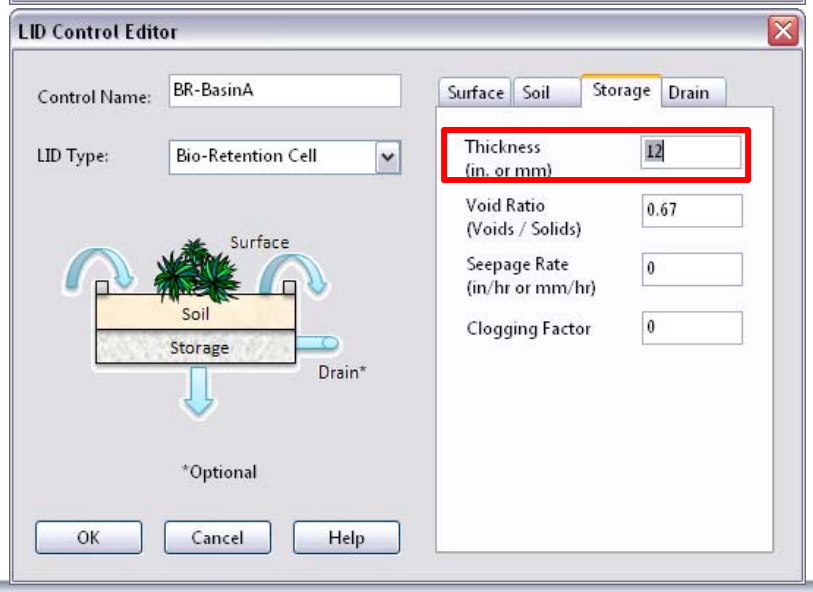
- Select “LID Controls” in the “Data Browser Panel”
- Click the “ + ” to add an “LID Control”
- Select “Bio-Retention Cell” as the “LID Type”

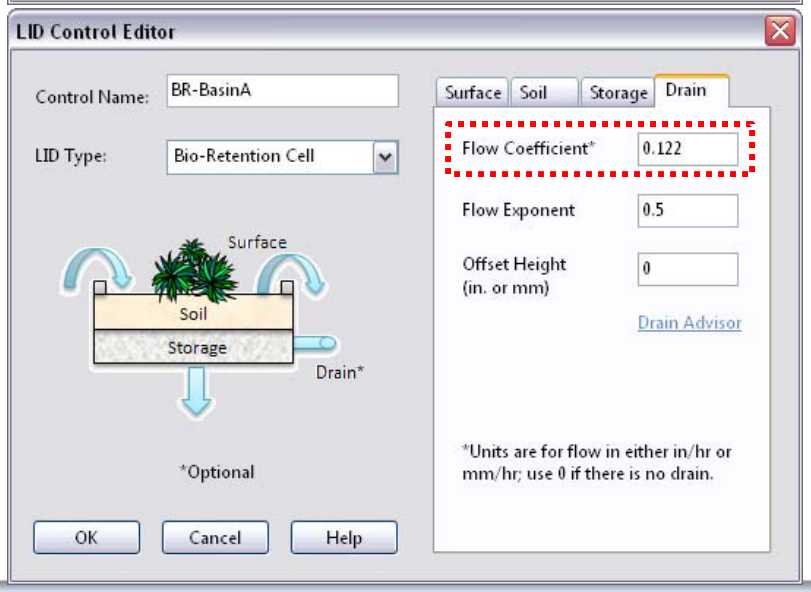


Bio-Retention Cell









Recall Definitions from Day 1

Standard Power Law (shown in SWMM User's Manual) $q = \boxed{C}(h - H_D)^n$

Where:
- q = Unit Flow Rate (ft/s)
- C = Flow Coefficient ($in^{0.5}$/hour)
- h = Pressure Head acting on orifice (ft)
- H_D = Drain Offset Height (ft) (modeled as zero in this example)
- n = Power Law Coefficient (n=0.5 to act like an orifice)

Unit Flow Rate (by definition) $q = \frac{Q_{orifice}}{\eta A_{LID}}$

Where:
- q = Unit Flow Rate (percolation rate through engineered soil) (ft/s)
- $Q_{orifice}$ = Volumetric Outflow Rate (ft^3/s)
- η = Engineered Soil Porosity (η = 0.40)
- A_{LID} = Surface Area of LID BMP (ft^2)

Orifice Equation (by definition) $Q_{orifice} = C_o A_o \sqrt{2g(H - \frac{1}{2}h_c)}$

Where:
- $Q_{orifice}$ = Volumetric Outflow Rate (ft^3/s)
- A_o = Orifice Cross-sectional Area (ft^2)
- g = Gravitation Acceleration, 32.2 ft/s^2
- H = Height of stored water above Orifice (ft)
- h_c = Height to Centroid of Orifice (ft)

Flow Coefficient Calculation

- Since we are modeling an orifice, the Power Law Coefficient (n) equals 0.5.
- Solving the three equations for the Flow Coefficient (C) and applying unit conversions…
  - Note: "h" in the Standard Power Law equals "H-0.5h_c" in the Orifice Equation, so they cancel out.

Standard Power Law	$q = C(h - H_D)^n$
Unit Flow Rate	$q = \frac{Q_{orifice}}{\eta A_{LID}}$
Orifice Equation	$Q_{orifice} = C_o A_o \sqrt{2g(H - \frac{1}{2}h_c)}$

$$Flow\ Coefficient\ (C)\left[{in^{0.5}}/{hour}\right] = \frac{C_o A_o \sqrt{2g}}{\eta A_{LID}} \times 12^{0.5} \times 3600$$

Where: C_o = Orifice Coefficient
A_o = Orifice Cross-sectional Area (in^2)
g = gravitational acceleration (ft/sec^2)
η = Engineered Soil Porosity (η=0.40)
A_{LID} = Surface Area of LID BMP (ft^2)

We Made It Easy!

	A	B	C	D
1				
2	**SWMM Model Flow Coefficient Calculation**			
3				
4				
5	**PARAMETER**	**ABBREV.**	**Bio-Retention Cell LID BMP**	
6	Ponding Depth	PD	12	in
7	Bioretention Soil Layer	S	24	in
8	Gravel Layer	G	12	in
9	TOTAL		4.0	ft
10			48	in
11				
12	Orifice Coefficient	c_g	0.6	--
13	Low Flow Orifice Diameter	D	0.625	in
14	Drain exponent	n	0.5	--
15				
16				
17	Flow Rate (volumetric)	Q	0.020	cfs
18				
20	Bioretention Surface Area	A_S, A_G	2613.6	ft^2
21		A_S, A_G	0.0600	ac
22	Porosity of Bioretention Soil	n	0.40	-
23	Flow Rate (per unit area)	q	0.845	in/hr
24				
26	Flow Coefficient	C	0.1220	--

FDCMit | FlowCoefficient

- Open “ExampleProject_PostProcessing_Scenario1.xlsx”
- Select the “FlowCoefficient” tab
- Input appropriate data into highlighted cells to calculated the Flow Coefficient (C).

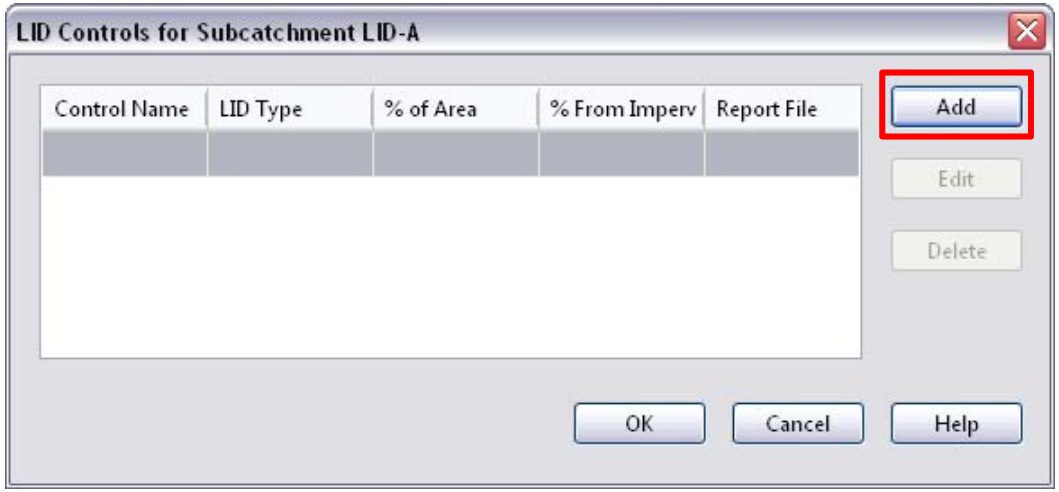
Apply LID Control

Subcatchment LID-A

Property	Value
Name	LID-A
X-Coordinate	2996.146
Y-Coordinate	5973.025
Description	
Tag	
Rain Gage	Poway
Outlet	POC-A
Area	0.06
Width	25
% Slope	0.1
% Imperv	0
N-Imperv	0.012
N-Perv	0.15
Dstore-Imperv	0.05
Dstore-Perv	0.1
%Zero-Imperv	25
Subarea Routing	OUTLET
Percent Routed	100
Infiltration	GREEN_AMPT
Groundwater	NO
Snow Pack	
LID Controls	0 ...
Land Uses	0
Initial Buildup	NONE
Curb Length	0

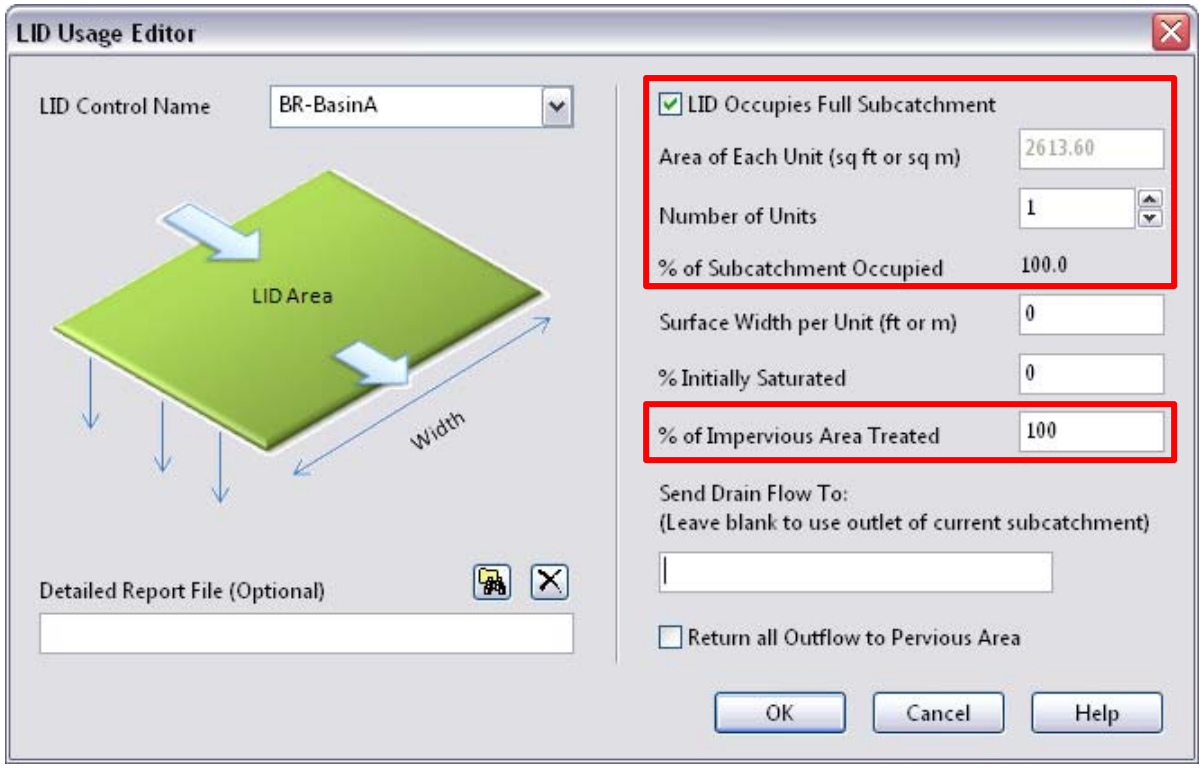
LID controls (click to edit)

- Under "LID Controls," click the "…" button to define the LID Controls.
- Click the "Add" button to open the "LID Usage Editor"



LID Usage Editor

- As previously mentioned, the *working solution* for this example project requires a LID BMP footprint occupying the full "LID-A" Subcatchment area; therefore, we would check the box "LID Occupies Full Subcatchment" for Scenario 1.
  - Note: Since the LID occupies the entire subcatchment, the "% of Impervious Area Treated" is ignored. Alternately, if the subcatchment did not occupy the full subcathment area, then the user would need to specify this value.



SWMM 5.1 - ExampleProject_POST-MIT_Scenario1.inp

File Edit View Project Report Tools Window Help

Project | Map

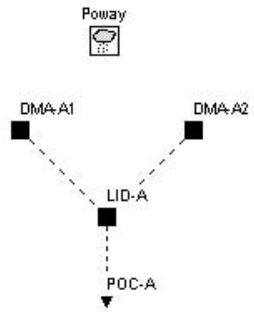
- Title/Notes
- Options
- Climatology
- Hydrology
  - Rain Gages
  - Subcatchments
  - Aquifers
  - Snow Packs
  - Unit Hydrographs
  - LID Controls
- Hydraulics
- Quality
- Curves
- Time Series
- Time Patterns
- Map Labels

Subcatchments

DMA-A1
DMA-A2
LID-A

Auto-Length: Off | Offsets

Study Area Map



LID Controls for Subcatchment LID-A

Control Name	LID Type	% of Area	% From Imperv	Report File
BR-BasinA	Bio-Retention	100.0	100	

Add | Edit | Delete

OK | Cancel | Help

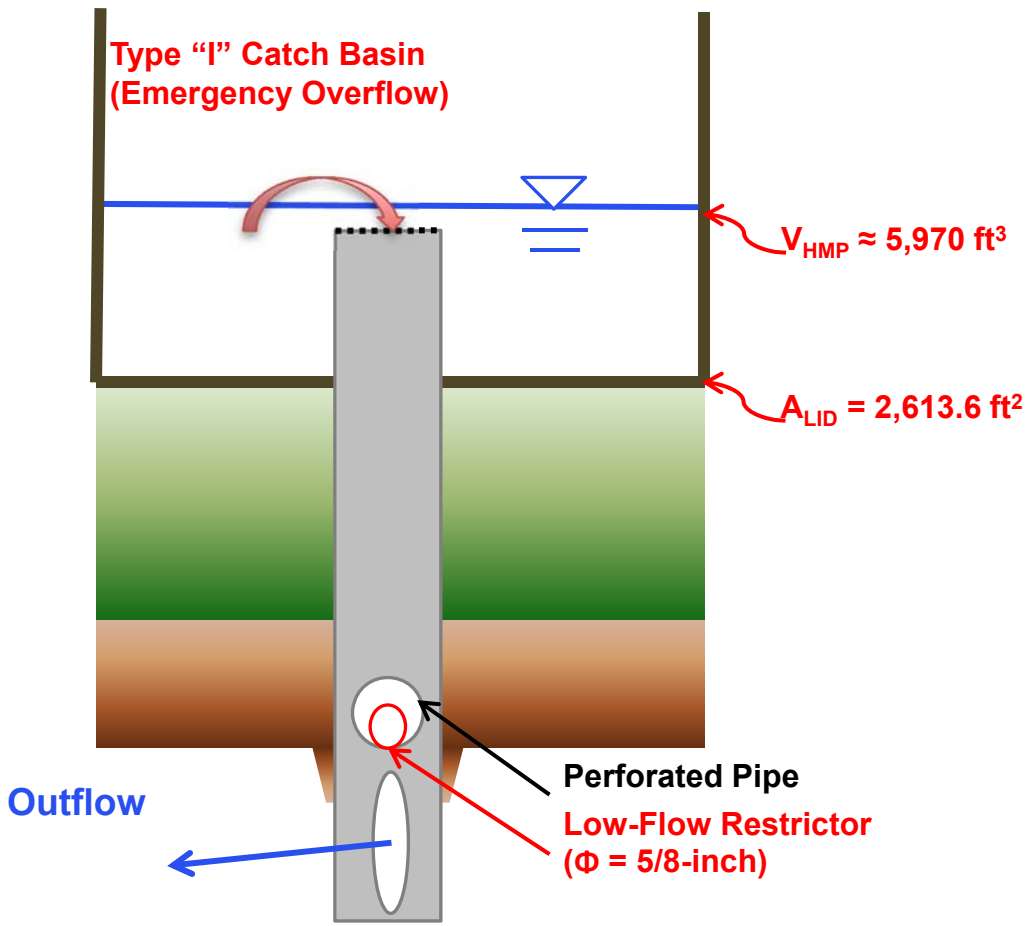
Subcatchment LID-A

Property	Value
Name	LID-A
X-Coordinate	3000.000
Y-Coordinate	6000.000
Description	
Tag	
Rain Gage	Poway
Outlet	POC-A
Area	0.06
Width	25
% Slope	0.1
% Imperv	0
N-Imperv	0.012
N-Perv	0.05
Dstore-Imperv	0.05
Dstore-Perv	0.1
%Zero-Imperv	25
Subarea Routing	OUTLET
Percent Routed	100
Infiltration	GREEN_AMPT
Groundwater	NO
Snow Pack	
LID Controls	1
Land Uses	0
Initial Buildup	NONE
Curb Length	0

LID controls (click to edit)

Scenario 1 Summary

Scenario 1: One Restrictor



Model Complete!

The *Post-project (Mitigated Scenario 1) Condition* model is now complete!

Next, let's run the **post-processing analysis** to see how our Biofiltration Basin performed.

Example Project – Institutional Living

POST-PROCESSING
POST-PROJECT MITIGATED SCENARIO 1

HMP Flow Control Performance Criteria

- The following are the ***peak flow*** and ***duration*** control requirements per the Final Hydromodification Management Plan, dated March 2011.

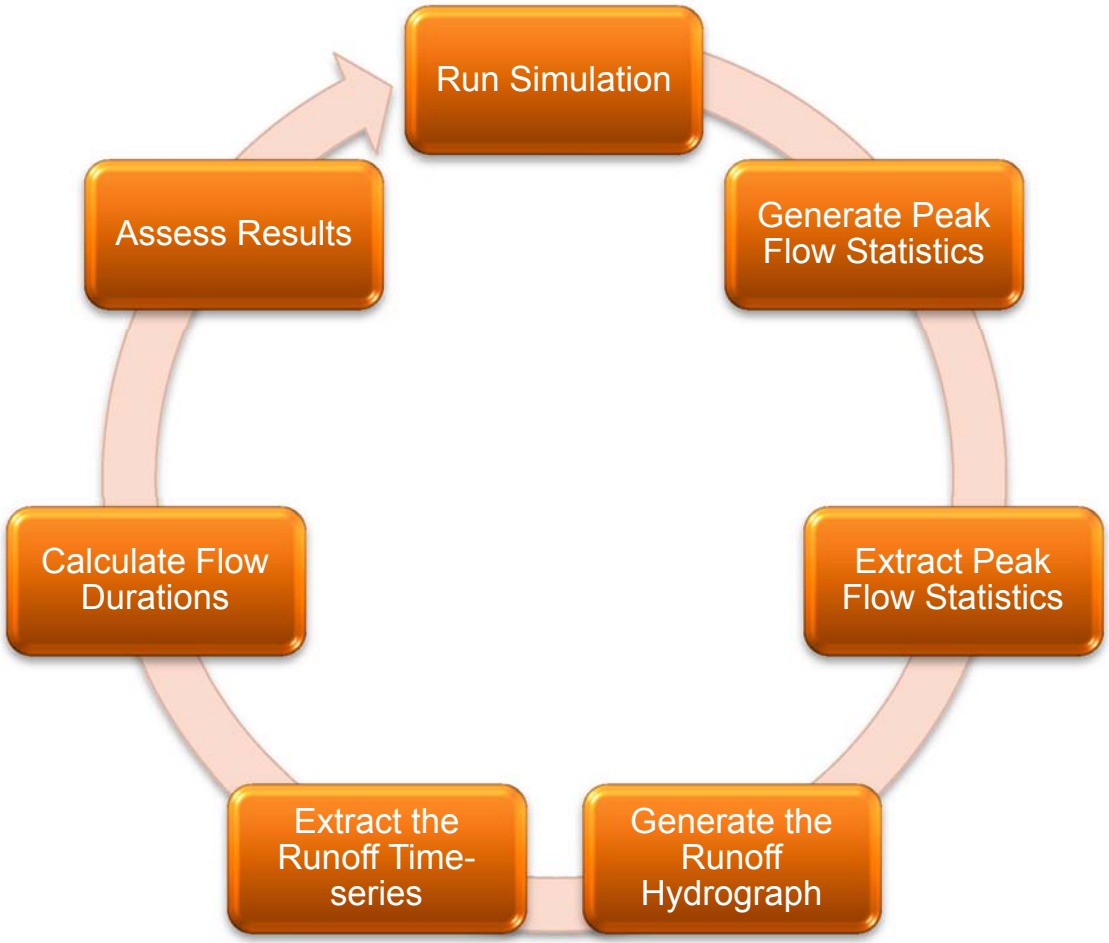
Section 6 Hydromodification Management Plan

Low-Impact Development (LID) and extended detention facilities are required to meet peak flow and duration controls as follows:

1. For flow rates ranging from 10 percent, 30 percent or 50 percent of the pre-project 2-year runoff event ($0.1Q_2$, $0.3Q_2$, or $0.5Q_2$) to the pre-project 10-year runoff event (Q_{10}), the post-project discharge rates and durations shall not deviate above the pre-project rates and durations by more than 10 percent over and more than 10 percent of the length of the flow duration curve. The specific lower flow threshold will depend on results from the SCCWRP channel screening study and the critical flow calculator.
2. For flow rates ranging from the lower flow threshold to Q_5, the post-project peak flows shall not exceed pre-project peak flows. For flow rates from Q_5 to Q_{10}, post-project peak flows may exceed pre-project flows by up to 10 percent for a 1-year frequency interval. For example, post-project flows could exceed pre-project flows by up to 10 percent for the interval from Q9 to Q10 or from Q5.5 to Q6.5, but not from Q8 to Q10.

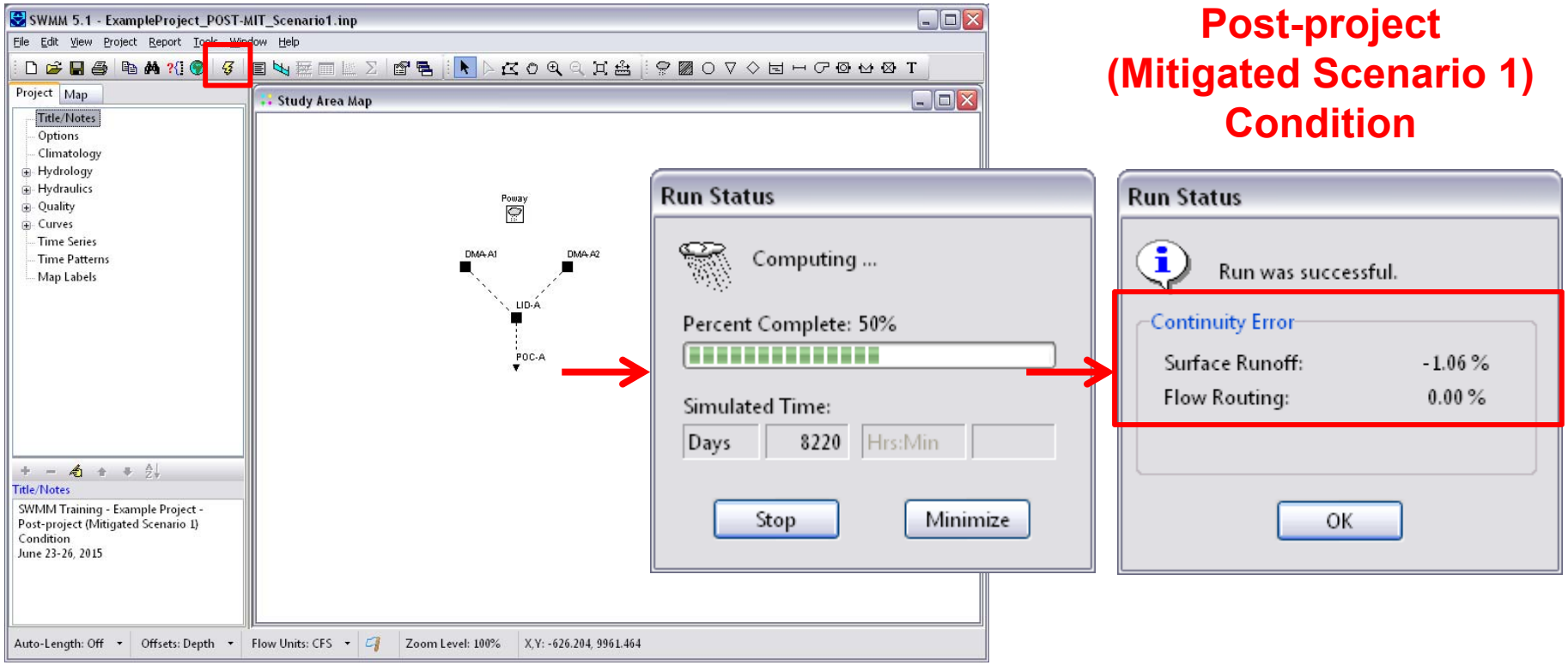
Recall…

- Let's repeat these steps for the Post-project (Mitigated) Condition…



Run Simulation

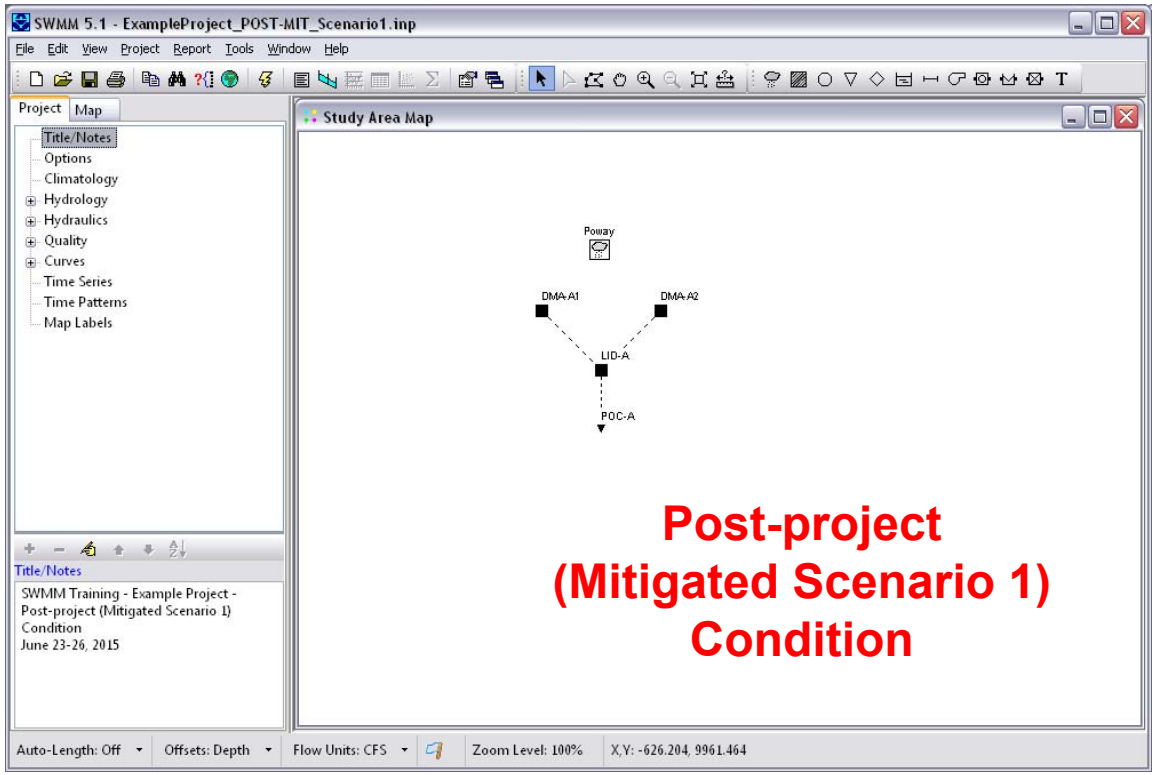
- Open the “ExampleProject_POST-MIT_Scenario1.inp” file
- Click the “Run a simulation” icon

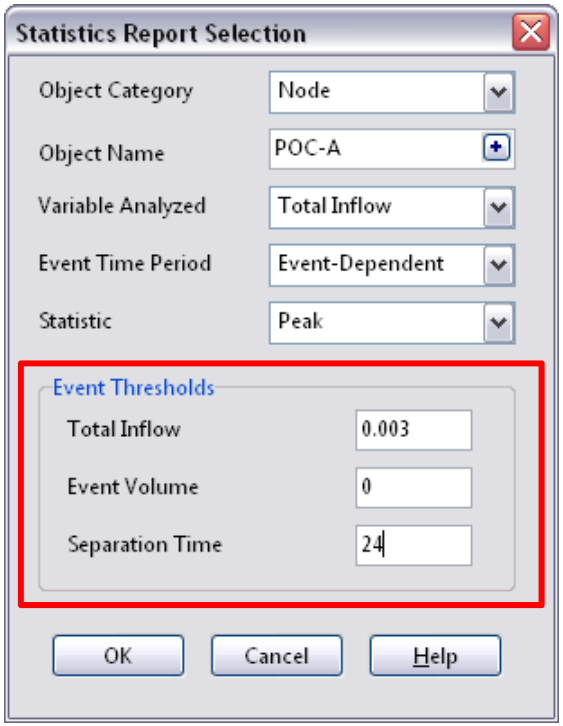


Post-project (Mitigated Scenario 1) Condition

Flow Frequency Statistics

- Report -> Statistics -> “Statistics Report Selection”
- Input the selections shown below.
  - Note: The “Total Inflow” Event Threshold is defined as 0.002 cfs/acre x Total Drainage Area





Statistics

Σ Statistics - Node POC-A Total Inflow

Summary | Events | Histogram | Frequency Plot

```
S U M M A R Y   S T A T I S T I C S
===================================
Object  ............. Node POC-A
Variable ............ Total Inflow  (CFS)
Event Period ........ Variable
Event Statistic ..... Peak  (CFS)
Event Threshold ..... Total Inflow > 0.0030  (CFS)
Event Threshold ..... Event Volume > 0.0000 (ft3)
Event Threshold ..... Separation Time >= 24.0  (hr)
Period of Record ..... 10/04/1962 to 05/23/2008

Number of Events ..... 579
Event Frequency*...... 0.056
Minimum Value ........ 0.003
Maximum Value ........ 1.047
Mean Value ........... 0.042
Std. Deviation ....... 0.092
Skewness Coeff. ...... 6.066

*Fraction of all reporting periods belonging to an ev
```

- SWMM's built-in statistics are based on the Weibull Plotting Position

Σ Statistics - Node POC-A Total Inflow

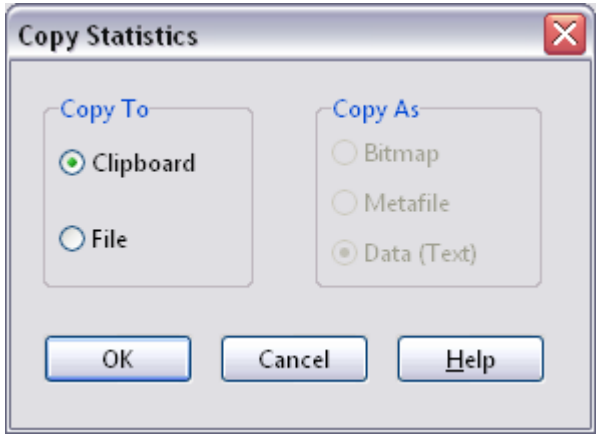
Summary | Events | Histogram | Frequency Plot

Rank	Start Date	Event Duration (hours)	Event Peak (CFS)	Exceedance Frequency (percent)	Return Period (years)
1	02/13/1980	232.0	1.047	0.17	47.00
2	01/09/1978	77.0	0.836	0.34	23.50
3	01/28/1980	100.0	0.646	0.52	15.67
4	12/27/1978	106.0	0.589	0.69	11.75
5	02/28/1970	67.0	0.559	0.86	9.40
6	11/22/1965	91.0	0.516	1.03	7.83
7	11/30/2007	59.0	0.503	1.21	6.71
8	01/03/1995	84.0	0.485	1.38	5.88
9	02/18/2005	157.0	0.443	1.55	5.22
10	03/05/1995	66.0	0.431	1.72	4.70
11	02/26/1983	205.0	0.382	1.90	4.27
12	12/17/1978	89.0	0.378	2.07	3.92

Post-project (Mitigated Scenario 1) Condition

Copy Statistics

- On the Statistics tab, click the top left corner of the table to highlight the entire table.
- Edit - > Copy to… -> “Copy Statistics”



External Post-processing Spreadsheet

- Open “SWMM_PostProcessing.xlsx”
- Click on the “PostMit-Q” tab and paste Post-project (Mitigated Scenario 1) Condition statistics in the highlighted cell
- Make adjustments to “Column I” as necessary to determine the Q_2, Q_5, and Q_{10} values.

Post-project (Mitigated Scenario 1)

10-year Q:	0.567	cfs
5-year Q:	0.438	cfs
2-year Q:	0.251	cfs

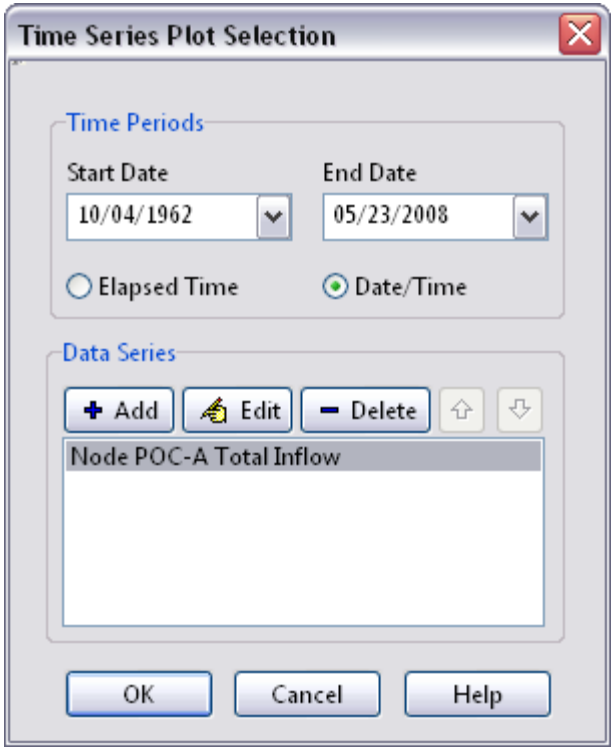
Lower Flow Threshold:	10%	
0.1xQ2 (Pre):	0.025	cfs

	A	B	C	D	E	F
1						
2	Post-project (Mitigated) Flow Frequency - Long-term					
3						
4	SWMM Training - Example Project - Post-project (Mitigated Scenario 1) Conditic					
5	Statistics - Node POC-A Total Inflow					
6			Event	Event	Exceedance	Return
7			Duration	Peak	Frequency	Period
8	Rank	Start Date	(hours)	(CFS)	(percent)	(years)
9	1	2/13/1980	232	1.047	0.17	47
10	2	1/9/1978	77	0.836	0.34	23.5
11	3	1/28/1980	100	0.646	0.52	15.67
12	4	12/27/1978	106	0.589	0.69	11.75
13	5	2/28/1970	67	0.559	0.86	9.4
14	6	11/22/1965	91	0.516	1.03	7.83
15	7	11/30/2007	59	0.503	1.21	6.71
16	8	1/3/1995	84	0.485	1.38	5.88
17	9	2/18/2005	157	0.443	1.55	5.22
18	10	3/5/1995	66	0.431	1.72	4.7
19	11	2/26/1983	205	0.382	1.9	4.27
20	12	12/17/1978	89	0.378	2.07	3.92
21	13	2/27/1978	187	0.369	2.24	3.62
22	14	10/27/2004	56	0.342	2.41	3.36
23	15	12/3/1966	119	0.321	2.59	3.13
24	16	1/6/1993	113	0.302	2.76	2.94
25	17	12/28/2004	104	0.294	2.93	2.76
26	18	2/15/1986	52	0.289	3.1	2.61
27	19	2/7/1993	63	0.275	3.28	2.47
28	20	1/5/1979	66	0.252	3.45	2.35
29	21	1/14/1978	136	0.252	3.62	2.24
30	22	12/9/1965	193	0.252	3.79	2.14
31	23	1/9/1980	115	0.252	3.97	2.04
32	24	3/14/1982	135	0.25	4.14	1.96
33	25	11/29/1982	66	0.247	4.31	1.88

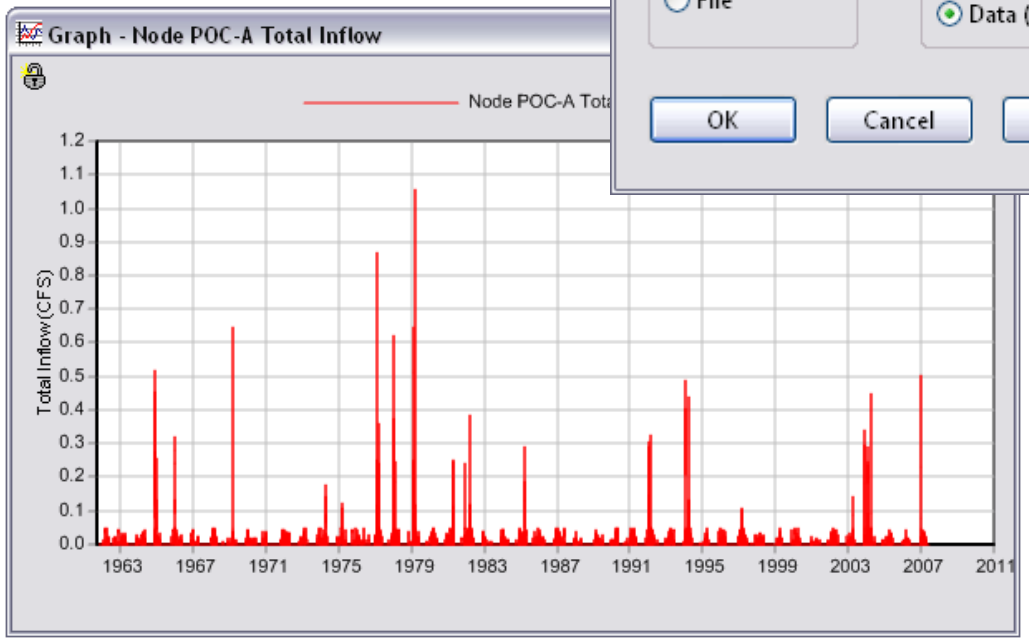
Disclaimer | Pre-Q | Post-Q | PostMit-Q | FF_Summ

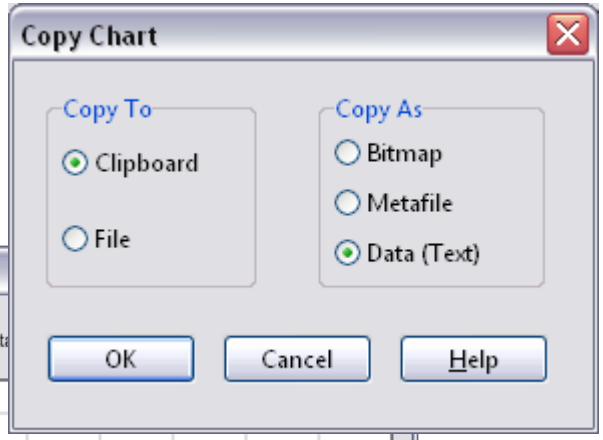
Copy Time-series

- Next, let's extract the runoff hydrograph time-series to calculate the flow durations.
- Report - > Graph - > Time Series - > "Time Series Plot Selection"
- Edit - > Copy to… - > "Copy Chart"

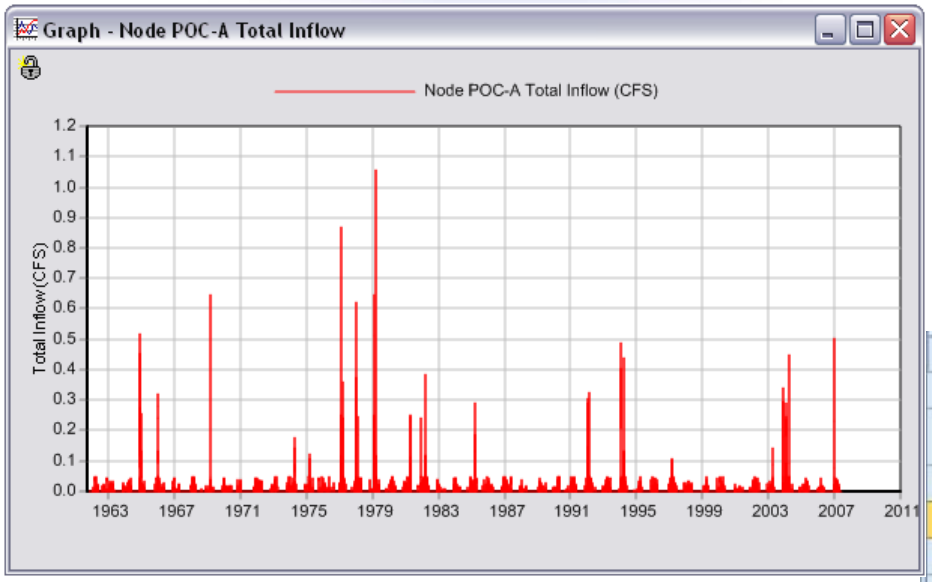


Post-project (Mitigated Scenario 1) Condition





External Post-processing Spreadsheet



Post-project (Mitigated Scenario 1) Condition

- Click on the "PostMit-TS" tab and paste Post-project (Mitigated) Condition runoff hydrograph (time-series) in the highlighted cell

	A	B	C	D	E	F
1						
2	Post-project (Mitigated) Time Series - Long-term					
3						
4	Node POC-A Tota	Inflow (CFS)				
5		Total Inflow (CFS)				
6	10/4/62 16:00	0				
7	10/4/62 17:00	0				
8	10/4/62 18:00	0				
9	10/4/62 19:00	0				
10	10/4/62 20:00	0				
11	10/4/62 21:00	0				
12	10/4/62 22:00	0				
13	10/4/62 23:00	0				
14	10/5/62 0:00	0				
15	10/5/62 1:00	0				
16	10/5/62 2:00	0				
17	10/5/62 3:00	0				
18	10/5/62 4:00	0				
19	10/5/62 5:00	0				

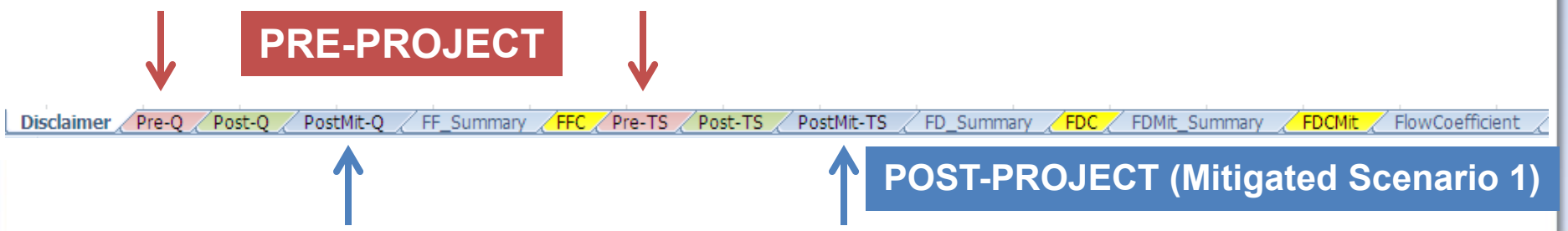
Pre-TS | Post-TS | PostMit-TS | FD_Summary | FDC | FDMit_Summa

Results?

- Let's take a look at the **post-processing spreadsheet**…

- Flow Frequency
  - Tables: "FF_Summary" tab
  - Curves: "FFC" tab

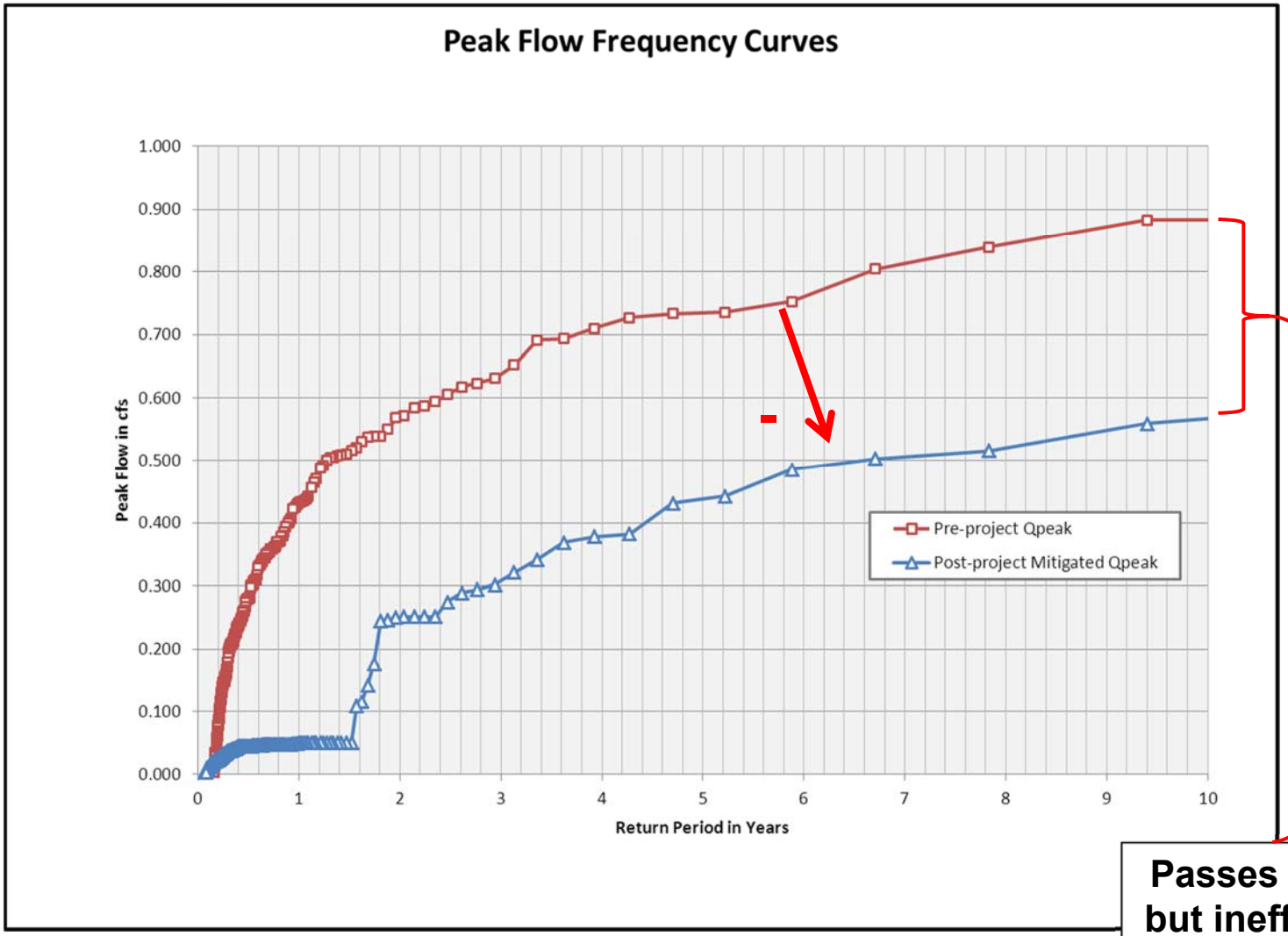
- Flow Duration
  - Tables: "FDMit_Summary" tab
  - Curves: "FDCMit" tab



Flow Frequency: Table

Return Period	Pre-project Qpeak (cfs)	Post-project - Unmitigated Q (cfs)	Post-project - Mitigated Q (cfs)
LF = 0.1xQ2	0.057	0.063	0.025
2-year	0.570	0.627	0.251
5-year	0.734	0.811	0.438
10-year	0.883	0.921	0.567

Flow Frequency: Curves



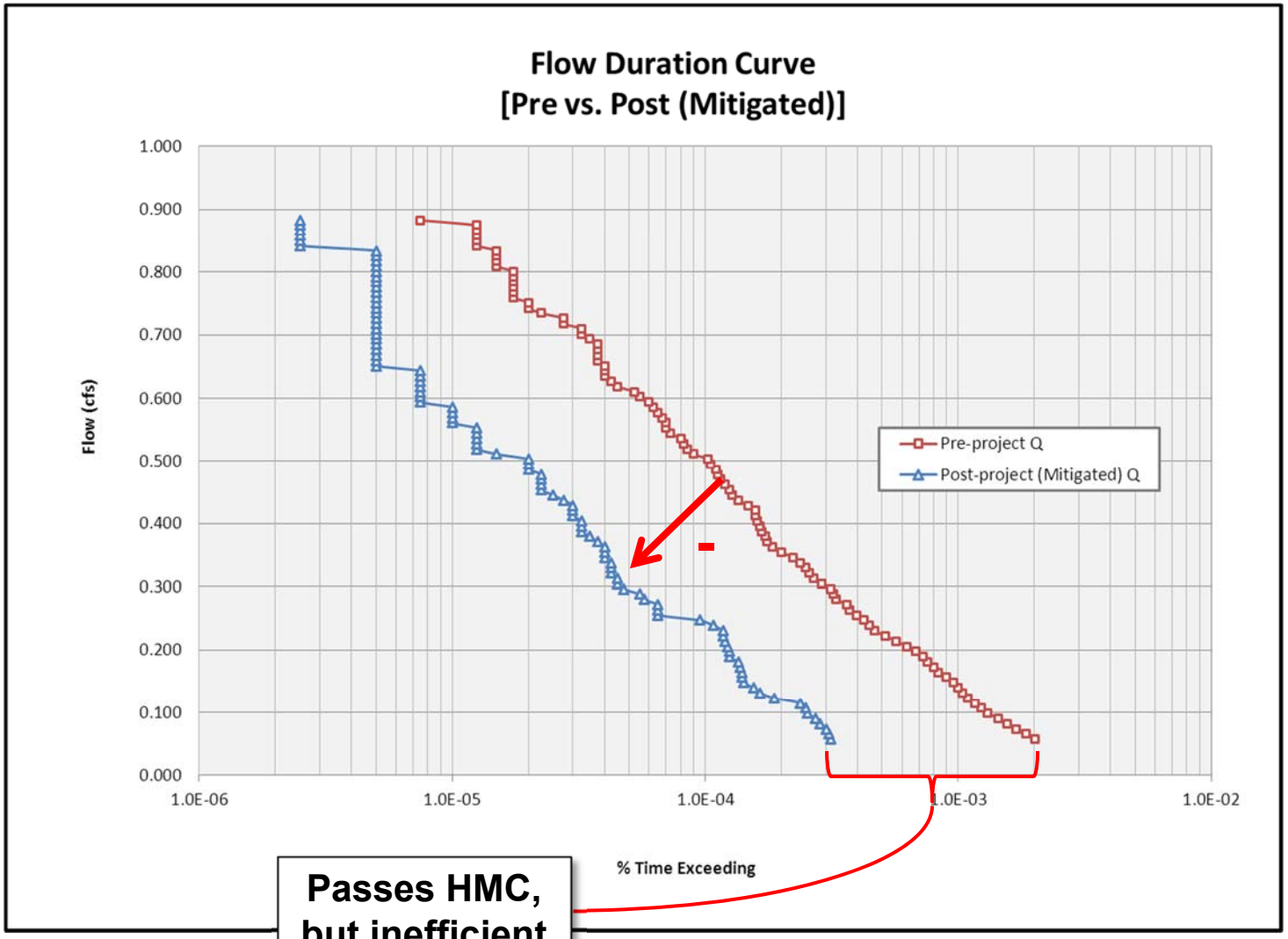
Passes HMC, but inefficient

Flow Duration: Table

	A	B	C	D	E	F	G	H
1		Low-flow Threshold:	10%					
2		0.1xQ2 (Pre):	0.057	cfs				
3		Q10 (Pre):	0.883	cfs				
4		Ordinate #:	100					
5		Incremental Q (Pre):	0.00826	cfs				
6		Total Hourly Data:	400032	hours			The proposed BMP:	PASSED
7								
8	Interval	Pre-project Flow (cfs)	Pre-project Hours	Pre-project % Time Exceeding	Post-project Hours	Post-project % Time Exceeding	Percentage	Pass/Fail
9	0	0.057	801	2.00E-03	125	3.12E-04	16%	Pass
10	1	0.065	743	1.86E-03	123	3.07E-04	17%	Pass
11	2	0.073	680	1.70E-03	120	3.00E-04	18%	Pass
12	3	0.082	627	1.57E-03	114	2.85E-04	18%	Pass
13	4	0.090	577	1.44E-03	109	2.72E-04	19%	Pass
14	5	0.098	524	1.31E-03	101	2.52E-04	19%	Pass
15	6	0.107	492	1.23E-03	100	2.50E-04	20%	Pass
16	7	0.115	466	1.16E-03	95	2.37E-04	20%	Pass
17	8	0.123	437	1.09E-03	75	1.87E-04	17%	Pass
18	9	0.131	417	1.04E-03	66	1.65E-04	16%	Pass
99	90	0.800	7	1.75E-05	2	5.00E-06	29%	Pass
100	91	0.809	6	1.50E-05	2	5.00E-06	33%	Pass
101	92	0.817	6	1.50E-05	2	5.00E-06	33%	Pass
102	93	0.825	6	1.50E-05	2	5.00E-06	33%	Pass
103	94	0.833	6	1.50E-05	2	5.00E-06	33%	Pass
104	95	0.842	5	1.25E-05	1	2.50E-06	20%	Pass
105	96	0.850	5	1.25E-05	1	2.50E-06	20%	Pass
106	97	0.858	5	1.25E-05	1	2.50E-06	20%	Pass
107	98	0.866	5	1.25E-05	1	2.50E-06	20%	Pass
108	99	0.875	5	1.25E-05	1	2.50E-06	20%	Pass
109	100	0.883	3	7.50E-06	1	2.50E-06	33%	Pass
110								

PostMit-Q | FF_Summary | FFC | Pre-TS | Post-TS | PostMit-TS | FD_Summary | FDC | FDMit_Summary

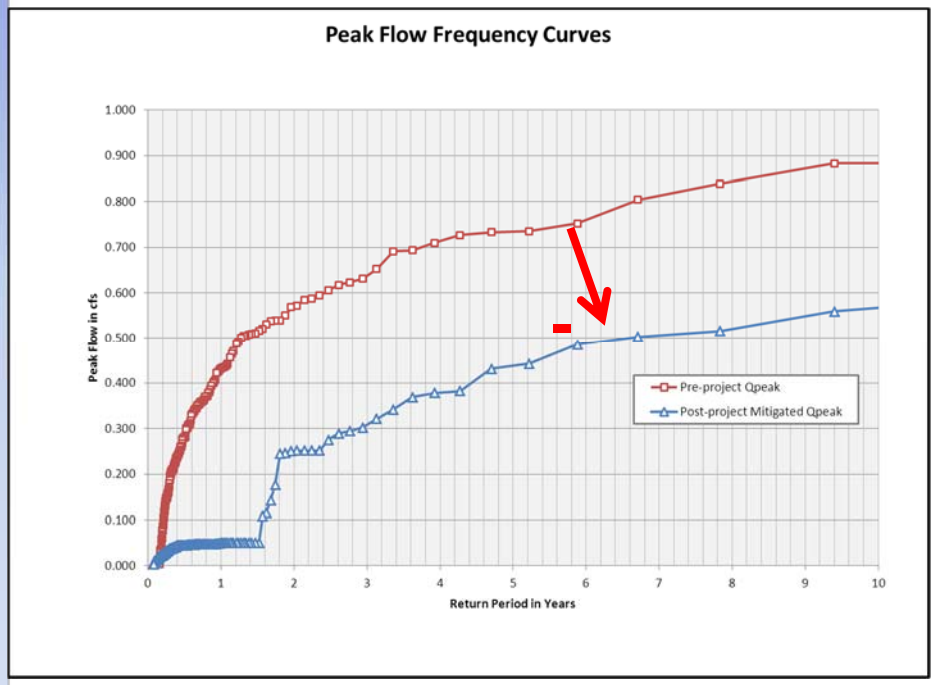
Flow Frequency: Curves



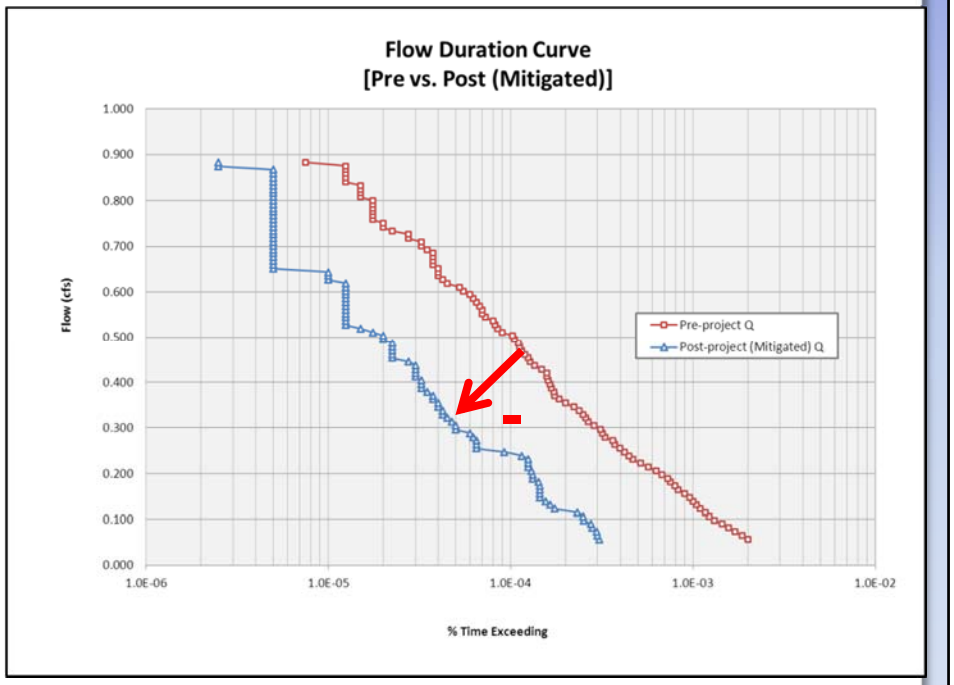
Passes HMC, but inefficient

Results Summary

- Now, let's compare the Pre-project and Post-project (Mitigated Scenario 1) Condition **peak flow frequency statistics** and **flow duration** (time-series) results within our HMP Flow range $0.1xQ_2$ to Q_{10}.



Decrease in Peak Flow Frequency



Decrease in Flow Durations

Passes the HMP Flow Control Performance Standards

∴ The Biofiltration Basin design is working solution.

Post-processing Complete!

The **post-processing analysis** for the *Post-project (Mitigated Scenario 1)* model is now complete!

What if we add additional HMP outlets? Next, let's set-up a **Post-project (Mitigated Scenario 2)** model to find out.

Example Project – Institutional Living

POST-PROJECT (MITIGATED) MODEL SETUP FOR SCENARIO 2

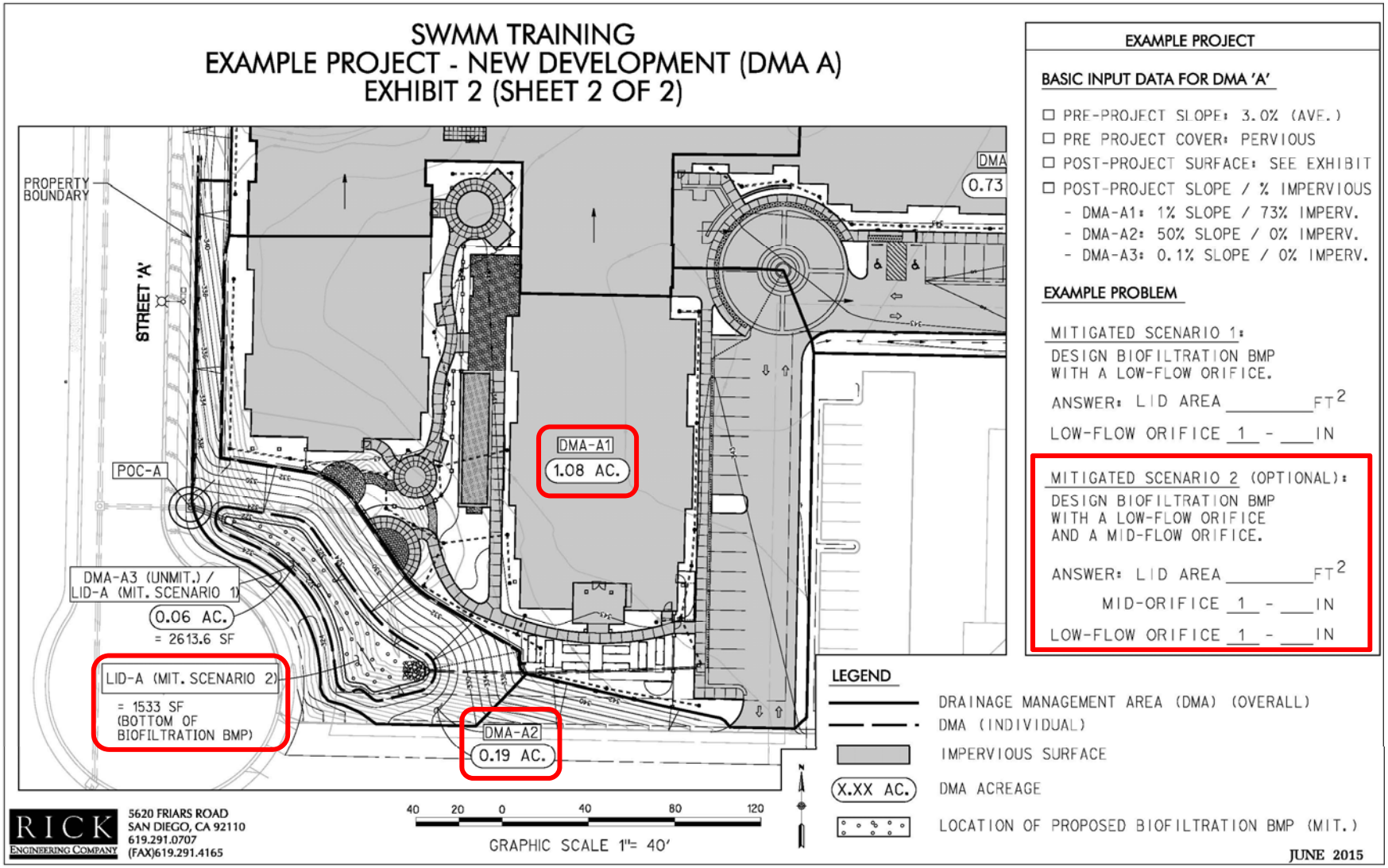
Provide More Flow Control

- Although the Post-project (Mitigated Scenario 1) model provided a working solution with a single Low-Flow Restrictor (orifice), the large gap between the Flow Frequency and Flow Duration curves indicates that we could develop a more efficient set of outlet works.

- Let's design a Post-project (Mitigated Scenario 2) Condition set of outlet works including a Mid-Flow Restrictor (orifice) on the side of the emergency overflow structure by building off of the Scenario 1 working solution.

- As Dory would sing, "Just keep SWMMing, just keep SWMMing!"

Drainage Management Area "A"



Scenario 2 Working Solution

- Recall, the Required Water Quality Volume is approximately 1,890 CF.
  - The entire Required Water Quality Volume must be treated; therefore, the Mid-Flow Restrictor flowline must be set at or above the Required Water Quality Volume.

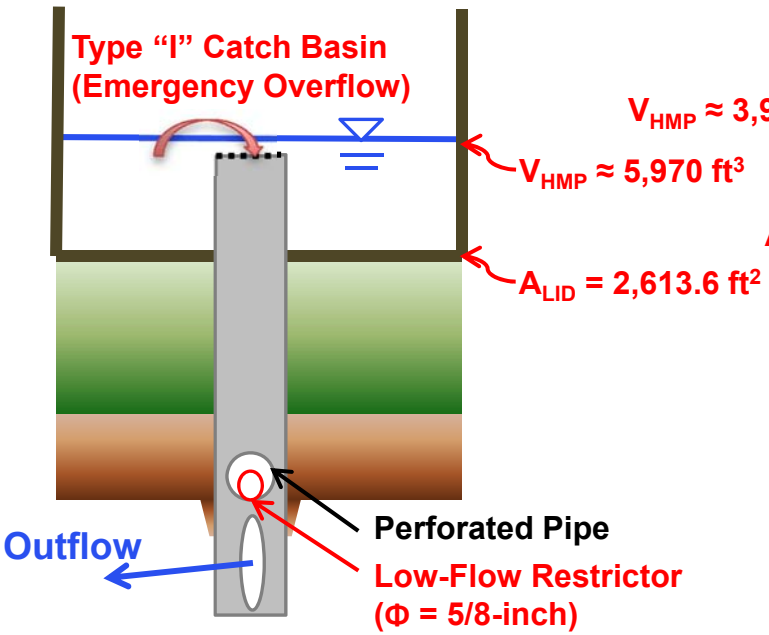
- Several iterations later…

- Working Solution Biofiltration Basin Cross-section
  - 12-inch Freeboard & Q_{100} Conveyance
    - Type "I" Grated Catch Basin (per SDRSD D-29) with Mid-Flow Restrictor (Φ = 1 1/2-inch (or 1.5-inches)) set 3-inches above the bottom of the basin ($V_{WQ,req.}$ @ ≈ 1-inch ponding)
  - 12-inch Surface Ponding Depth
  - 24-inch Engineered Soil (η=40%)
  - 12-inch Gravel Layer (η=40% or e=0.67)
  - 4-inch Perforated Pipe with Low-Flow Restrictor (Φ = 3/4-inch (or 0.75-inches))
    - Both flowlines set at the bottom of the Gravel Layer
  - 3-inch Dead Storage Layer (Gravel)
    - Located longitudinally below the perforated pipe only
    - Does not provided storage volume

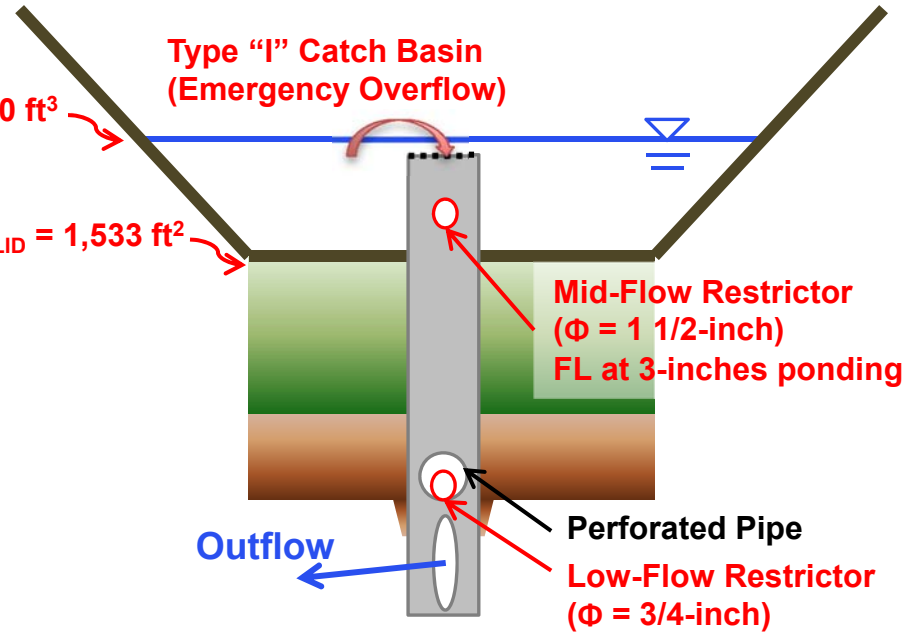
Outlet Works
Scenario 1 vs. Scenario 2

- Let's compare the two working solutions' outlet works.

Scenario 1: One Restrictor



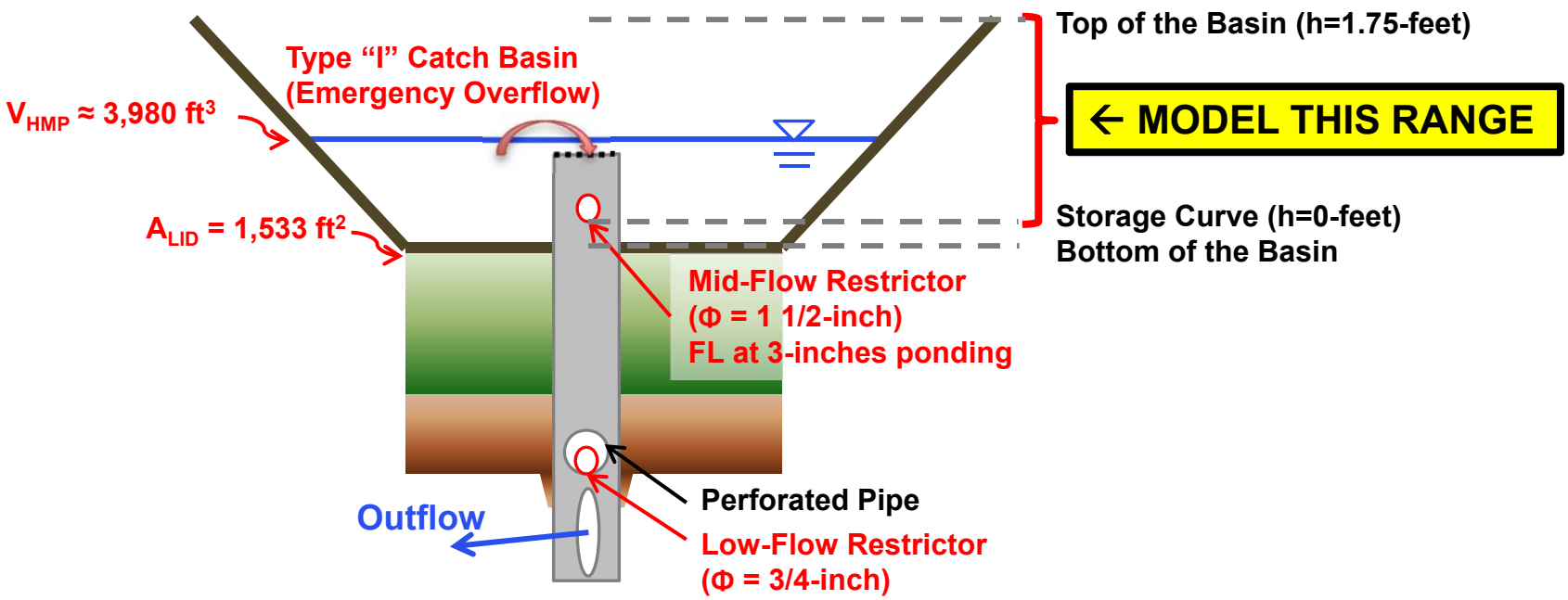
Scenario 2: Two Restrictors



Modeling "High Flows"

- Although adding a Mid-Flow Restrictor seems simple, it is not always straightforward to model in SWMM.
- For modeling the "high flows" (Mid-Flow Restrictor and emergency overflow), it is very important to remember the range of flows and volumes that are being modeled.

Scenario 2: Two Restrictors



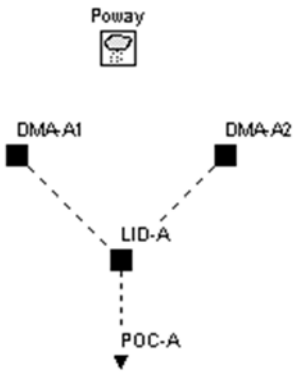
SWMM Models
Scenario 1 vs. Scenario 2

Scenario 1 Working Solution

1. Low-Flow Restrictor
   - Φ = 5/8-inch (or 0.625-inches)

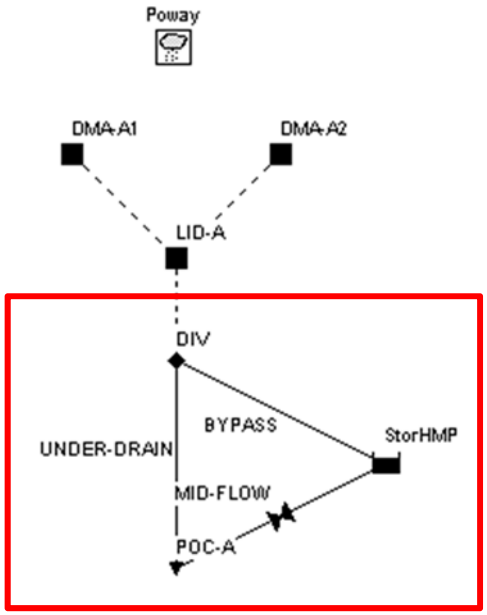
Scenario 2 Working Solution

1. Low-Flow Restrictor
   - Φ = 3/4-inch (or 0.75-inches)
2. Mid-Flow Restrictor
   - Φ = 1 1/2-inch (or 1.5-inches)
3. Type "I" Grated Catch Basin



New Objects

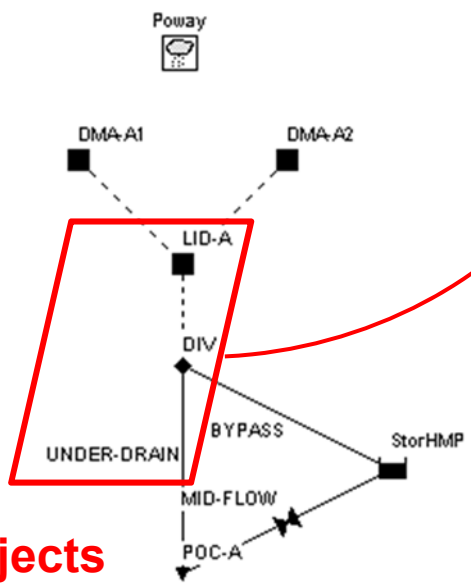
- 2 Nodes
- 3 Links
- 2 Curves



Additional SWMM Elements

Scenario 2 Working Solution

1. Low-Flow Restrictor
   - Φ = 3/4-inch (or 0.75-inches)
2. Mid-Flow Restrictor
   - Φ = 1 1/2-inch (or 1.5-inches)
3. Type "I" Grated Catch Basin

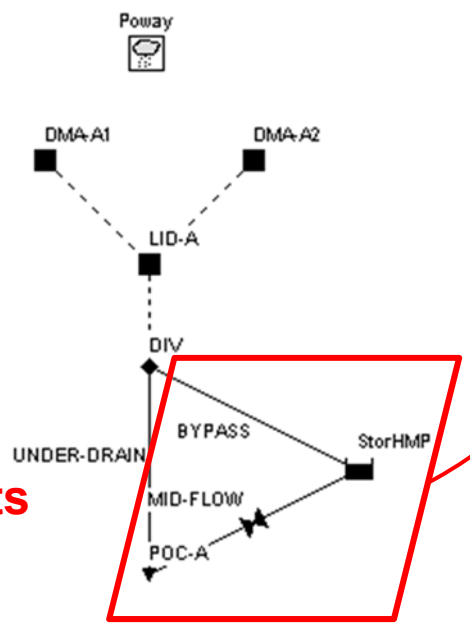


New Objects

- 1 Nodes
- 1 Links

Scenario 2 Working Solution

1. Low-Flow Restrictor
   - Φ = 3/4-inch (or 0.75-inches)
2. Mid-Flow Restrictor
   - Φ = 1 1/2-inch (or 1.5-inches)
3. Type "I" Grated Catch Basin

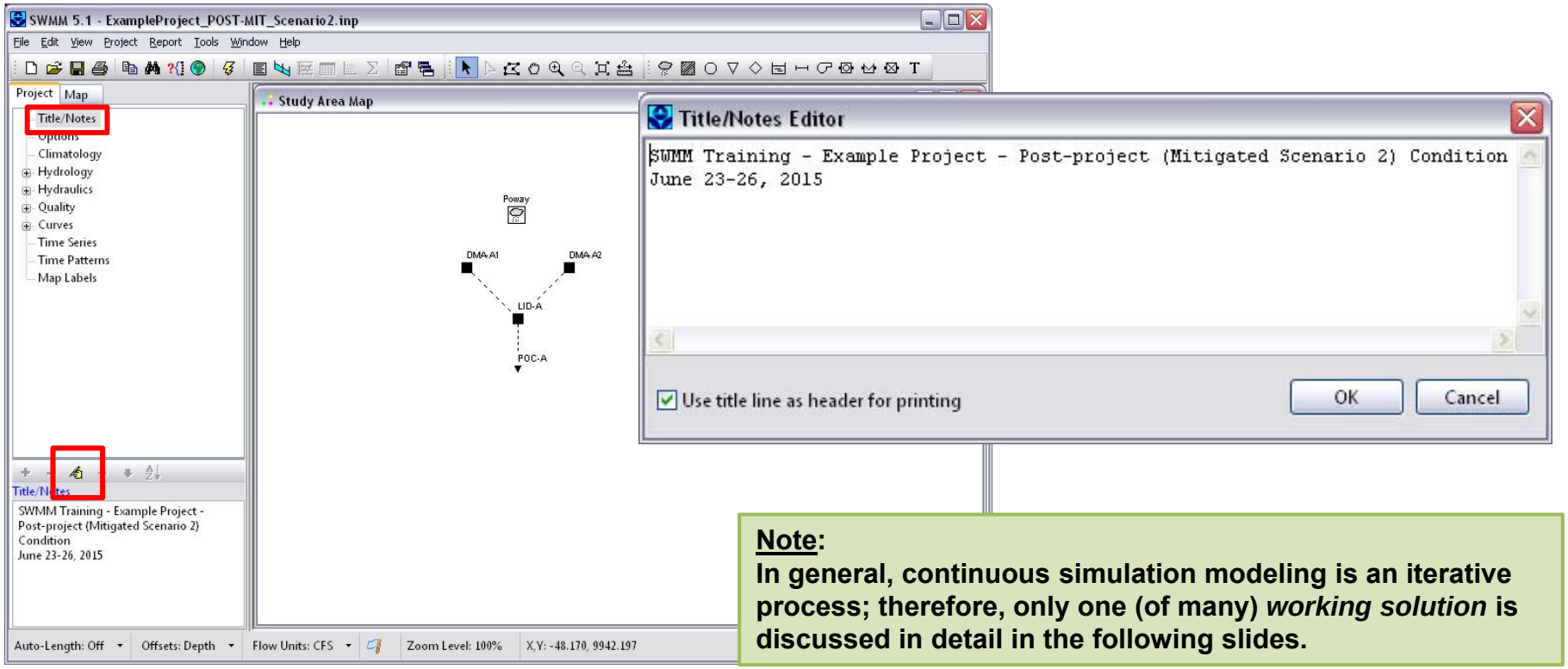


New Objects

- 1 Nodes
- 2 Links
- 2 Curves

New File

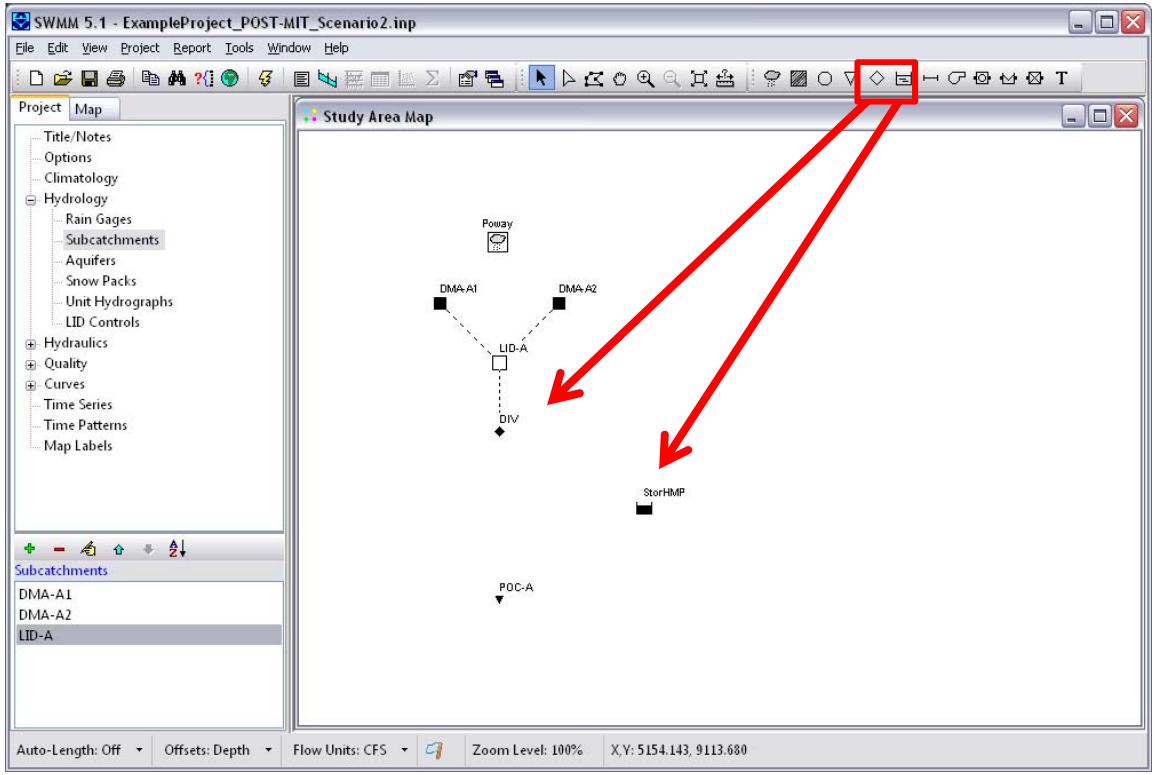
- Open the “ExampleProject_Post-Mit_Scenario1..inp”
- Save As “ExampleProject_Post-Mit_Scenario2.inp” in the folder “…\MyModel\” to create Scenario 2 of the Post-project (Mitigated) model.
- Update the “Title/Notes Editor” as shown below.



Note:
In general, continuous simulation modeling is an iterative process; therefore, only one (of many) *working solution* is discussed in detail in the following slides.

Add Divider & Storage Unit

- One way to model the Mid-Flow Restrictor is to separate treated flows exiting through the Low-Flow Restrictor from the high flows.
  - Insert a “Divider” by clicking “Add a flow divider node” from the “Object Toolbar.”
- Diverted flows must be sent to the “Storage Unit” Node to model the storage volume of the aforementioned high flows.
  - Insert a “Storage Unit” by clicking “Add a storage node” from the “Object Toolbar”
- Rename default labels…
  - “DIV1” - > “DIV”
  - “STOR1” - > “StorHMP”
- Now, connect “LID-A” to “DIV.”

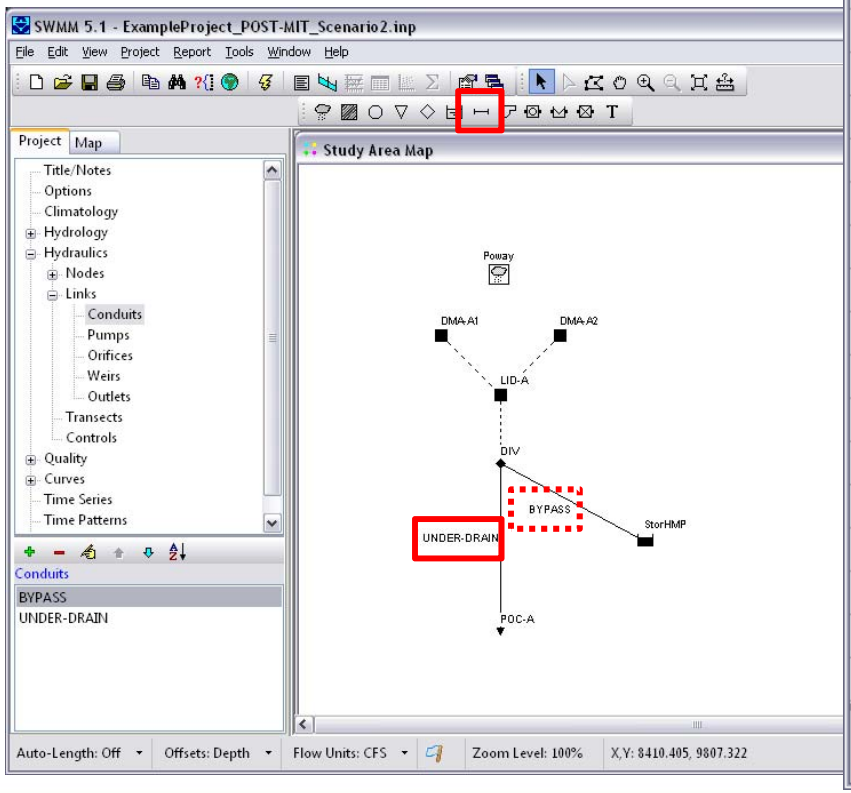


Subcatchment LID-A

Property	Value
Name	LID-A
X-Coordinate	3000.000
Y-Coordinate	6000.000
Description	
Tag	
Rain Gage	Poway
Outlet	DIV
Area	0.06

Add Conduit Links

- Add two (2) “Conduit” Links to split the flows. Click the upstream Node first, then click the downstream Node.
- Rename links as “BYPASS” and “UNDERDRAIN”



Low Flows (Low-Flow Restrictor)

Conduit UNDER-DRAIN

Property	Value
Name	UNDER-DRAIN
Inlet Node	DIV
Outlet Node	POC-A
Description	
Tag	
Shape	CIRCULAR
Max. Depth	0.33
Length	100
Roughness	0.013
Inlet Offset	0
Outlet Offset	0
Initial Flow	0
Maximum Flow	0
Entry Loss Coeff.	0
Exit Loss Coeff.	0
Avg. Loss Coeff.	0
Seepage Loss Rate	0
Flap Gate	NO
Culvert Code	

User-assigned name of Conduit

High Flows (Mid-Flow Restrictor and Emergency Overflow)

Conduit BYPASS

Property	Value
Name	BYPASS
Inlet Node	DIV
Outlet Node	StorHMP
Description	
Tag	
Shape	DUMMY
Max. Depth	0
Length	400
Roughness	0.01
Inlet Offset	0
Outlet Offset	0
Initial Flow	0
Maximum Flow	0
Entry Loss Coeff.	0
Exit Loss Coeff.	0
Avg. Loss Coeff.	0
Seepage Loss Rate	0
Flap Gate	NO
Culvert Code	

User-assigned name of Conduit

Edit Divider

- The Mid-Flow Restrictor is set at 3-inches above the bottom of the basin. All flows exiting the basin must first percolate through the engineered soil before exiting through the Low-Flow Restrictor. The "Cutoff Flow" represents the maximum flow rate leaving the "low flow" outlet. The Low-Flow Restrictor is *typically* more restrictive (i.e. smaller flow rate) than the percolation rate through the engineered soil; therefore, use the Orifice Equation to calculate the Q_{cutoff} for a ¾-inch orifice.

- Edit the Divider Properties as shown.

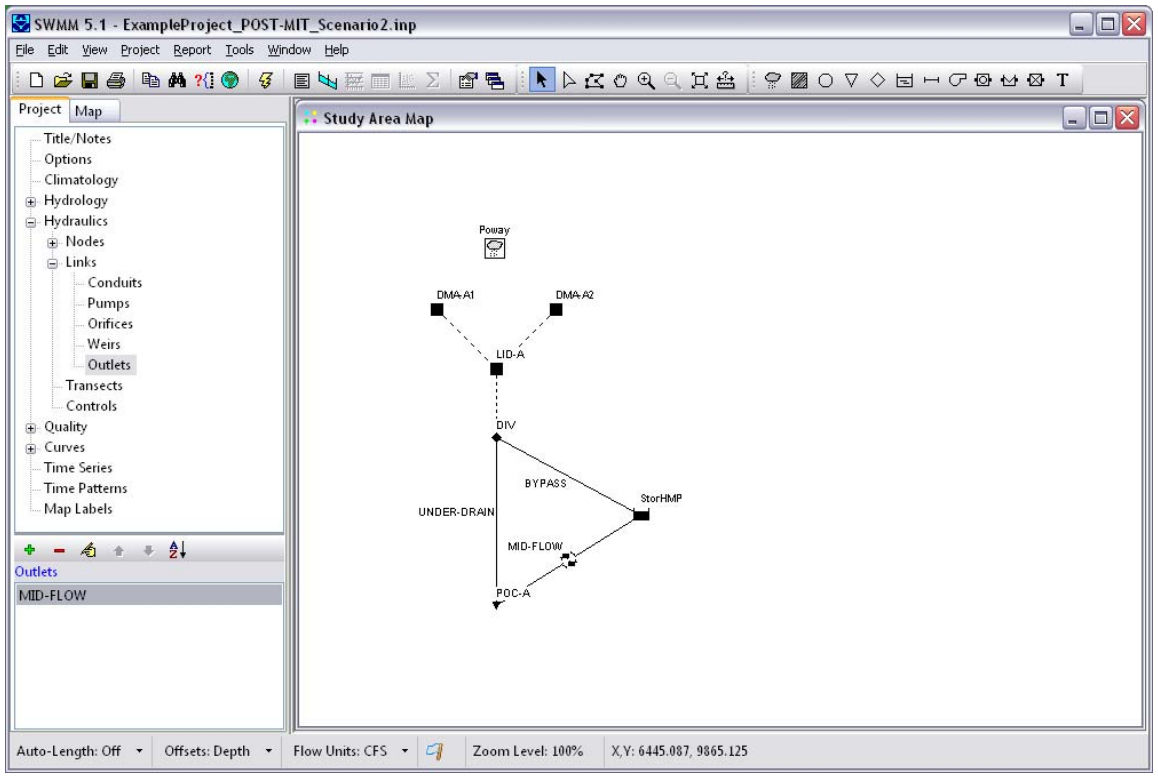
Divider DIV

Property	Value
Name	DIV
X-Coordinate	3000.000
Y-Coordinate	5000.000
Description	
Tag	
Inflows	NO
Treatment	NO
Invert El.	0
Max. Depth	0
Initial Depth	0
Surcharge Depth	0
Ponded Area	0
Diverted Link	BYPASS
Type	CUTOFF
Cutoff Divider	
Cutoff Flow	0.0265
Tabular Divider	
Curve Name	*
Weir Divider	
Min. Flow	0
Max. Depth	0
Coefficient	0

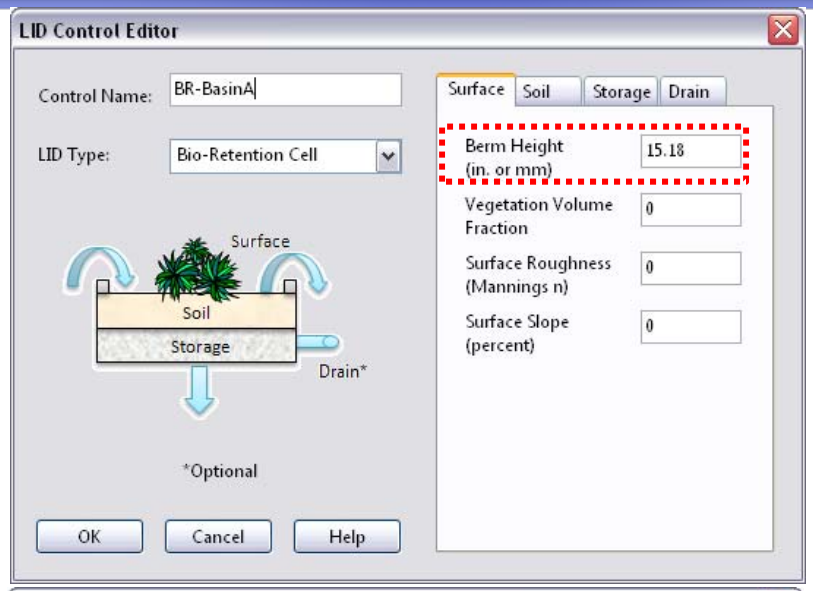
User-assigned name of divider

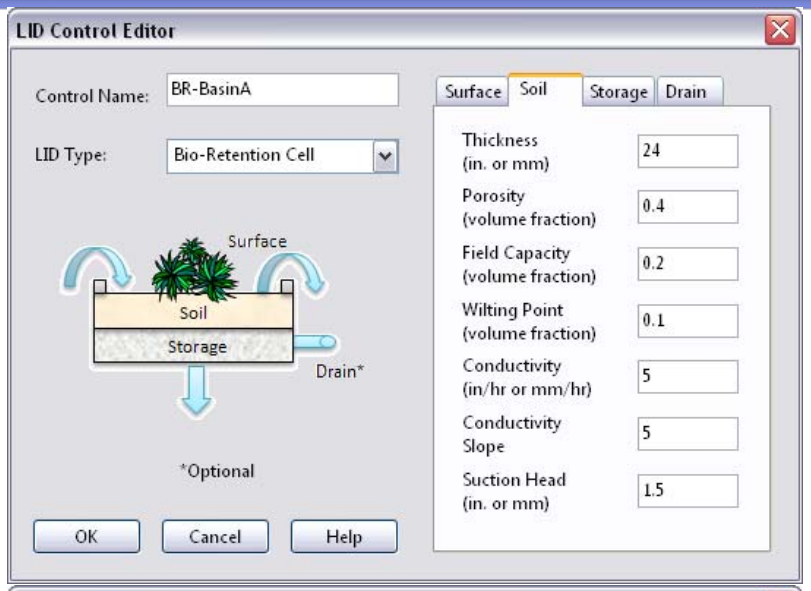
Add Outlet Link

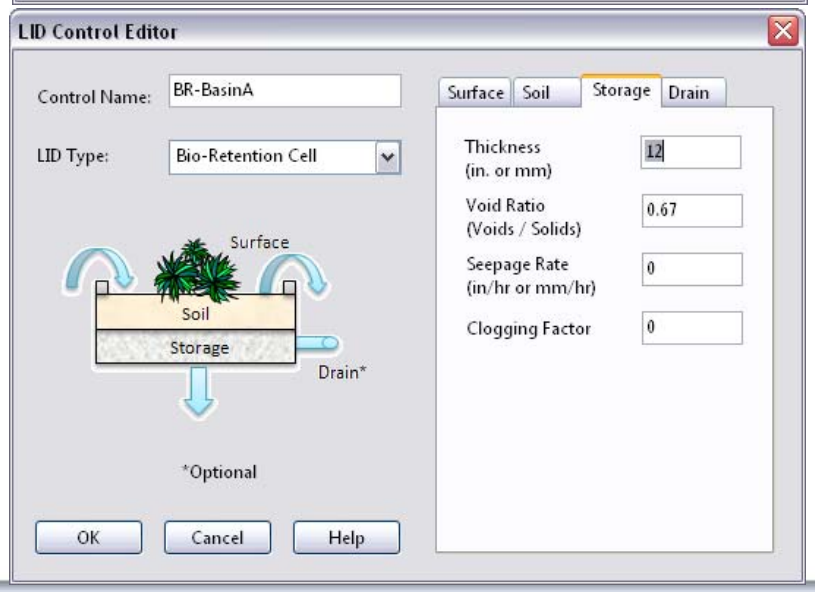
- Connect the “Storage Unit” Node (“StorHMP”) to the “Outfall” Node (“POC-A”) using an “Outlet” Link.
- Rename the “Outlet” Link to “MID-FLOW.”

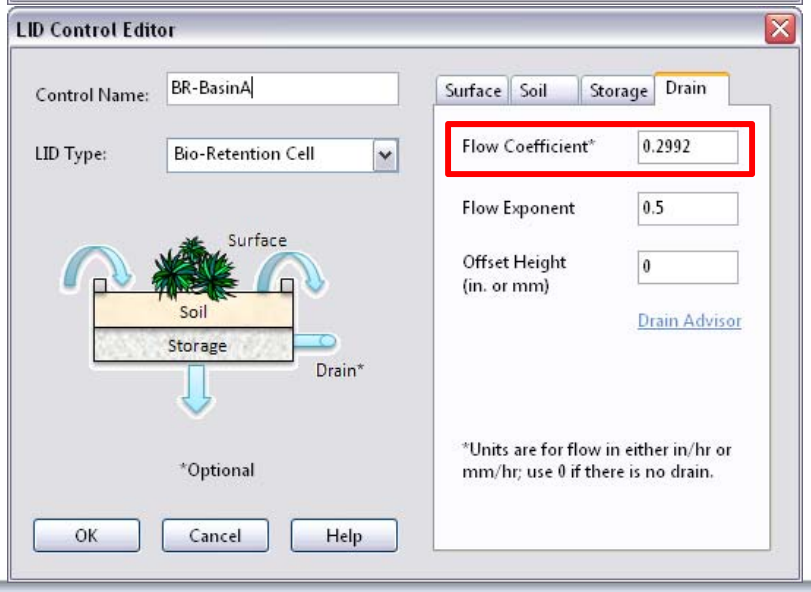


Edit LID Control

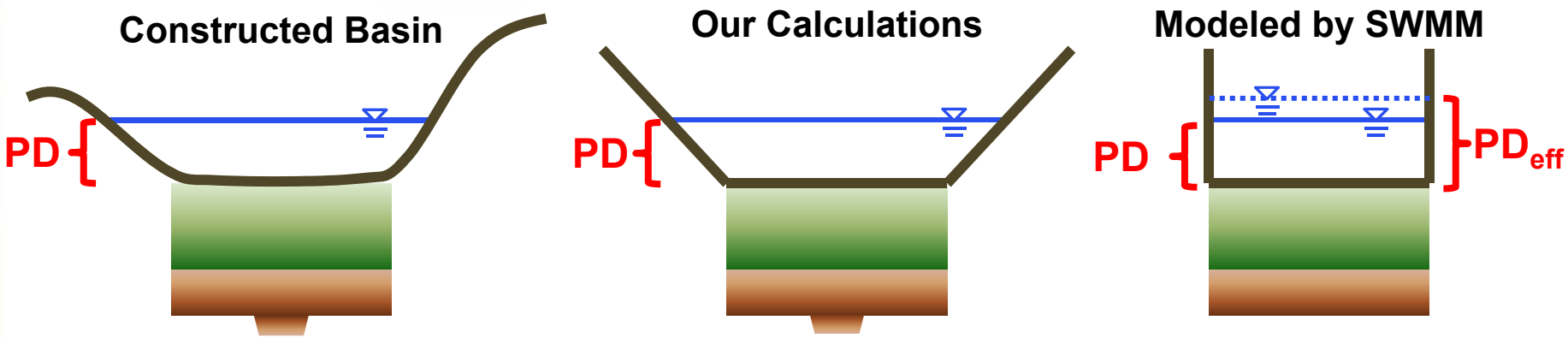








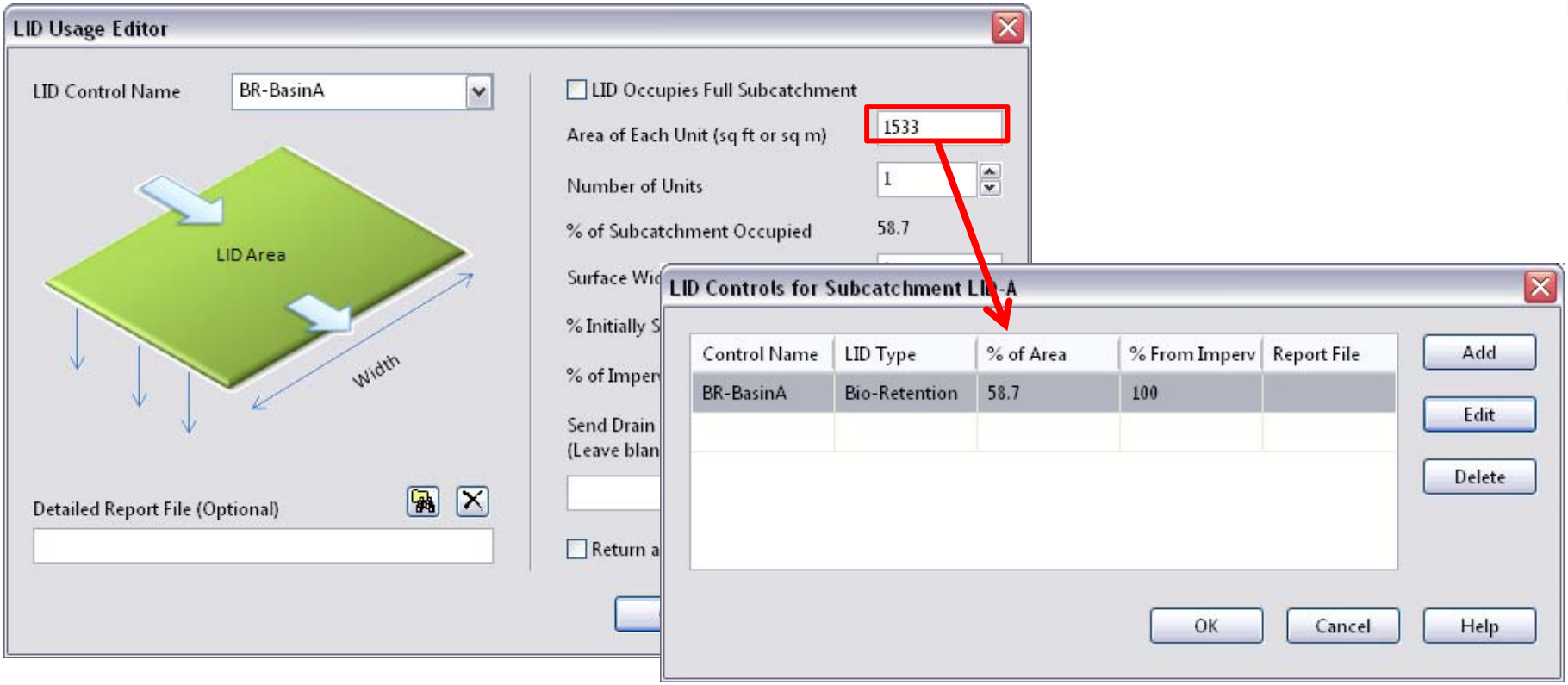
Actual vs. Modelled Storage Volume



- The LID Control for "Bio-Retention Cell" does <u>not</u> consider side slopes; therefore, a *optional modification* can be applied to the model to account for the *<u>full</u>* volume provided.
- In this example, the Ponding Depth (PD) is 12-inches. To model the full surface volume, the Ponding Depth must be increased to account for storage along the side slopes. Based on this basin configuration, the effective Ponding Depth (PD_{eff}) is calculated by dividing the surface storage volume by the surface area at the bottom of the basin (see "Flow Coefficient" tab).
  - Note: In the SWMM LID Control Editor, the "Berm Height" variable represents the Ponding Depth.

Update LID Usage Editor

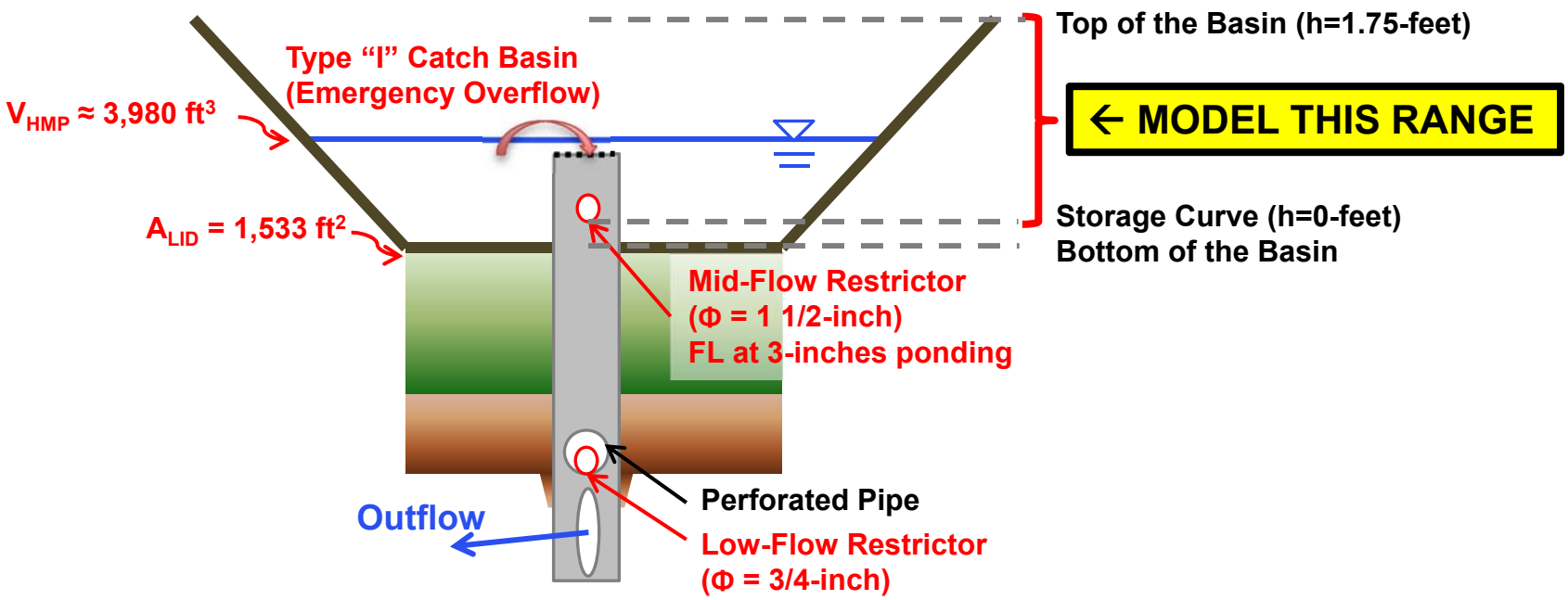
- The framework for modeling the “high flows” is nearly complete. As previously mentioned, a more efficient solution was found using a smaller biofiltration basin footprint; therefore, updates to the parameters are required for Subcatchment “LID-A.”
- Open “LID-A” properties
- Under “LID Controls,” click on “ … ” and edit “BR-BasinA.”



Storage and Release of the "High Flows"

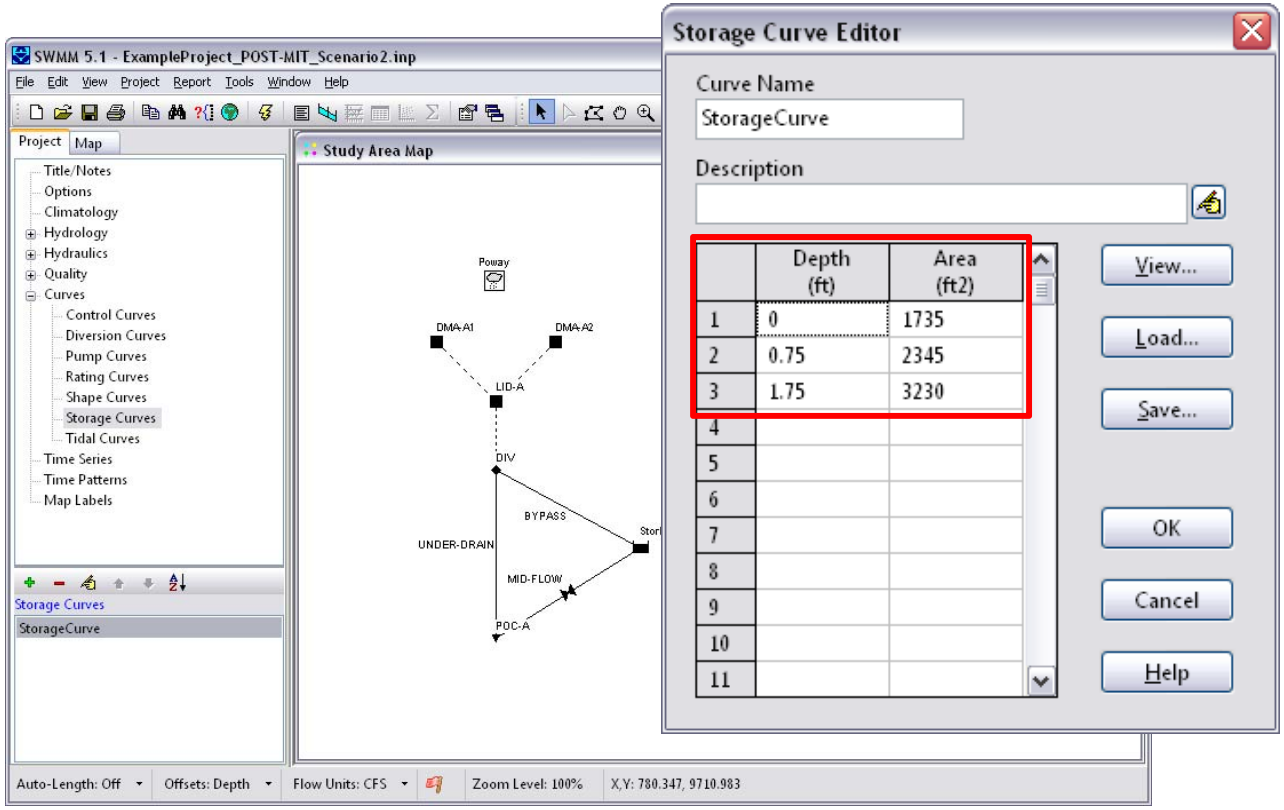
- Lastly, the storage volume and flow release rate must be modeled by using a "Storage Curve" and "Rating Curve," respectively.
- In the "Data Browser Panel," expand the "Curves" menu to add both curves.

Scenario 2: Two Restrictors



Add Storage Curve

- The Storage Curve requires the input of depth and surface area (not volume). The storage volume is calculated within the program. Insert values as shown.
- Open the “StorHMP” Node and define the tabular curve name as “StorageCurve.”



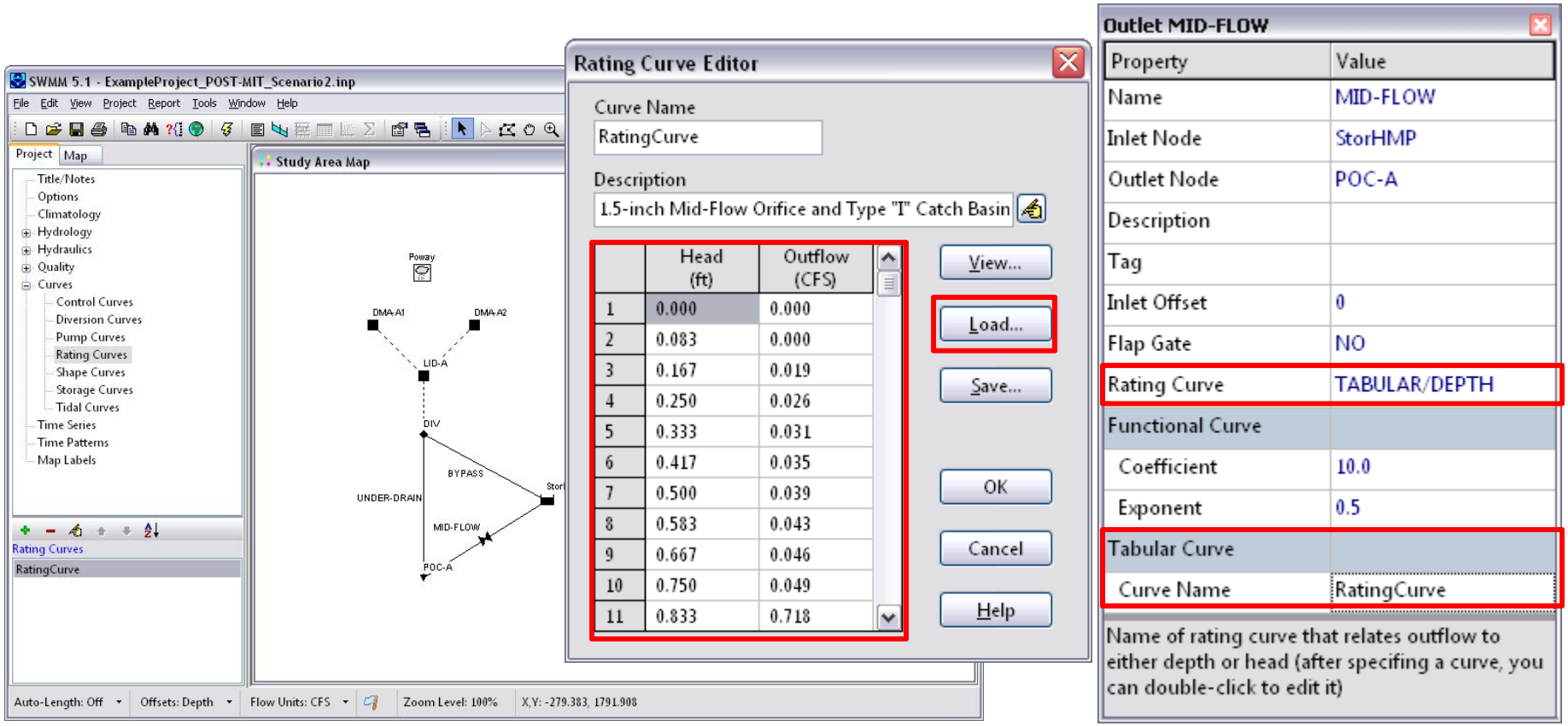
Storage Unit StorHMP

Property	Value
Name	StorHMP
X-Coordinate	5423.892
Y-Coordinate	3526.012
Description	
Tag	
Inflows	NO
Treatment	NO
Invert El.	0
Max. Depth	1.75
Initial Depth	0
Ponded Area	0
Evap. Factor	0
Seepage Loss	NO
Storage Curve	TABULAR
Functional Curve	
Coefficient	1000
Exponent	0
Constant	0
Tabular Curve	
Curve Name	StorageCurve

Maximum depth of the storage unit (ft)

Add Rating Curve

- The Rating Curve models both the Mid-Flow Restrictor and Emergency Overflow (Type “I” Catch Basin). This user-specified input allows flexibility in modeling.
- Open the “Rating Curve Editor” and load the .dat file called, “RatingCurve_Mid-Flow_CatchBasin.dat.”



Model Complete!

The *Post-project (Mitigated Scenario 2) Condition* model is now complete!

Next, let's run the **post-processing analysis** to see how the Biofiltration Basin performed.

Example Project – Institutional Living

POST-PROCESSING
POST-PROJECT MITIGATED SCENARIO 2

HMP Flow Control Performance Criteria

- The following are the ***peak flow*** and ***duration*** control requirements per the Final Hydromodification Management Plan, dated March 2011.

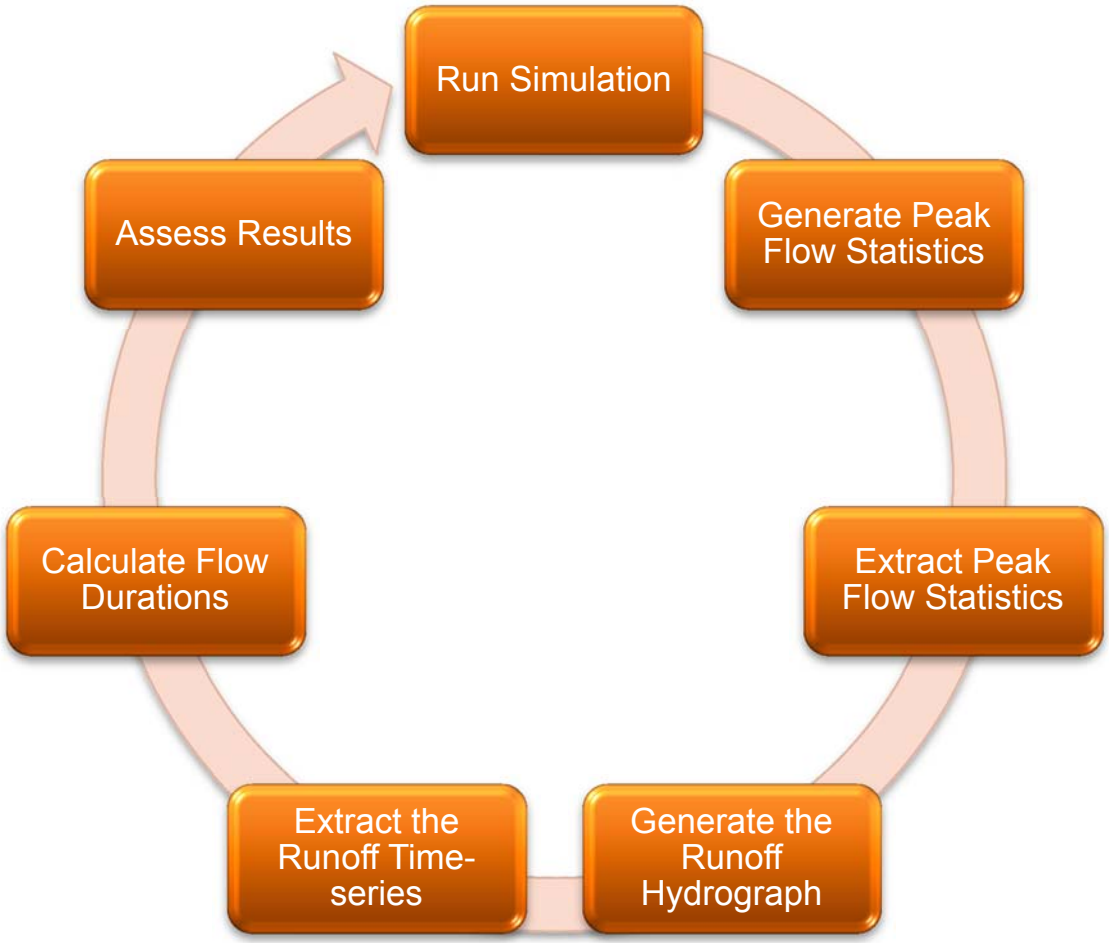
Section 6 Hydromodification Management Plan

Low-Impact Development (LID) and extended detention facilities are required to meet peak flow and duration controls as follows:

1. For flow rates ranging from 10 percent, 30 percent or 50 percent of the pre-project 2-year runoff event ($0.1Q_2$, $0.3Q_2$, or $0.5Q_2$) to the pre-project 10-year runoff event (Q_{10}), the post-project discharge rates and durations shall not deviate above the pre-project rates and durations by more than 10 percent over and more than 10 percent of the length of the flow duration curve. The specific lower flow threshold will depend on results from the SCCWRP channel screening study and the critical flow calculator.
2. For flow rates ranging from the lower flow threshold to Q_5, the post-project peak flows shall not exceed pre-project peak flows. For flow rates from Q_5 to Q_{10}, post-project peak flows may exceed pre-project flows by up to 10 percent for a 1-year frequency interval. For example, post-project flows could exceed pre-project flows by up to 10 percent for the interval from Q9 to Q10 or from Q5.5 to Q6.5, but not from Q8 to Q10.

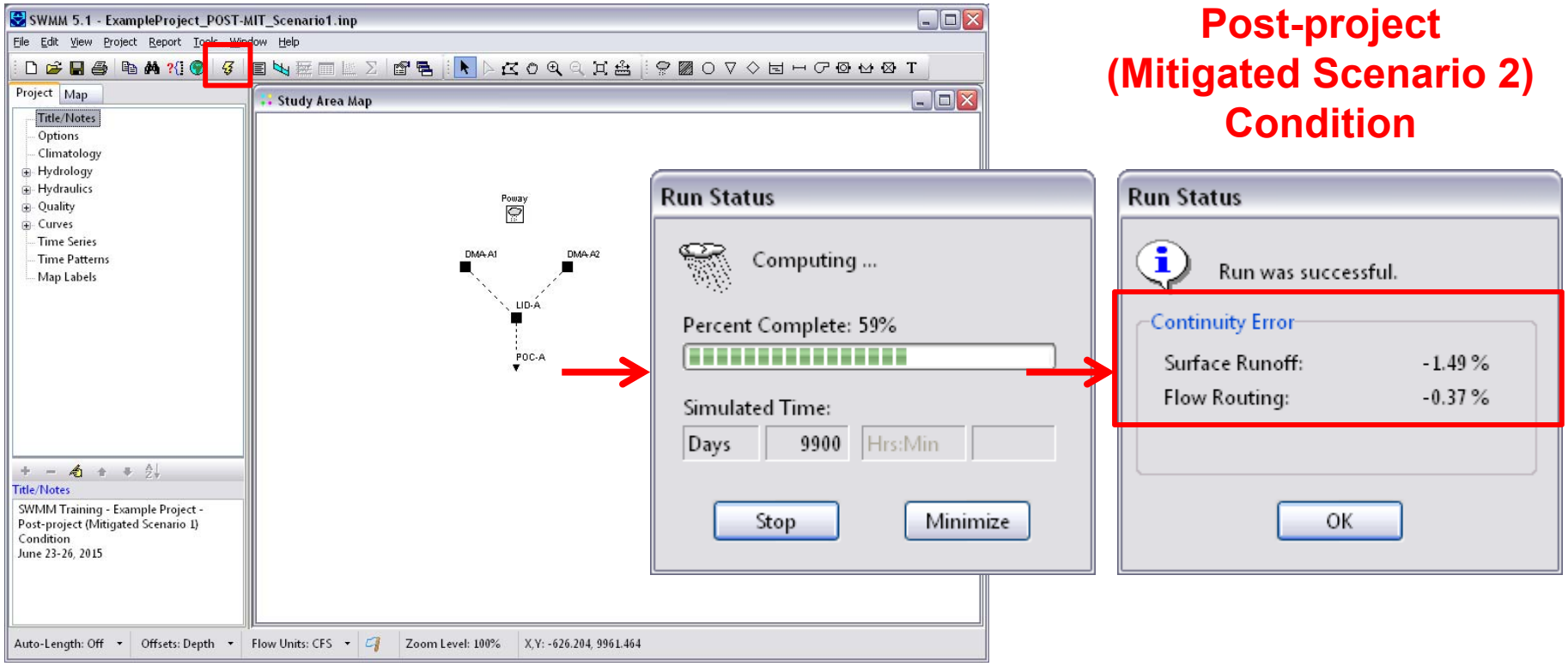
Recall…

- Let's repeat these steps for the Post-project (Mitigated) Condition…



Run Simulation

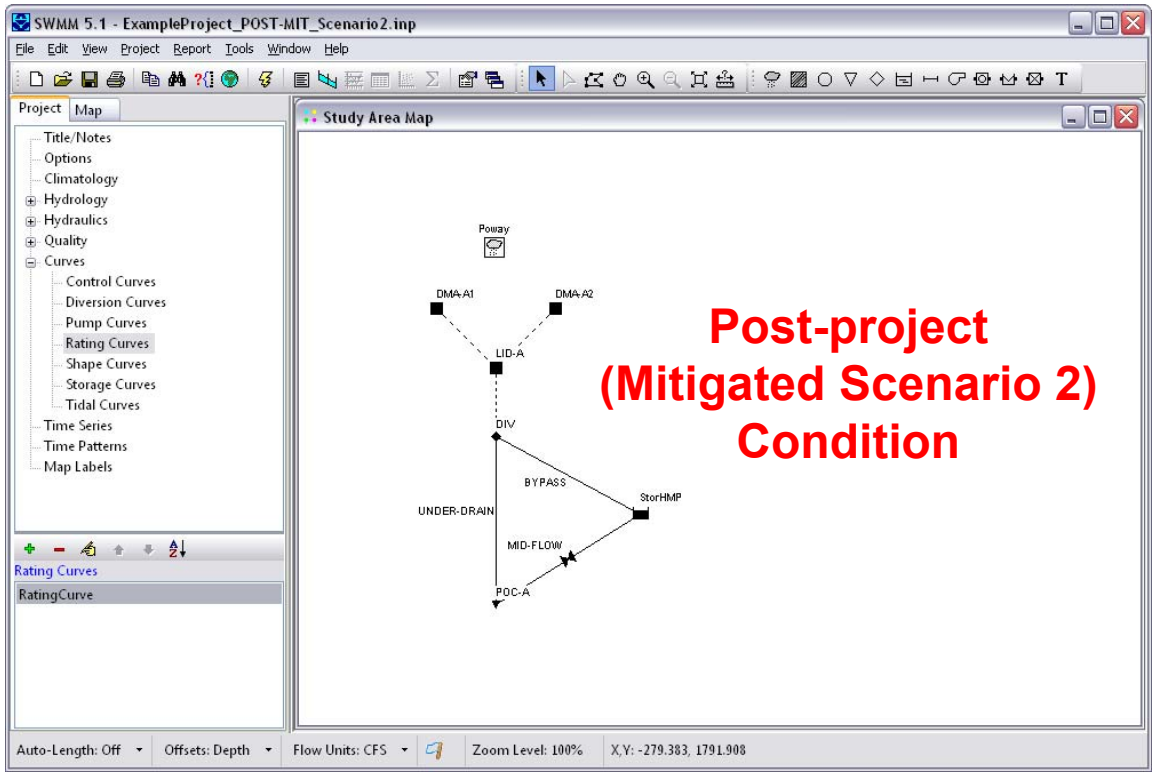
- Open the “ExampleProject_POST-MIT_Scenario2.inp” file
- Click the “Run a simulation” icon

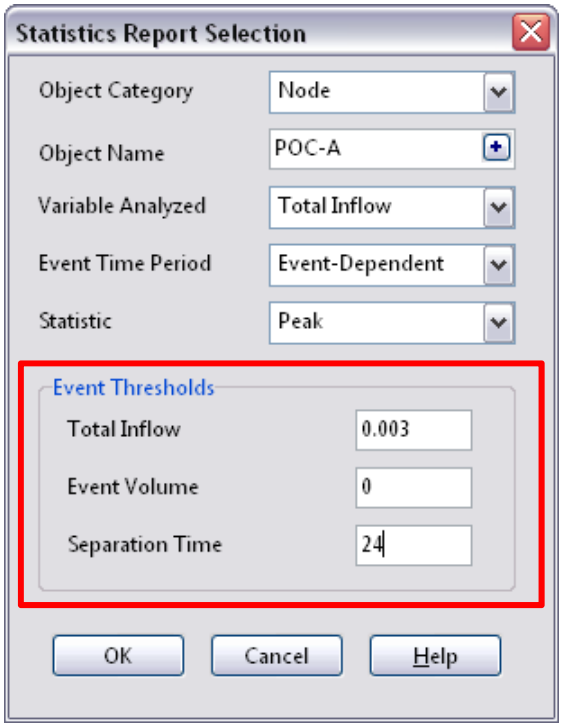


Post-project (Mitigated Scenario 2) Condition

Flow Frequency Statistics

- Report -> Statistics -> “Statistics Report Selection”
- Input the selections shown below.
  - Note: The “Total Inflow” Event Threshold is defined as 0.002 cfs/acre x Total Drainage Area





Statistics

Σ Statistics - Node POC-A Total Inflow

Summary | Events | Histogram | Frequency Plot

```
S U M M A R Y   S T A T I S T I C S
===================================
Object  ............... Node POC-A
Variable ............. Total Inflow  (CFS)
Event Period ......... Variable
Event Statistic ...... Peak  (CFS)
Event Threshold ...... Total Inflow > 0.0030  (CFS)
Event Threshold ...... Event Volume > 0.0000 (ft3)
Event Threshold ...... Separation Time >= 24.0  (hr)
Period of Record ..... 10/04/1962 to 05/23/2008

Number of Events ..... 762
Event Frequency*...... 0.040
Minimum Value ........ 0.003
Maximum Value ........ 1.002
Mean Value ........... 0.063
Std. Deviation ....... 0.139
Skewness Coeff. ...... 3.900

*Fraction of all reporting periods belonging to an event
```

- SWMM's built-in statistics are based on the Weibull Plotting Position

Σ Statistics - Node POC-A Total Inflow

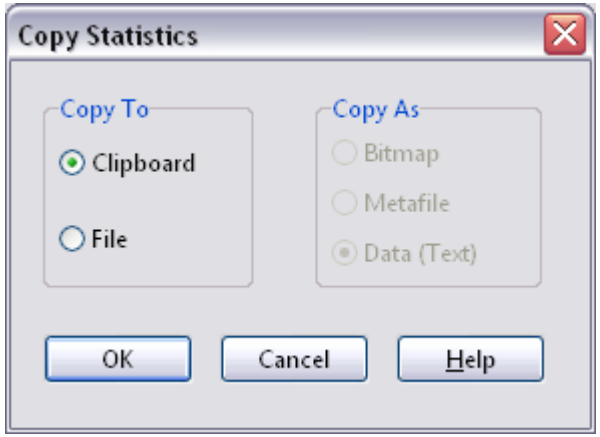
Summary | Events | Histogram | Frequency Plot

Rank	Start Date	Event Duration (hours)	Event Peak (CFS)	Exceedance Frequency (percent)	Return Period (years)
1	02/13/1980	202.0	1.002	0.13	47.00
2	03/21/1983	94.0	0.980	0.26	23.50
3	01/09/1978	48.0	0.880	0.39	15.67
4	03/17/1982	53.0	0.828	0.52	11.75
5	01/24/1995	61.0	0.816	0.66	9.40
6	11/12/1976	17.0	0.782	0.79	7.83
7	02/28/1970	52.0	0.750	0.92	6.71
8	02/06/1998	79.0	0.739	1.05	5.88
9	02/03/1998	47.0	0.733	1.18	5.22
10	12/17/1978	71.0	0.730	1.31	4.70
11	12/28/2004	45.0	0.716	1.44	4.27
12	02/14/1998	41.0	0.656	1.57	3.92
13	12/27/1978	87.0	0.625	1.70	3.62

Post-project (Mitigated Scenario 2) Condition

Copy Statistics

- On the Statistics tab, click the top left corner of the table to highlight the entire table.
- Edit - > Copy to… -> “Copy Statistics”



External Post-processing Spreadsheet

- Open “SWMM_PostProcessing.xlsx”
- Click on the “PostMit-Q” tab and paste Post-project (Mitigated Scenario 2) Condition statistics in the highlighted cell
- Make adjustments to “Column I” as necessary to determine the Q_2, Q_5, and Q_{10} values.

Post-project (Mitigated Scenario 2)

10-year Q:	0.819	cfs
5-year Q:	0.732	cfs
2-year Q:	0.532	cfs

Lower Flow Threshold:	10%	
0.1xQ2 (Pre):	0.053	cfs

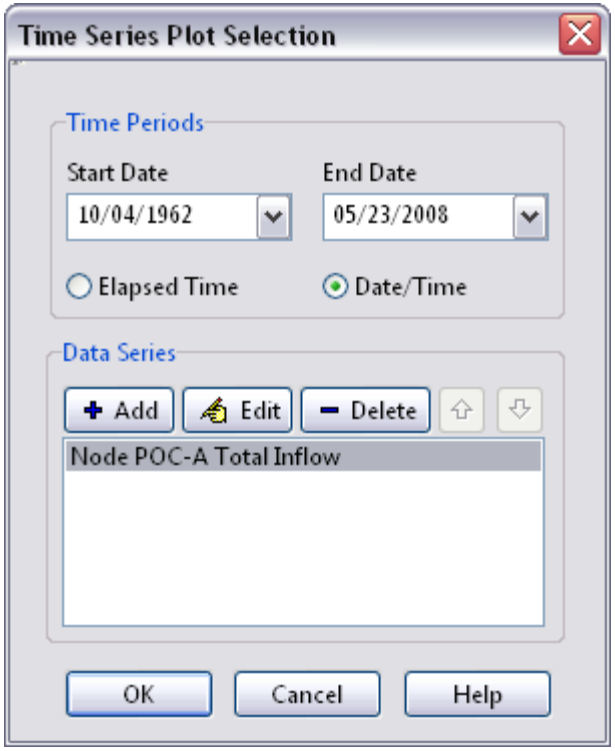
	A	B	C	D	E	F
1						
2	**Post-project (Mitigated) Flow Frequency - Long-term**					
3						
4	SWMM Training - Example Project - Post-project (Mitigated Scenario 2) Conditic					
5	Statistics - Node POC-A Total Inflow					
6			Event	Event	Exceedance	Return
7			Duration	Peak	Frequency	Period
8	Rank	Start Date	(hours)	(CFS)	(percent)	(years)
9	1	2/13/1980	202	1.002	0.13	47
10	2	3/21/1983	94	0.98	0.26	23.5
11	3	1/9/1978	48	0.88	0.39	15.67
12	4	3/17/1982	53	0.828	0.52	11.75
13	5	1/24/1995	61	0.816	0.66	9.4
14	6	11/12/1976	17	0.782	0.79	7.83
15	7	2/28/1970	52	0.75	0.92	6.71
16	8	2/6/1998	79	0.739	1.05	5.88
17	9	2/3/1998	47	0.733	1.18	5.22
18	10	12/17/1978	71	0.73	1.31	4.7
19	11	12/28/2004	45	0.716	1.44	4.27
20	12	2/14/1998	41	0.656	1.57	3.92
21	13	12/27/1978	87	0.625	1.7	3.62
22	14	2/26/1983	155	0.625	1.83	3.36
23	15	11/29/1982	37	0.621	1.97	3.13
24	16	1/27/1980	80	0.618	2.1	2.94
25	17	1/5/1979	37	0.617	2.23	2.76
26	18	2/5/1983	77	0.617	2.36	2.61
27	19	1/4/1974	117	0.599	2.49	2.47
28	20	1/7/2005	116	0.579	2.62	2.35
29	21	2/7/1993	59	0.571	2.75	2.24
30	22	12/4/1974	20	0.558	2.88	2.14
31	23	3/15/1963	50	0.538	3.01	2.04
32	24	4/18/1995	25	0.525	3.15	1.96
33	25	11/21/1996	39	0.507	3.28	1.88

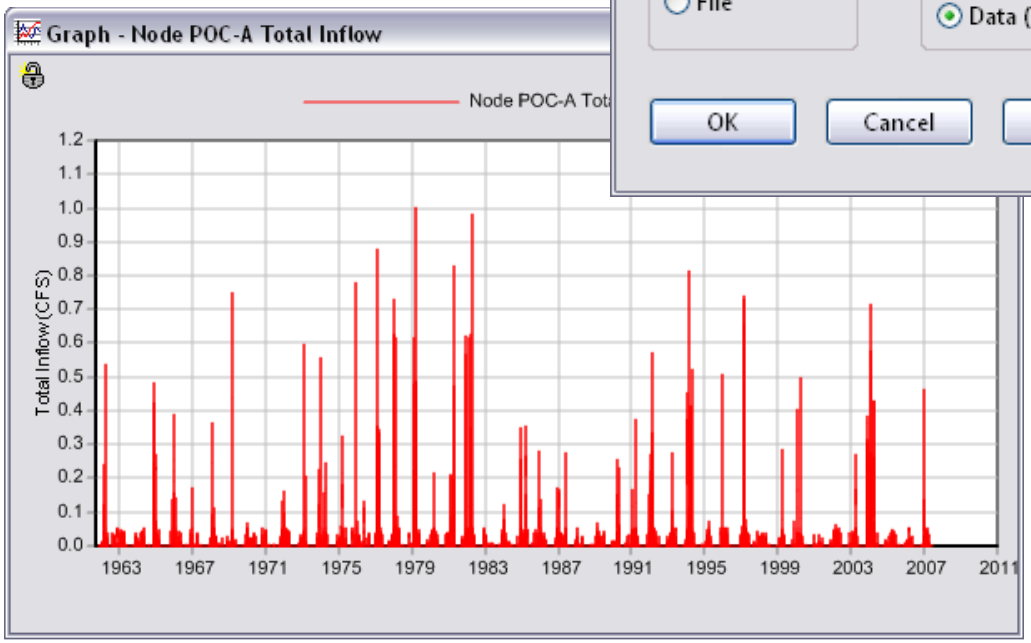
Post-Q | PostMit-Q | FF_Summary | FFC | Pre-TS | Post-TS

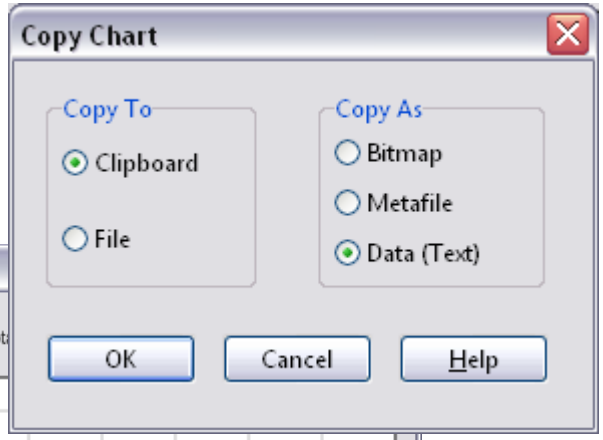
Copy Time-series

- Next, let's extract the runoff hydrograph time-series to calculate the flow durations.
- Report - > Graph - > Time Series - > "Time Series Plot Selection"
- Edit - > Copy to… - > "Copy Chart"

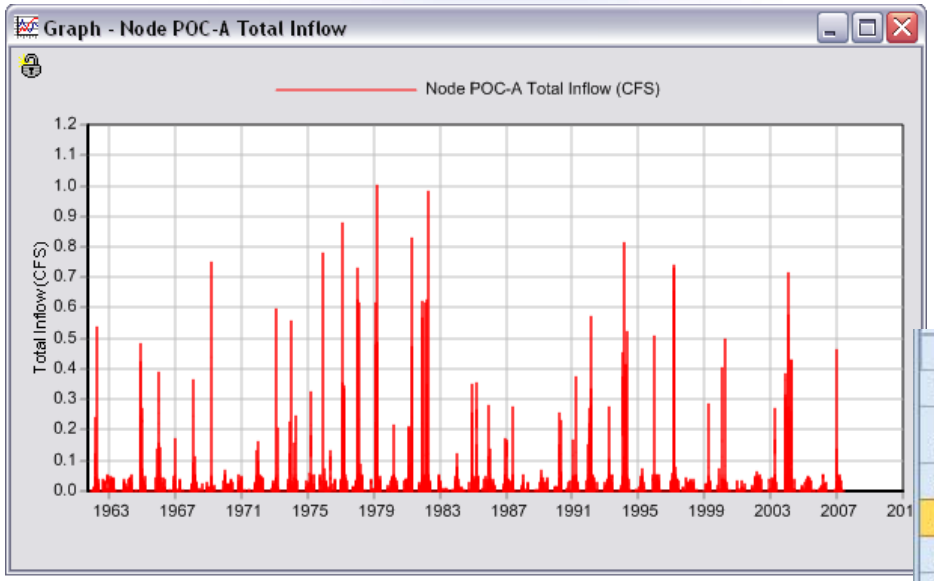
Post-project (Mitigated Scenario 2) Condition







External Post-processing Spreadsheet



Post-project (Mitigated Scenario 2) Condition

- Click on the "PostMit-TS" tab and paste Post-project (Mitigated) Condition runoff hydrograph (time-series) in the highlighted cell

	A	B	C	D	E	F
1						
2	Post-project (Mitigated) Time Series - Long-term					
3						
4	Node POC-A Tota	Inflow (CFS)				
5		Total Inflow (CFS)				
6	10/4/62 16:00	0				
7	10/4/62 17:00	0				
8	10/4/62 18:00	0				
9	10/4/62 19:00	0				
10	10/4/62 20:00	0				
11	10/4/62 21:00	0				
12	10/4/62 22:00	0				
13	10/4/62 23:00	0				
14	10/5/62 0:00	0				
15	10/5/62 1:00	0				
16	10/5/62 2:00	0				
17	10/5/62 3:00	0				
18	10/5/62 4:00	0				
19	10/5/62 5:00	0				

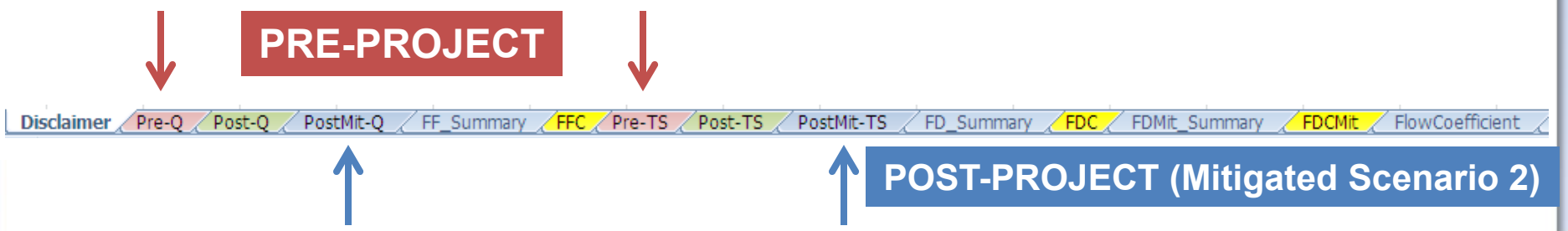
Pre-TS | Post-TS | PostMit-TS | FD_Summary | FDC | FDMit_Summa

Results?

- Let's take a look at the **post-processing spreadsheet**…

- Flow Frequency
  - Tables: "FF_Summary" tab
  - Curves: "FFC" tab

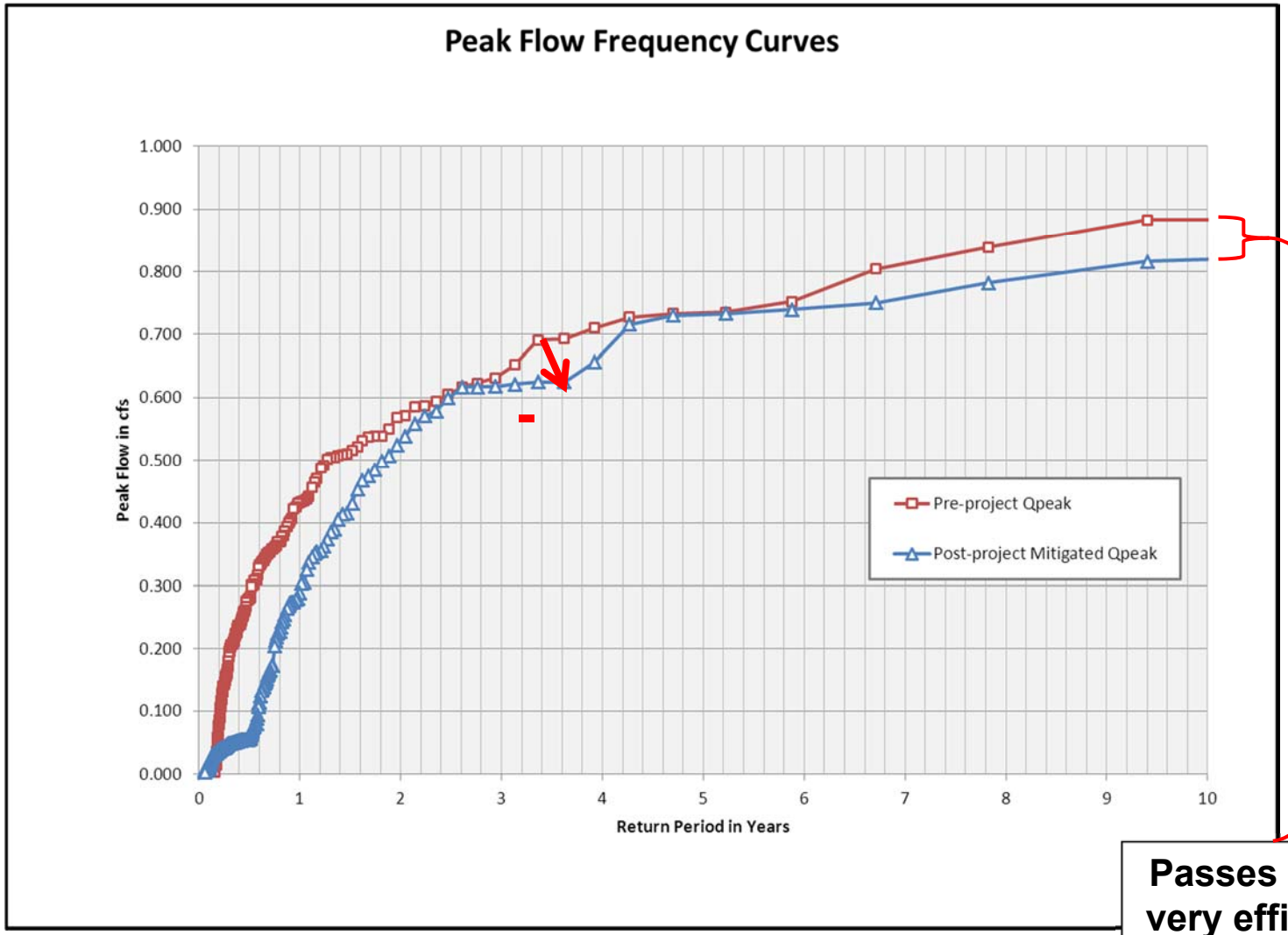
- Flow Duration
  - Tables: "FDMit_Summary" tab
  - Curves: "FDCMit" tab



Flow Frequency: Table

Return Period	Pre-project Qpeak (cfs)	Post-project - Unmitigated Q (cfs)	Post-project - Mitigated Q (cfs)
LF = 0.1xQ2	0.057	0.063	0.053
2-year	0.570	0.627	0.532
5-year	0.734	0.811	0.732
10-year	0.883	0.921	0.819

Flow Frequency: Curves



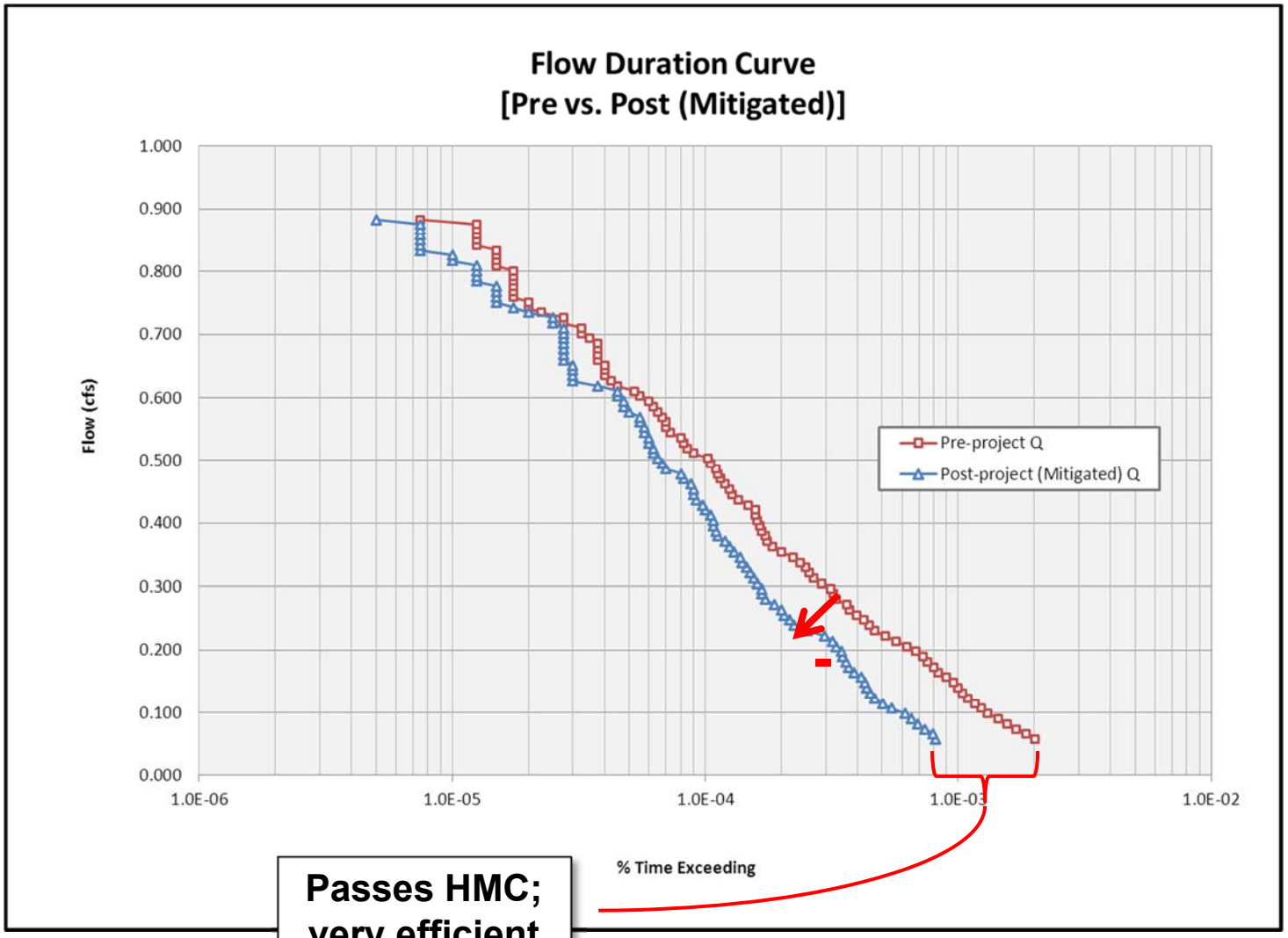
Passes HMC; very efficient!

Flow Duration: Table

	A	B	C	D	E	F	G	H
1		Low-flow Threshold:	10%					
2		0.1xQ2 (Pre):	0.057	cfs				
3		Q10 (Pre):	0.883	cfs				
4		Ordinate #:	100					
5		Incremental Q (Pre):	0.00826	cfs				
6		Total Hourly Data:	400032	hours			The proposed BMP:	PASSED
7								
8	Interval	Pre-project Flow (cfs)	Pre-project Hours	Pre-project % Time Exceeding	Post-project Hours	Post-project % Time Exceeding	Percentage	Pass/Fail
9	0	0.057	801	2.00E-03	326	8.15E-04	41%	Pass
10	1	0.065	743	1.86E-03	318	7.95E-04	43%	Pass
11	2	0.073	680	1.70E-03	296	7.40E-04	44%	Pass
12	3	0.082	627	1.57E-03	276	6.90E-04	44%	Pass
13	4	0.090	577	1.44E-03	262	6.55E-04	45%	Pass
14	5	0.098	524	1.31E-03	246	6.15E-04	47%	Pass
15	6	0.107	492	1.23E-03	218	5.45E-04	44%	Pass
16	7	0.115	466	1.16E-03	201	5.02E-04	43%	Pass
17	8	0.123	437	1.09E-03	187	4.67E-04	43%	Pass
18	9	0.131	417	1.04E-03	180	4.50E-04	43%	Pass
99	90	0.800	7	1.75E-05	5	1.25E-05	71%	Pass
100	91	0.809	6	1.50E-05	5	1.25E-05	83%	Pass
101	92	0.817	6	1.50E-05	4	1.00E-05	67%	Pass
102	93	0.825	6	1.50E-05	4	1.00E-05	67%	Pass
103	94	0.833	6	1.50E-05	3	7.50E-06	50%	Pass
104	95	0.842	5	1.25E-05	3	7.50E-06	60%	Pass
105	96	0.850	5	1.25E-05	3	7.50E-06	60%	Pass
106	97	0.858	5	1.25E-05	3	7.50E-06	60%	Pass
107	98	0.866	5	1.25E-05	3	7.50E-06	60%	Pass
108	99	0.875	5	1.25E-05	3	7.50E-06	60%	Pass
109	100	0.883	3	7.50E-06	2	5.00E-06	67%	Pass

Post-TS | PostMit-TS | FD_Summary | FDC | FDMit_Summary | FDCMit | FlowCoefficient

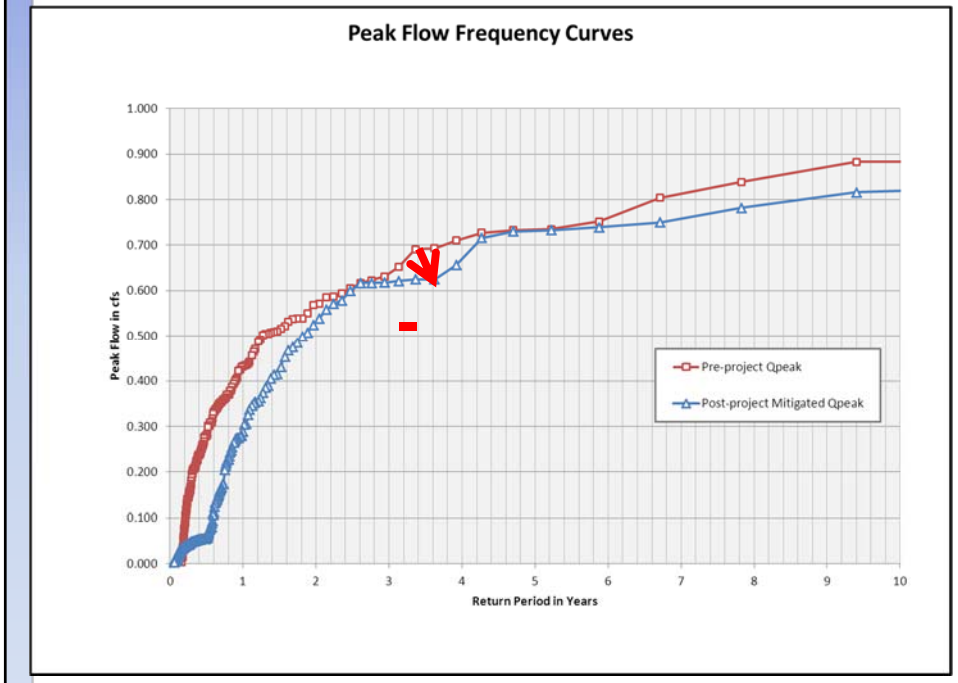
Flow Frequency: Curves



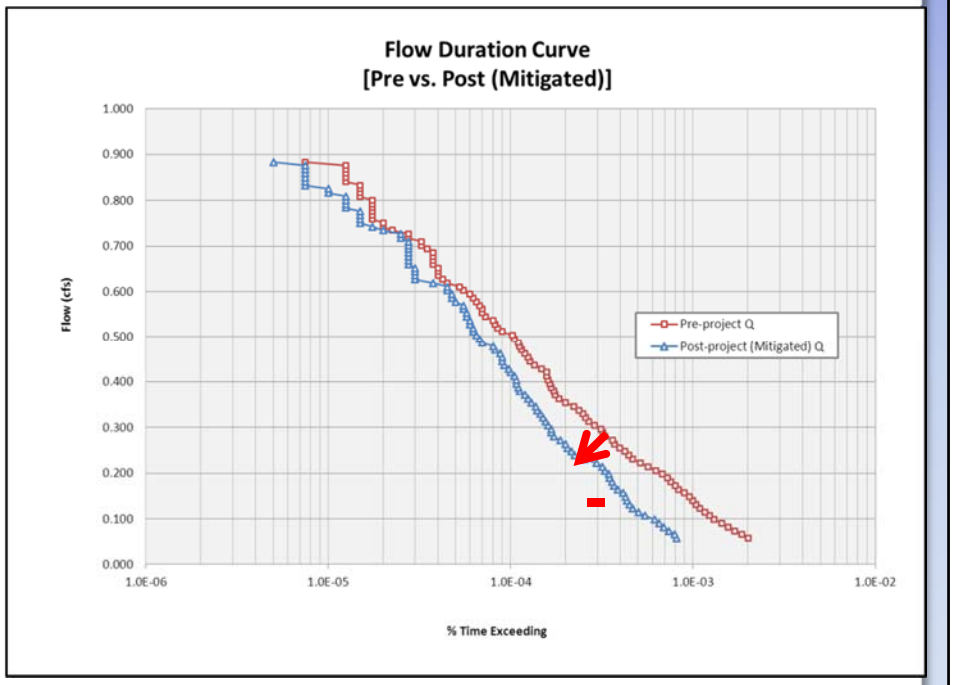
Passes HMC; very efficient

Results Summary

- Now, let's compare the Pre-project and Post-project (Mitigated Scenario 2) Condition **peak flow frequency statistics** and **flow duration** (time-series) results within our HMP Flow range $0.1xQ_2$ to Q_{10}.



Decrease in Peak Flow Frequency



Decrease in Flow Durations

Passes the HMP Flow Control Performance Standards

∴ The Biofiltration Basin design is an efficient working solution.

Post-processing Complete!

The **post-processing analysis** for the *Post-project (Mitigated Scenario 2)* model is now complete!

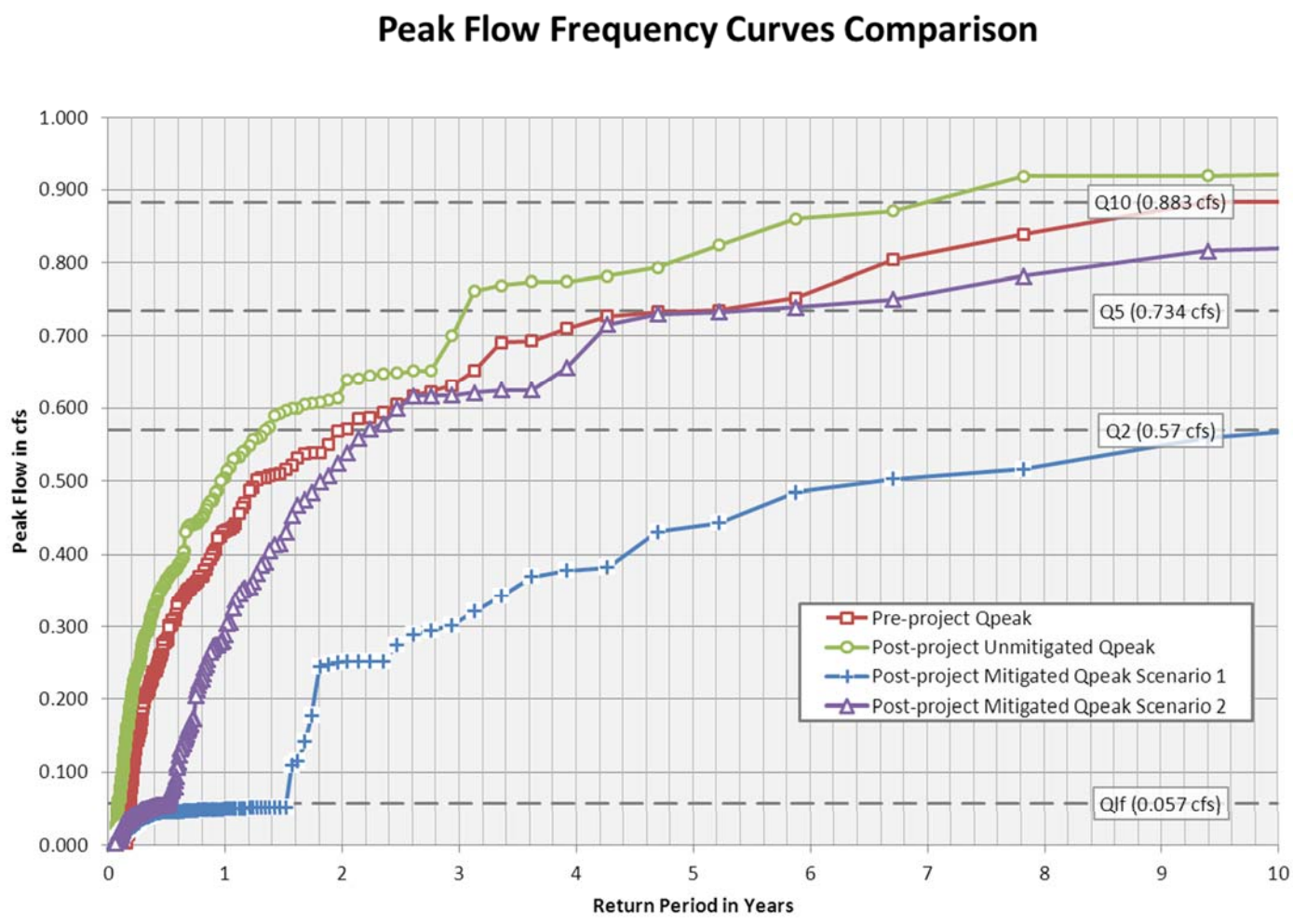
Let's take a look at all four models together!

EXAMPLE PROJECT SUMMARY

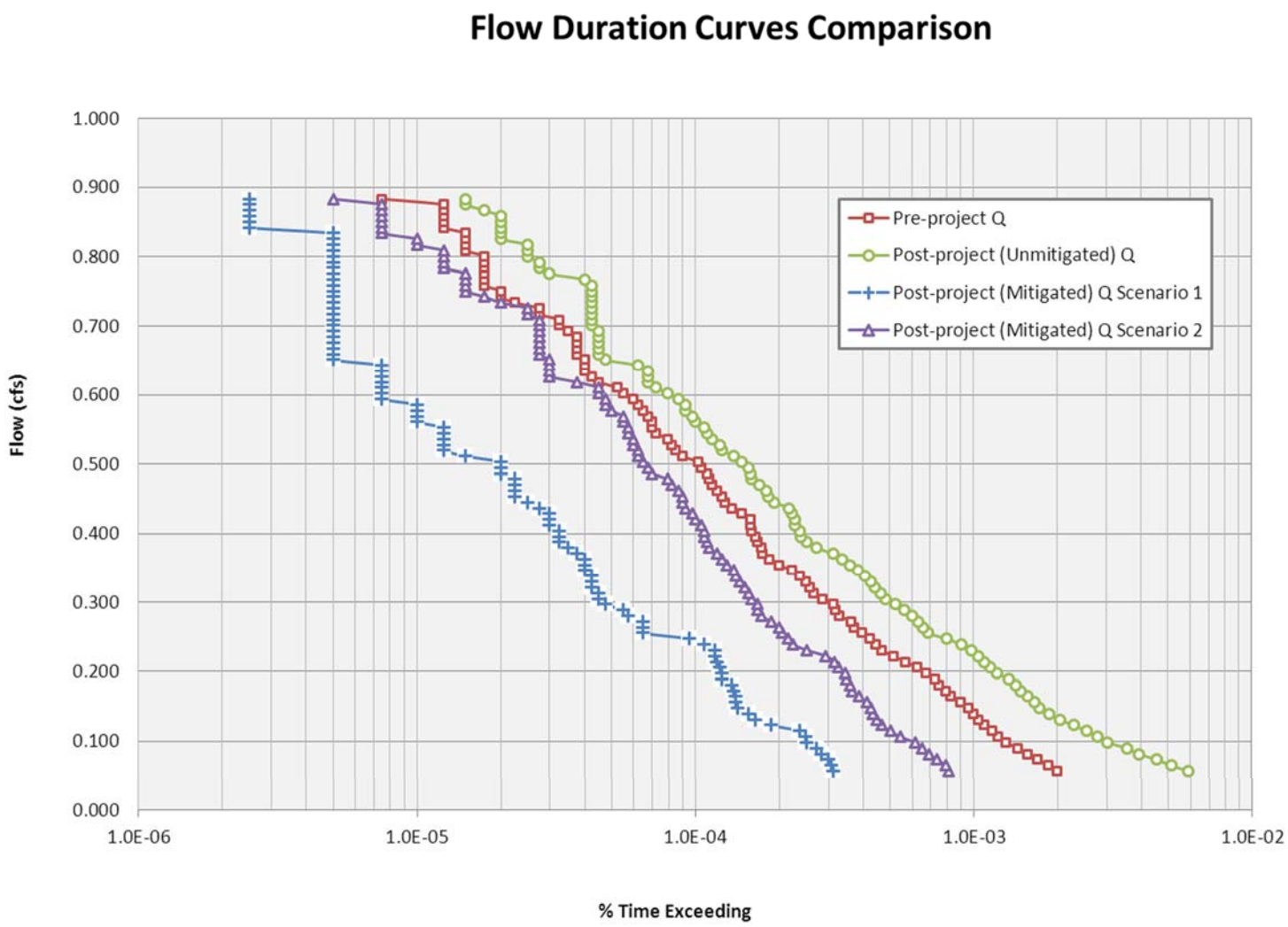
Flow Frequency Table

Return Period	Pre-project Qpeak (cfs)	Post-project - Unmitigated Q (cfs)	Post-project - Mitigated Q Scenario 1 (cfs)	Post-project - Mitigated Q Scenario 2 (cfs)
LF = 0.1*Q2	0.057	0.063	0.025	0.053
2-year	0.570	0.627	0.251	0.532
3-year	0.638	0.719	0.308	0.619
4-year	0.714	0.776	0.379	0.670
5-year	0.734	0.811	0.438	0.732
6-year	0.760	0.862	0.488	0.741
7-year	0.813	0.883	0.506	0.758
8-year	0.844	0.918	0.521	0.786
9-year	0.872	0.919	0.548	0.807
10-year	0.883	0.921	0.567	0.819

Flow Frequency Curves



Flow Duration Curves



Volume Summary

- Required Water Quality Volume ≈ 1,890 CF
- Required HMP Volume Comparison
  - BMP Sizing Spreadsheet ≈ 10,900 CF
  - SWMM Scenario 1 ≈ 5,970 CF
  - SWMM Scenario 2 ≈ 3,980 CF
- Required HMP Volumes modeled in SWMM are significantly smaller.

Questions?