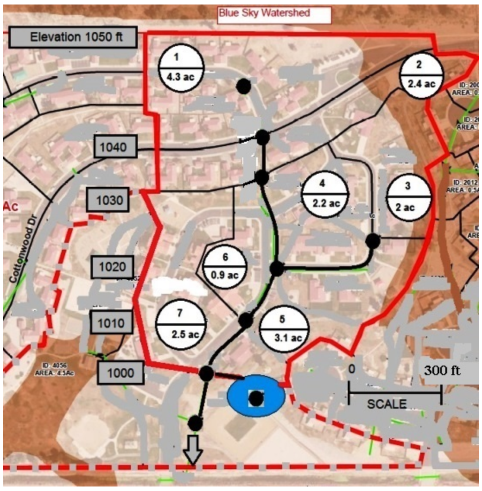
SWMM- A Storm Runoff Simulation Model



Dr. James C.Y. Guo,
P.E., Professor and Director
Civil Engineering, UC-Denver

Progressive Stages in Watershed Development

Development Stages of the Watershed under Study

- Historic Condition – before any urban development
- Existing Condition – the current condition
- Fully Developed Condition – according to the land use plan
- Historic VS Fully Development =➔ basis for regional plan for flood control

Before the watershed is to be developed

Regional Master Drainage Planning – No LID's

- Baseline model to detect flooding problems –**KW Model**
- Alternatives models to find solutions -- **KW Model**
- Final Regional Master Plan model based on cost and safety – **KW Model**
- Hydraulic design for the proposed Outfall System Design – **DW Model**

After the implementation of Master Plan, each development project shall conduct:

Proposed Individual Project -- On-site impact assessment study

- Pre-development VS Post-development –**DW Model**
- LIDs on-site (1) Cascading flow (2) LID Features – **DW Model**

Retrofitting Stormwater Management for Urban Renewal

(a) Low flow control for WQ (LIDs)
(b) Extreme flow control for flood damage reduction

Storm Water Management Model (SWMM)

1. Basic Inputs

a) watershed parameters

b) rainfall inputs: (1) event-based or (2) long-term

c) climatology: evaporation, wind, snow, temperature

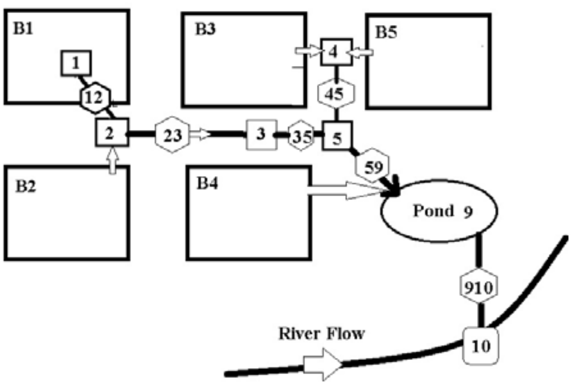
d) drainage network: street, sewer, culvert, pond, flow diversion

2. ***Goals of SWMM***

a) to predict the time- and space-distributions of flood volume in the watershed,
b) to understand the pre-development, existing, and future developed conditions.
c) to identify the existing and future flooding and waters quality problems,
d) to develop drainage alternatives for both "flood" and "stormwater" controls
e) to conduct floodplain and inundation studies,
f) to develop stormwater management and maintenance program, and
g) to assess and to monitor the impacts to the water environment

Node-Link System

- A watershed is converted into a **node-link** representation.
- **A node =** to receive hydrographs, **A link =** tot convey hydrographs.
- A link hydrograph is referenced to the downstream end of the link.
- **Dummy node** = to store computing information or to combine hydrographs
- **Dummy link** = to store computing information or to translate a hydrograph



Node – Design Point

Where to place a node – Design Point

- •Design point where a hydraulic structure will be installed.
- •Outlet point for sub-catchment
- •Outfall point for entire watershed – required for DW
- •Confluence point
- •Flow diversion point – street intersections
- •Storage point – detention pod
- •Dummy point to reveal more computational information.

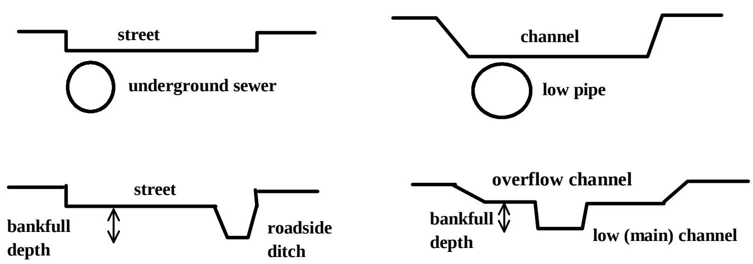
A Node is treated like a manhole, the basic node information include

- •Invert Elevation (bottom elevation of the manhole)
- •Depth from the ground surface (height of manhole)
- •Initial water depth (residual depth from previous event)
- •Surcharge depth (additional water depth in street gutter)
- •Storage area on the ground surface (storage volume around the manhole)

Link -- Waterways in Model

In an urban area, flood flows are collected and conveyed by streets, sewers, roadside ditches, and channels.

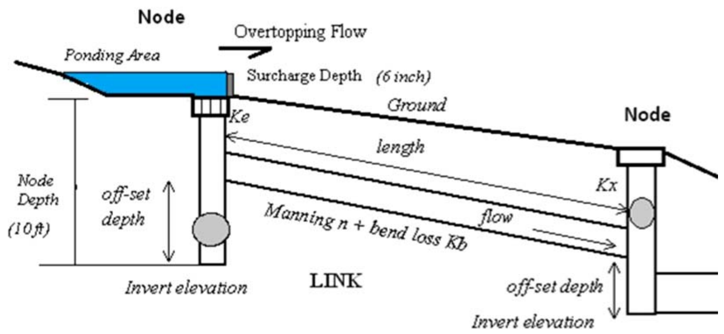
Gutter section representing street with no roadside ditch,
Pipe section representing crossing culvert with no overtopping,
Overbank channel section representing street with a roadside ditch
Overbank pipe-channel section representing street with an underground pipe



Input Parameters for a Link and Node unit

Node = ID + Draining into Link ID + Height + Ponding Area + Surcharge Depth

Link = ID + Length + X-section + Maximum water depth + upst and downst offset depths + Roughness + Loss coefficients + Floodgate at the exit



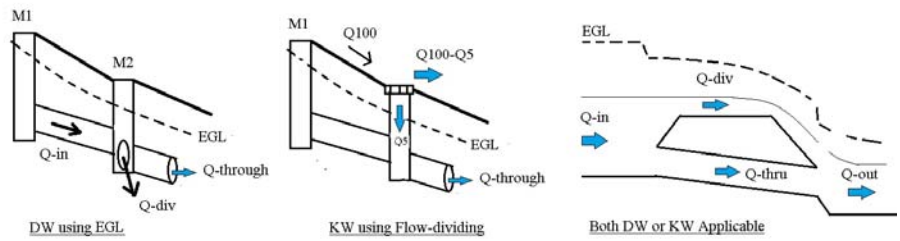
A link can be converted to Pump, Orifice, Weir, and Outlet
A node can be converted to Divider, Outfall, Detention Pond

Flow Dividers For KW and DW

A Node can serve as a Divider where the inflow can be split into two outflows. For instance, as soon as the main link (sewer) is full, the excess water can be diverted into another link (street). A **KW model** requires "conversions of regular node into diversion node+ overflow for diversion ".

There are four types of KW flow dividers:

Cutoff Divider: diverts the excessive inflow above a user-defined cutoff value.
Overflow Divider: diverts excessive inflow above the gravity-flow capacity.
Tabular Divider: uses a table that defines the diversion flow ratios
Weir Divider: uses a weir equation to compute the diverted flow.

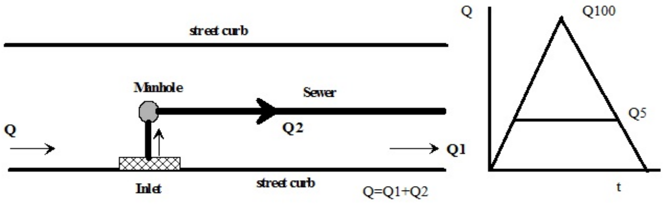


Example Tabular KW Divider at Street Inlet

Storm sewer systems are usually designed to carry a 5-yr event. When modeling a 100-year event, the flow on the street is the difference between Q100=158 cfs and Q5=40 cfs. The runoff diversion table shall cover the rising hydrograph of the 100-yr event with a maximum diverted flow equal to the sewer capacity of 40 cfs.

For example:

Inflow cfs	0	40	41	158 (Q100)
Diverted flow cfs	0	40	40	40 (Q5)



Can you draw the outflow hydrograph on top of the inflow hydrograph?

Example: Tabular Divider at Street Intersection

At a street intersection, the water depth is applied to both downstream sloping streets. As a result, the flow ratio is formulated as:

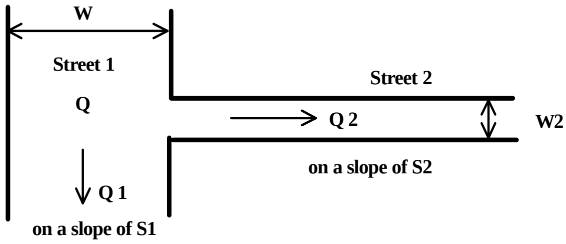
$$Q = \frac{1.49}{N} W Y^{\frac{5}{3}} \sqrt{S}$$

$$R = \frac{Q_1}{Q_2} = \frac{W_1}{W_2} \frac{\sqrt{S_1}}{\sqrt{S_2}}$$

$$Q_1 = R Q_2$$

$$Q = Q_1 + Q_2 = (1+R) Q_2$$

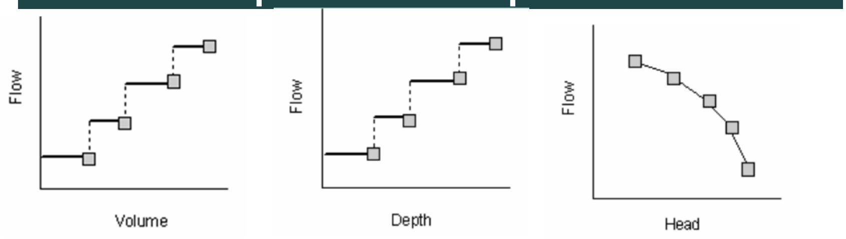
$$Q_2 = \frac{1}{1+R} Q$$

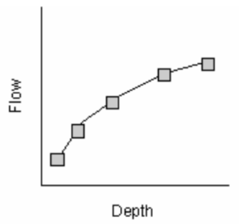


W1=	60	ft	S1=	0.02
W2=	30	ft	S2=	0.05
R=	1.265			
Q2=	0.442	Q		

Q cfs	0	100	1000
Q2 cfs	0	44.2	442

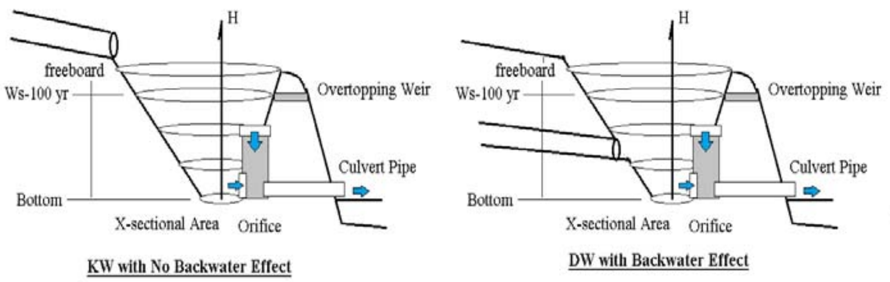
Pump Station – a special link





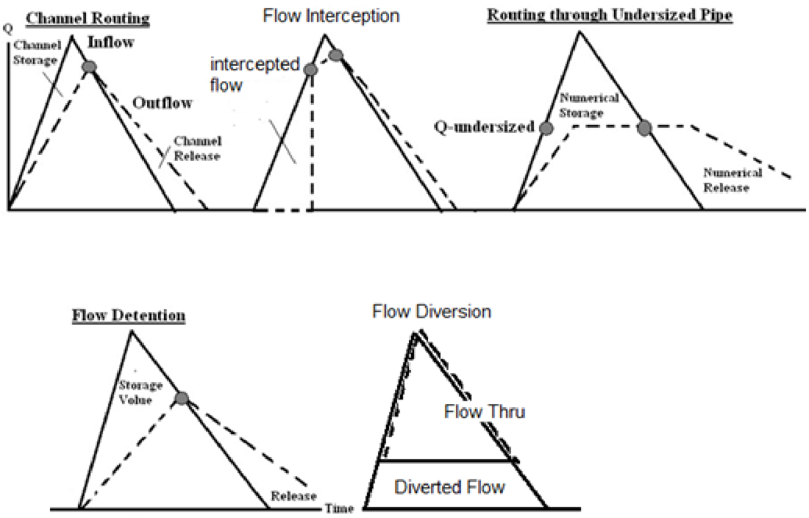
(1) Pump Type : I to 4
(2) Operational Curve: 1-4
(3) Ideal Pump= Direct Flow Transfer (Its outflow rate equals the inflow rate). No curve is required.
(4) Pump status at the beginning= on or off
(5) Operation rule
water depth> Y1, the pump will be on
water depth<Y2, the pump will be off

Detention Basin – a special node

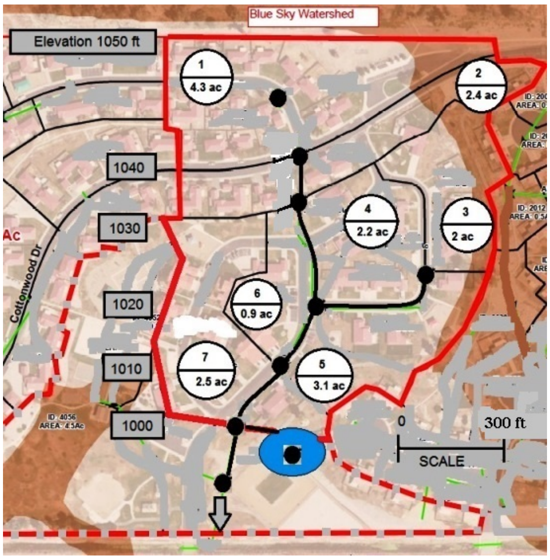


Pond geometry – stage-X-sectional area
Flow system – orifice, weir, conduit, or known stage-outflow curve
Routing method – KW or DW (W/O backwater effects)

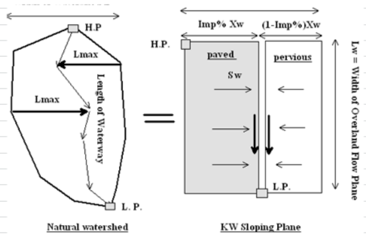
Hydrograph Routings



WORKSHOP ON WATERSHED MODELING



Project: Watershed Input Parameters for Pre- and Post-development



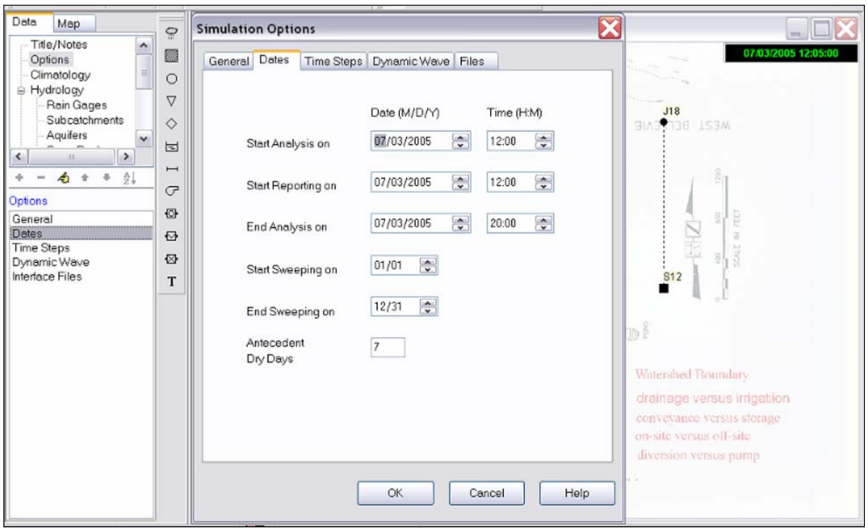
Collector Location	Center	Z=0
	Side	Z=1
	Skewed	0<Z<1
Outlet Type	Outlet	Runoff Water
	Impervious	Runon Water
	Pervious	Runof Water

		INPUT										
Subarea	**Area**	**L**	**So**	**Imp**	**Z=Am/A**	**X=A/L^2**	**Y=Lw/L**	**So/Sw**	**Sw**	**Lw**	**Collector**	**Outlet**
ID	**KW**	**ft**	**ft/ft**	**%**					**ft/ft**	**ft**	**Location**	**Type**
1	4.30	250.00	0.06	45.00	0.65	3.00	3.64	4.46	**0.013**	**909.98**	Skewed	Outlet
2	2.40	750.00	0.06	45.00	1.00	0.19	0.21	1.10	**0.054**	**155.62**	Side	Outlet
3	2.00	400.00	0.04	45.00	1.00	0.54	0.58	1.52	**0.026**	**231.99**	Side	Outlet
4	2.20	300.00	0.06	65.00	1.00	1.06	1.05	2.06	**0.029**	**316.48**	Side	Outlet
5	3.10	650.00	0.04	45.00	1.00	0.32	0.35	1.26	**0.032**	**227.96**	Side	Outlet
6	0.90	750.00	0.04	65.00	1.00	0.07	0.08	0.96	**0.042**	**59.23**	Side	Outlet
7	2.5	600.00	0.04	50.00	0.50	0.30	0.67	1.12	**0.036**	**399.21**	Skewed	Outlet

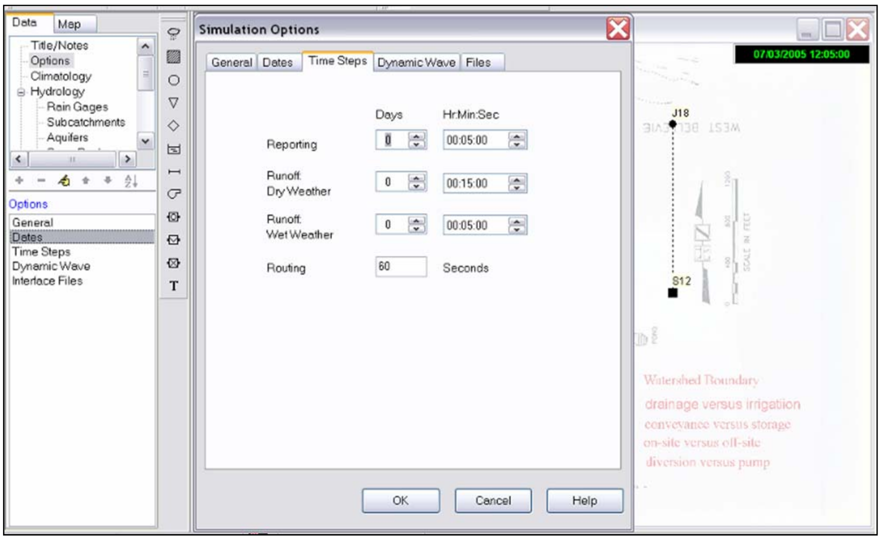
Watershed Parameters for SWMM INPUT

	Catchment			Land	Use	Soil	Infiltration		Depression loss		Manning's	N
Subarea	Area	Width	Slope	Existing	Future	fo	fc	K	Perv	Imp	N-per	N-imp
	ace	ft	%	Imp%	Imp%	inch/hr	in/hr	1/hr	inch	inch		
1	4.30	909.98	1.30	10.00	80.00	3.00	0.50	6.50	0.40	0.10	0.15	0.015
2	2.40	155.62	5.40	10.00	80.00	3.00	0.50	6.50	0.40	0.10	0.15	0.015
3	2.00	231.99	2.60	10.00	80.00	3.00	0.50	6.50	0.40	0.10	0.15	0.015
4	2.20	316.48	2.90	10.00	80.00	3.00	0.50	6.50	0.40	0.10	0.15	0.015
5	3.10	227.96	3.20	10.00	80.00	3.00	0.50	6.50	0.40	0.10	0.15	0.015
6	0.90	59.23	4.20	10.00	80.00	3.00	0.50	6.50	0.40	0.10	0.15	0.015
7	2.50	399.21	3.60	10.00	80.00	3.00	0.50	6.50	0.40	0.10	0.15	0.015
Sum	17.40											

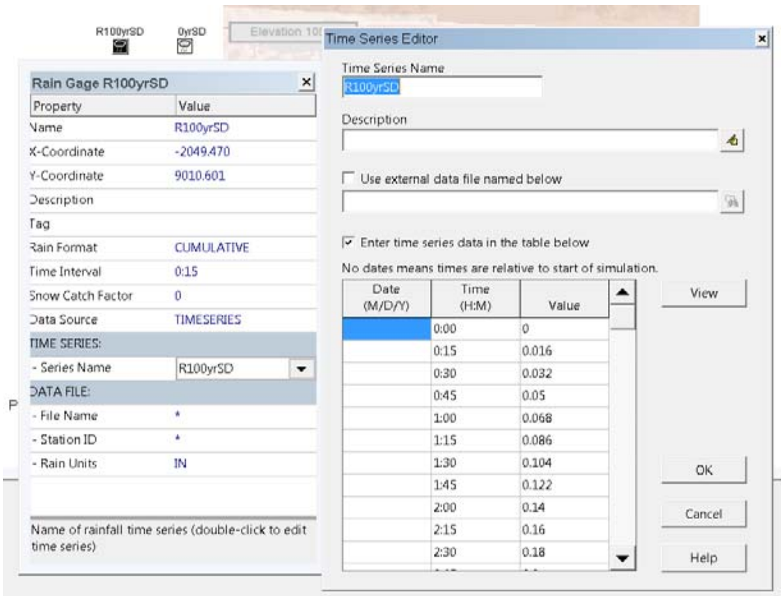
Time Parameters

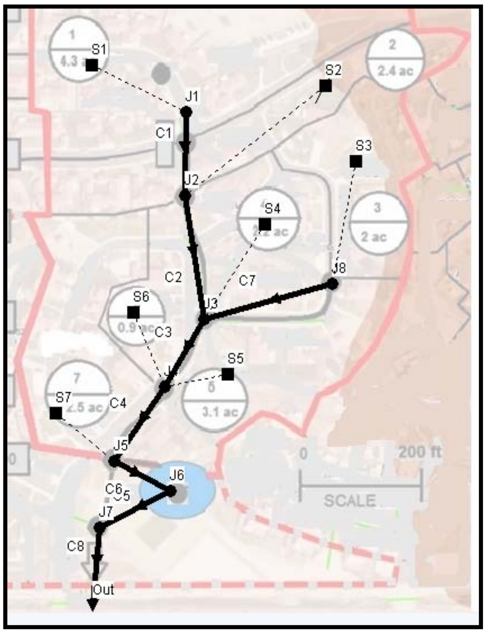


Time Steps for Numerical Simulation and Reports



Rain Gages used to produce hydrographs



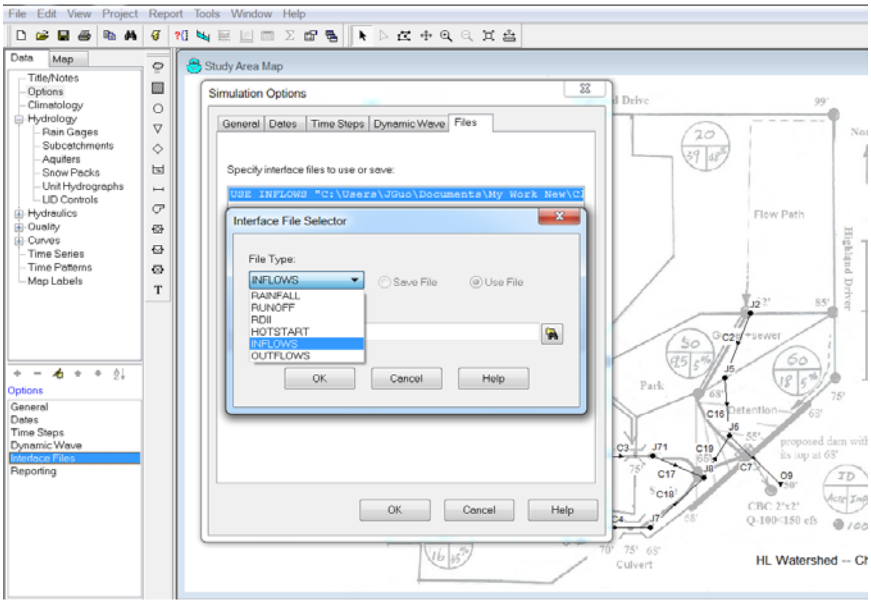


COMPARISON OF PRE- and POST-DEVELOPMENT 100-yr Peak Flows			
Node	Pre-CFS	Post-CFS	Peak Time
J1	1.68	6.49	10:30
J2	3.84	10.54	10:30
J3	4.91	17.3	10:30
J4	5.83	23.29	10:30
J5	6.57	27.32	10:30
J6	6.52	27.35	10:30
J7	6.48	27.38	10:30
J8	0.69	2.98	10:30
Out	6.44	27.4	10:30

Tasks:

1. **How to design the detention pond at J6 to mitigate the increased runoff peak flow?**
2. **Ho to design LID's to reduce the increased runoff volume?**

No rain gages -- Transfer pre-processed hydrographs into SWMM



Format of Pre-Processed Hydrographs

```
SWMM5

300
1
FLOW CFS
6
J1
J2
J3
J4
J5
J6

J1  2005  1  1  0  5  0  0
J2  2005  1  1  0  5  0  0
J3  2005  1  1  0  5  0  0
J4  2005  1  1  0  5  0  0
J5  2005  1  1  0  5  0  0
J6  2005  1  1  0  5  0  0
J1  2005  1  1  0  10  0  .375944333571204
J2  2005  1  1  0  10  0  .238167422436649
J3  2005  1  1  0  10  0  5.22467144236487E-02
J4  2005  1  1  0  10  0  3.21703155994083E-02
J5  2005  1  1  0  10  0  2.31949093011973E-04
J6  2005  1  1  0  10  0  1.08669835838018E-03
J1  2005  1  1  0  15  0  11.5680035812388
J2  2005  1  1  0  15  0  7.34174897671447
J3  2005  1  1  0  15  0  1.64200283527912
J4  2005  1  1  0  15  0  1.00065956851409
J5  2005  1  1  0  15  0  7.23651791616234E-03
J6  2005  1  1  0  15  0  3.34130421189606E-02
```

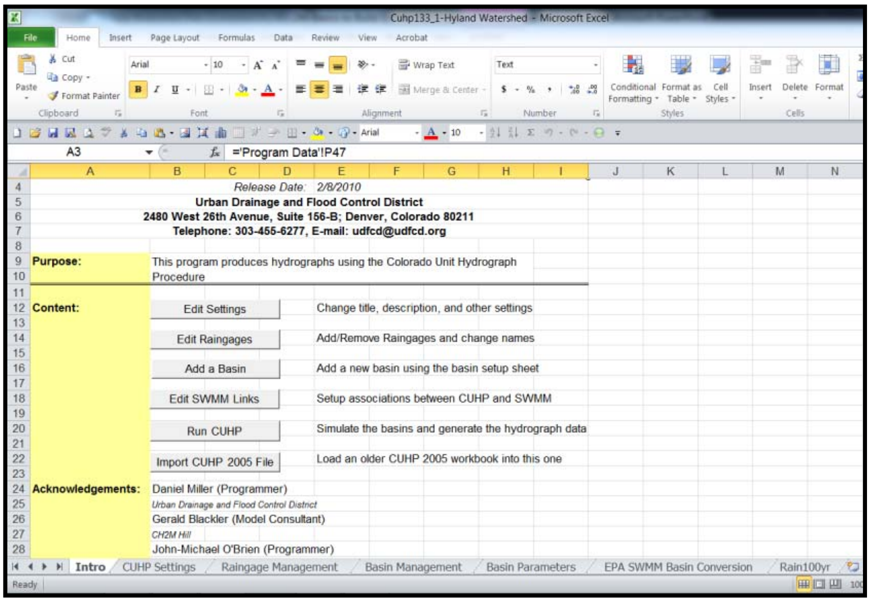
Data Structure

300 = 5 min used as time step
1= single event simulation
Flow cfs = flow unit
6 = six hydrographs pre-prepared
J1 to J6 = nodes that receive the hydrographs
Blank card
2005 1 1 = event starts on 01/01/2005
0 5 0 0 = at 5 min elapsed time, zero flow
0 10 0 0.3759 = 0.3759 cfs at 10 min at J1

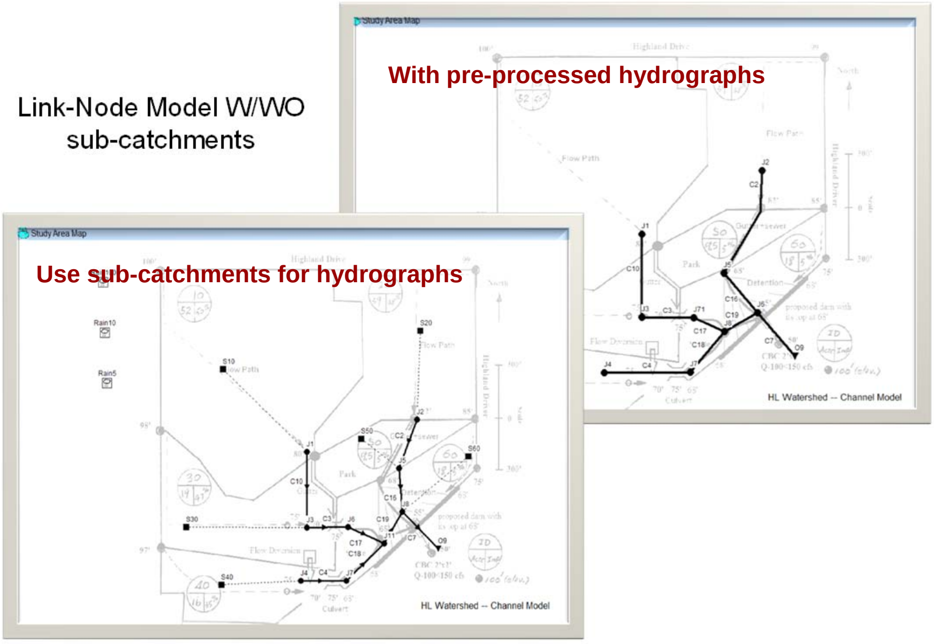
How to prepare the hydrographs?

Colorado Urban Hydrograph Procedure (CUHP)
Review of CUHP pre-processor of storm hydrographs
For EPA SWMM.

CUHP Pre-processor



Link-Node Model W/WO sub-catchments



Q and A – Mobile Green

References

Guo, James C.Y. and Cheng, J. Y.C.(2008) "Retrofit Stormwater Retention Volume for Low Impact Development", ASCE J. of Irrigation and Drainage Engineering, Vol 134, No 6, December.

Guo, James C.Y. (2007) Stormwater Detention and Retention systems, Invited, J. of Urban Water Management, July

Guo, James C.Y. and Hsu, E.S.C. (2006). "Hydrologic Modeling Consistency and Sensitivity to Watershed Size", J. of PB Network for Water Engineering and Management, Vol 21, No 3, Issue No. 64, December.

Jones, J, Guo, J.C.Y., and Urbonas, B. (2006). "Safety on Detention and Retention Pond Designs", J. of Storm Water, Jan/Feb.

Guo, James C.Y. (2004). "Hydrology-Based Approach to Storm Water Detention Design Using New Routing Schemes," ASCE J. of Hydrologic Engineering, Vol 9, No. 4, July/August

Guo, James C.Y. (2002). "Overflow Risk of Storm Water BMP Basin Design," ASCE J. of Hydrologic Engineering, Vol 7, No. 6, Nov.

Guo, James C.Y. and Urbonas, Ben. (2002). "Runoff Capture and Delivery Curves for Storm Water Quality Control Designs," ASCE J. of Water Resources Planning and Management, Vol 128, Vo. 3, May/June.

Guo, James C.Y. and Hughes, William. (2001). "Runoff Storage Volume for Infiltration Basin," ASCE J. of Irrigation and Drainage Engineering, Vol 127, No. 3, May/June.

Guo, James C.Y. (2001). "Design of Circular Infiltration Basin Under Water Mounding Effects," ASCE J. of Water Resources Planning and Management, Vol 127, No.1, Jan/Feb.

Guo, James C.Y. (1999). "Detention Basin Sizing for Small Urban Catchments," ASCE J. of Water Resources Planning and Management, Vol 125, No.6, Nov.

FOR MORE INFORMATION

James.Guo@UCDenver.edu

WWW.UCDENVER.EDU/~Jguo -- Website
WWW.UDFCD.ORG -- Free Software
WWW.URBANWATERSHEDS.ORG – Training Classes

Porous Pavements in UC-Denver Campus