Tools, Models and Calculators for Modeling Stormwater Control Measures (SCMs)

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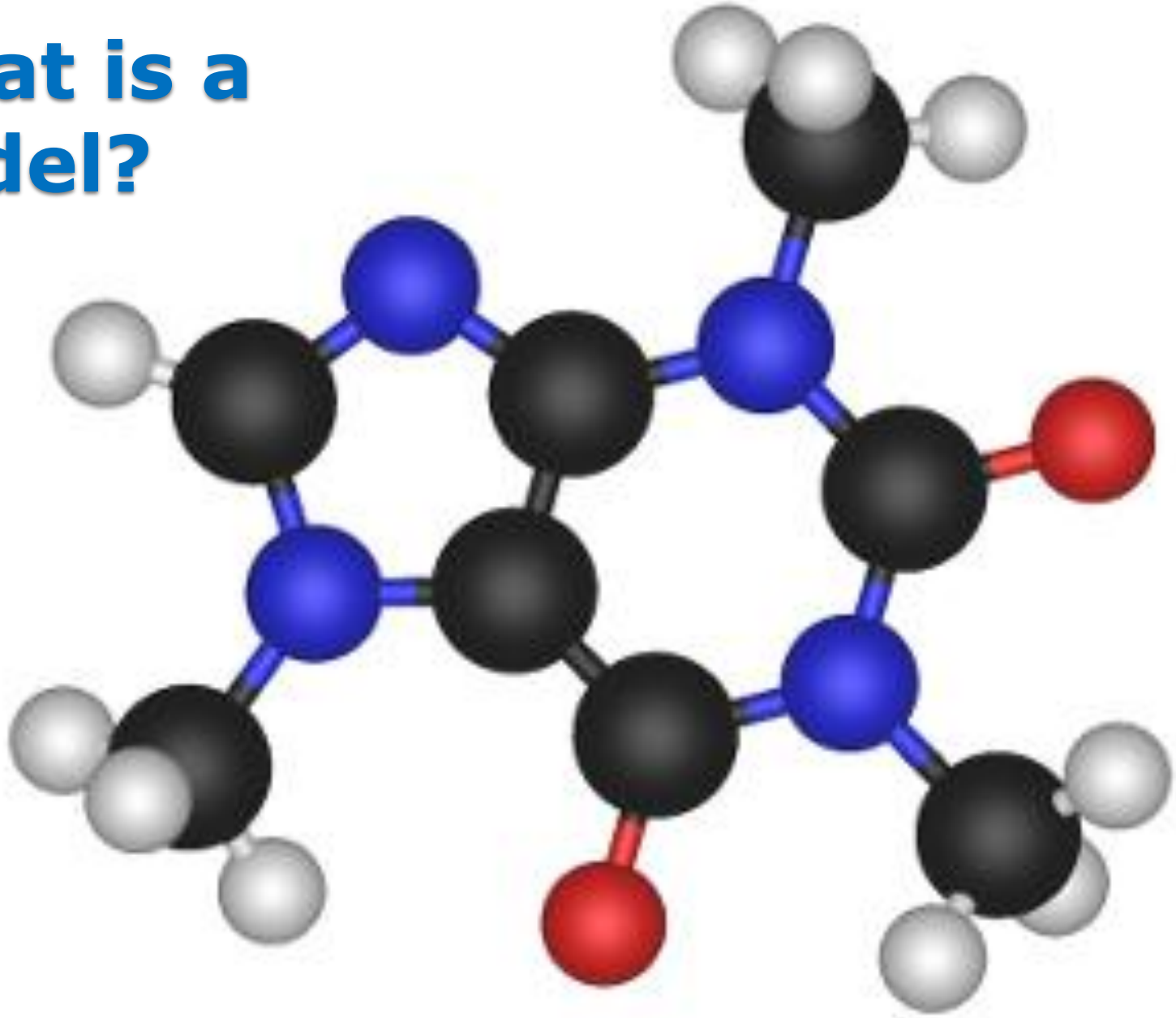
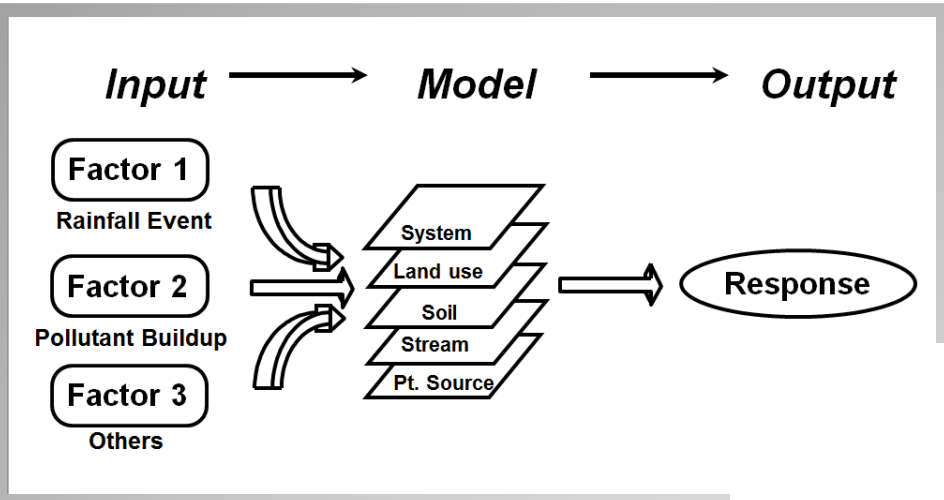
TETRA TECH

Agenda

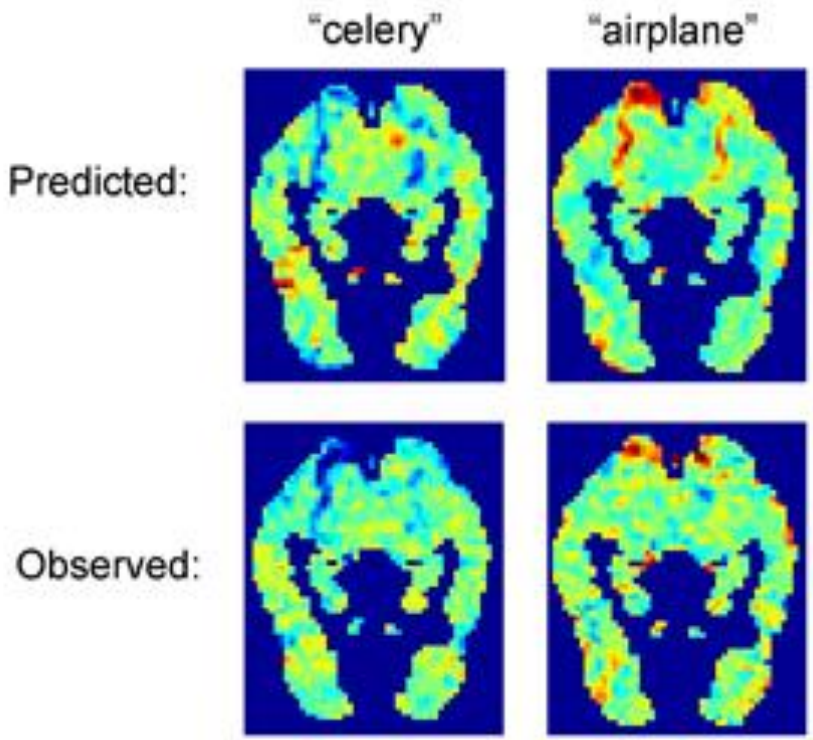
- What is a Model
- Common Questions
- Review of Models
- Model Summary
- What’s Next

What is a Model?




Input
Model
Output
Factor 1
Rainfall Event
Factor 2
Pollutant Buildup
Factor 3
Others
System
Land use
Soil
Stream
Pt. Source
Response

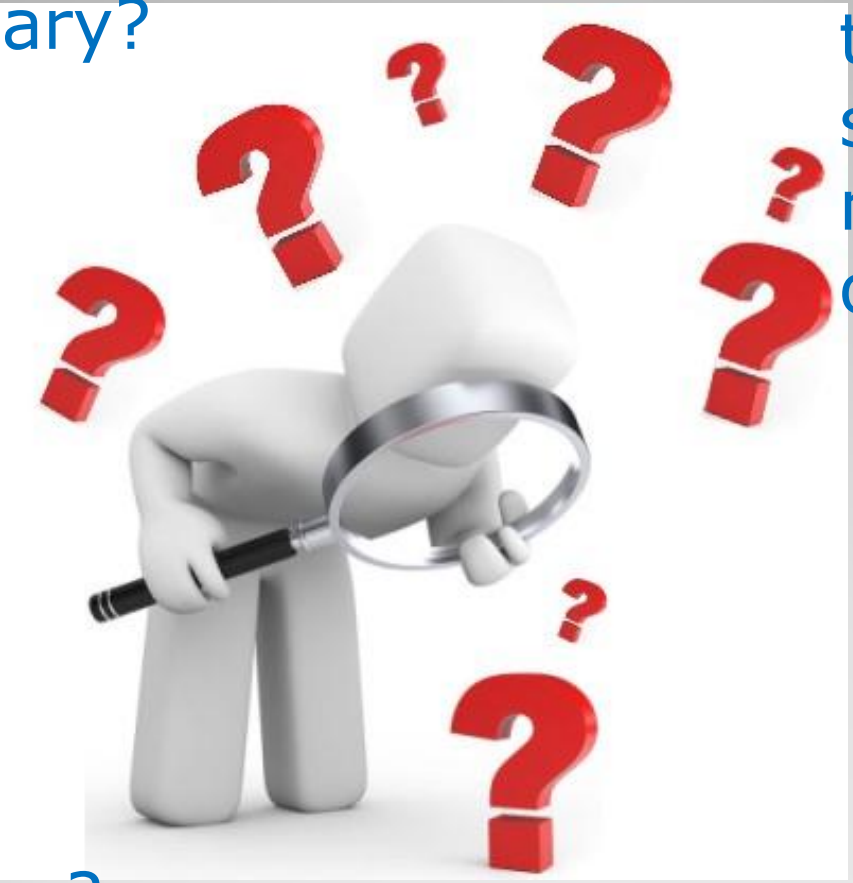
A model is…


"celery"
"airplane"
Predicted:
Observed:

Common Questions?

Is a model necessary?

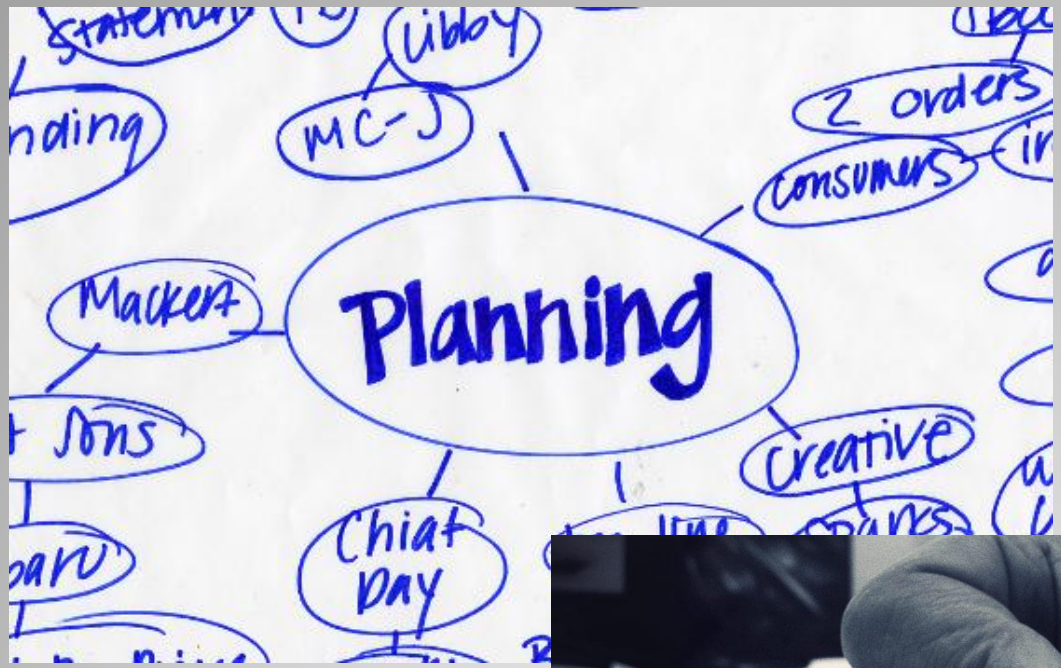
What features of the system should the modeling focus on?



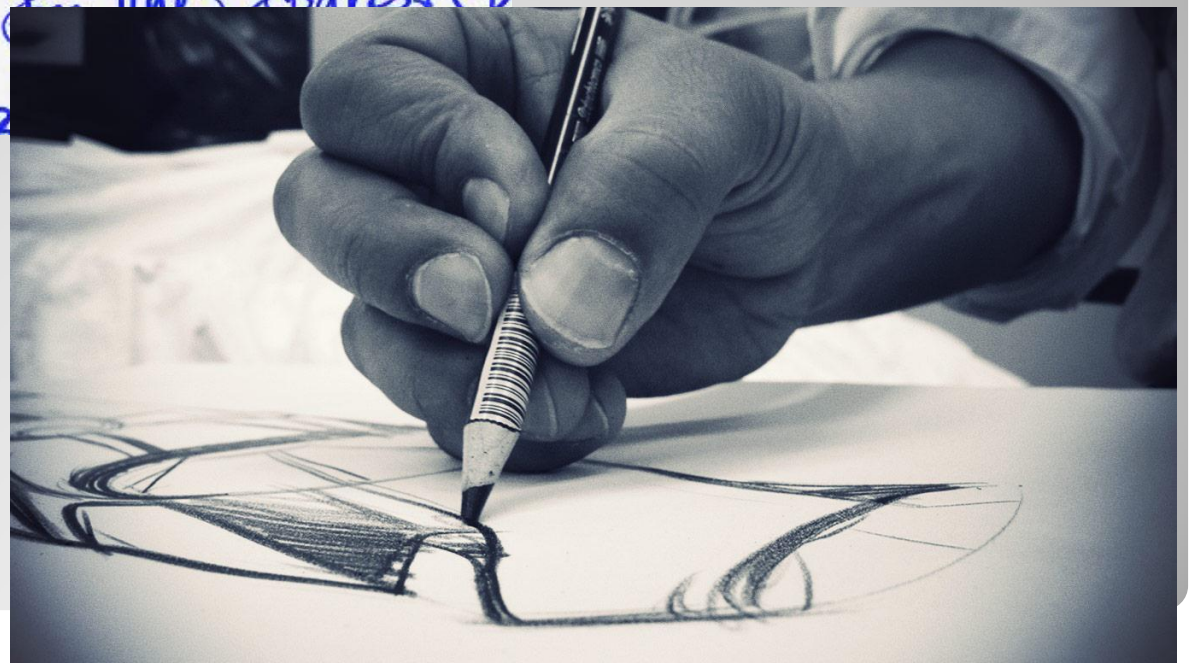
User Interface?

$$$$

Scale


Planning
Mackert
MC-J
2 orders
consumers
creative
Chiat Day

End Use



RUNOFF DETENTION

Detention is required for an increase in impervious area greater than 1000 SF.
These criteria are cumulative over sequential site plans.

SITE LOCATION

(A)	DRAINAGE AREA =	1.37 Ac	(B)	MAXIMUM ALLOWABLE DISCHARGE =		1.32 CFS
	IMPERVIOUS AREA =	0.82 Ac		Existing "C" =	0.4	
	PERVIOUS AREA =	0.55 Ac	(H)	POND SIZE REQUIRED =		3541 CFT

DURATION	(C) RAINFALL INTENSITY 30-YEAR STORM t(HR)	I(in/HR)	R(in)	(D) AVE COEF	(E) 30-YEAR RUNOFF (CFT)	(F) PERMITTED OUTFLOW (CFT)	(G) REQUIRED STORAGE (CFT)
10 MIN	0.17 *	7.15 =	1.19	0.60	3551	789	2762
20 MIN	0.33 *	5.05 =	1.68	0.60	5013	1578	3435
30 MIN	0.50 *	3.96 =	1.98	0.60	5908	2367	3541
40 MIN	0.67 *	3.28 =	2.19	0.60	6535	3156	3378
50 MIN	0.83 *	2.82 =	2.35	0.60	7012	3946	3066
60 MIN	1.00 *	2.48 =	2.48	0.60	7400	4735	2665
70 MIN	1.17 *	2.22 =	2.59	0.60	7728	5524	2204
80 MIN	1.33 *	2.02 =	2.69	0.60	8027	6313	1714
90 MIN	1.50 *	1.85 =	2.77	0.60	8265	7102	1163
100 MIN	1.67 *	1.71 =	2.85	0.60	8504	7891	613
110 MIN	1.83 *	1.59 =	2.92	0.60	8713	8680	33
120 MIN	2.00 *	1.49 =	2.98	0.60	8892	9469	-578
24 HRS	24.00 *	0.21 =	5.02	0.60	14979	113633	-98654

INSTRUCTIONS

A) DRAINAGE AREAS shall be calculated in acres and divided into impervious and pervious areas.

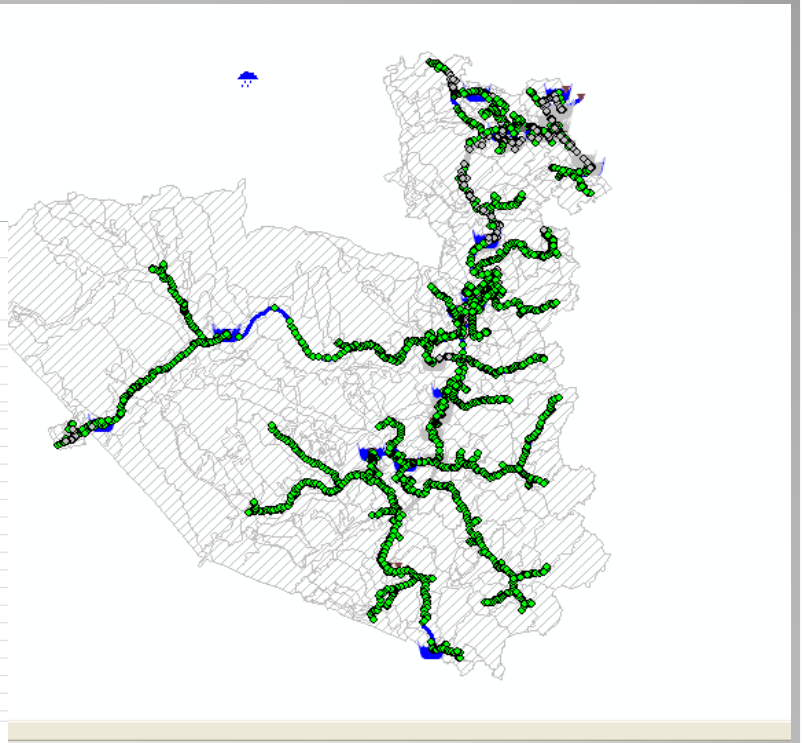
B) MAXIMUM ALLOWABLE DISCHARGE (Q) (CFS) shall be for a 10 yr storm - 30 min. duration

Q = C I A
I = 2.40 Inches/Hour
A = Drainage area in acres

C = 0.40 for Previously Residential areas
C = 0.15 for Previously Undeveloped areas
C = 0.00 for Non-Storm sewer areas
or C = Design Value for storm system

C) Inches of rainfall, given for a 30 year storm, source: Camp, Dresser & McKee, Inc., December 1986 (I = 76.6/(t + 8.62)^0.811)

D) AVERAGE COEFFICIENT for runoff, used for all durations, is calculated by the weighted average of pervious and impervious areas, using a pervious coefficient of 0.15 and an impervious coefficient of 0.90
(ie: AVE COEF = (IMPERVIOUS AREA * 0.90)+(PERVIOUS AREA * 0.15)/DRAINAGE AREA



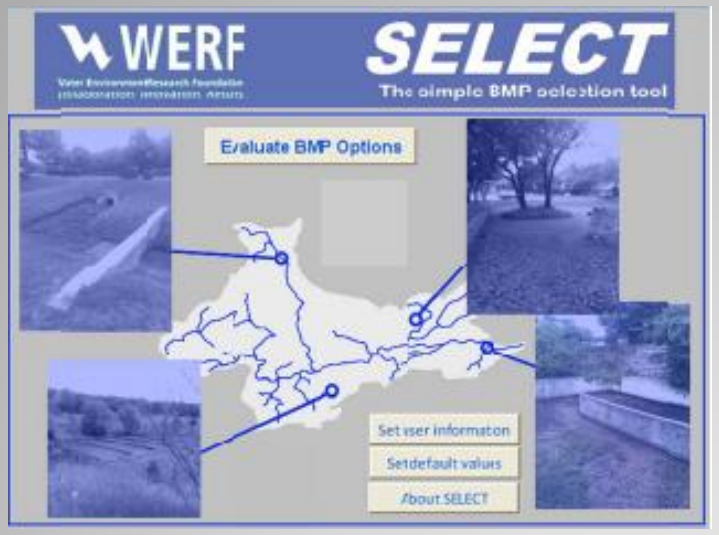
Complexity

What output information do we need?

- Water quality
- Runoff volume
- Cost

Output

Review of Models

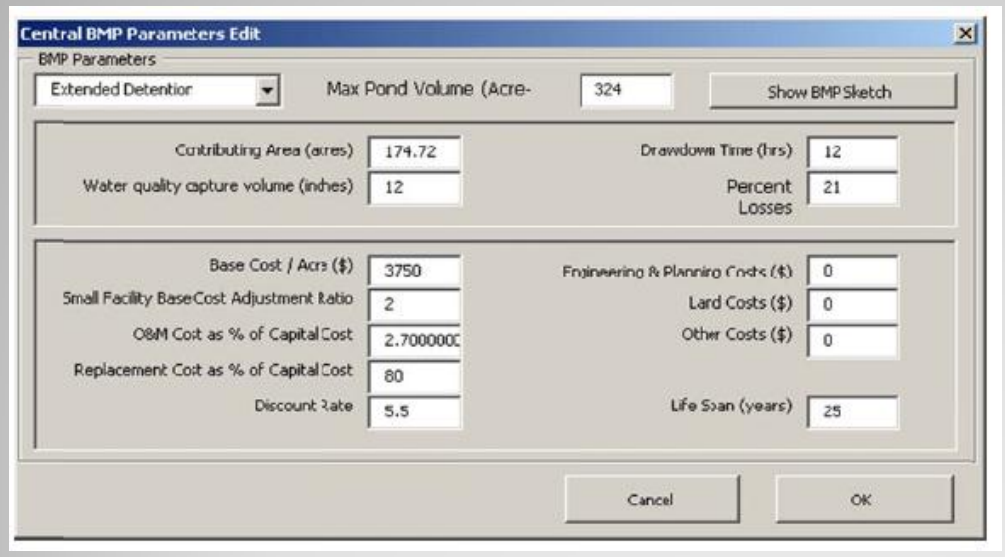


- Evaluates alternatives for controlling stormwater pollution including <u>whole life costs</u>.
- Simple and quick to use
- Based on:
  - Local Rainfall Data (hourly)
  - Drainage Area Characteristics
  - SCM Parameters
  - Event Mean Concentrations

BMP SELECT

(Water Environment Research Foundation)

- Site scale
  - Evaluate alternative scenarios
  - Including life cycle cost
- Can I meet TMDL limits with the SCMs that are proposed? How much is it going to cost?

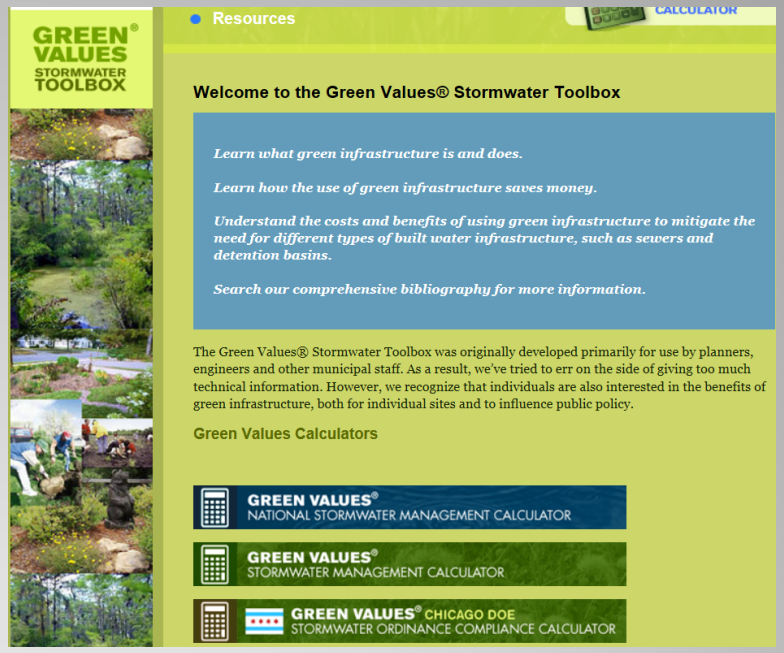


Green Roofs
Permeable Pavement
Rain Gardens
Retention Ponds
Swales
Cisterns
Bioretention
Extended Detention Basins

Example Applications

BMP SELECT

- Evaluates sustainable design on a <u>site-scale</u> using research-based assumptions for SCMs
- Weather data is based on Great Lakes region
- Simple and quick to use
- Based on:
  - Development type
  - Characteristics of development
  - Site size
  - SCM type



Green Roofs
Planter Boxes
Rain Gardens
Cisterns
Native Vegetation
Vegetated Filter Strips
Swales
Trees
Permeable Pavement

Green Values Stormwater Calculator

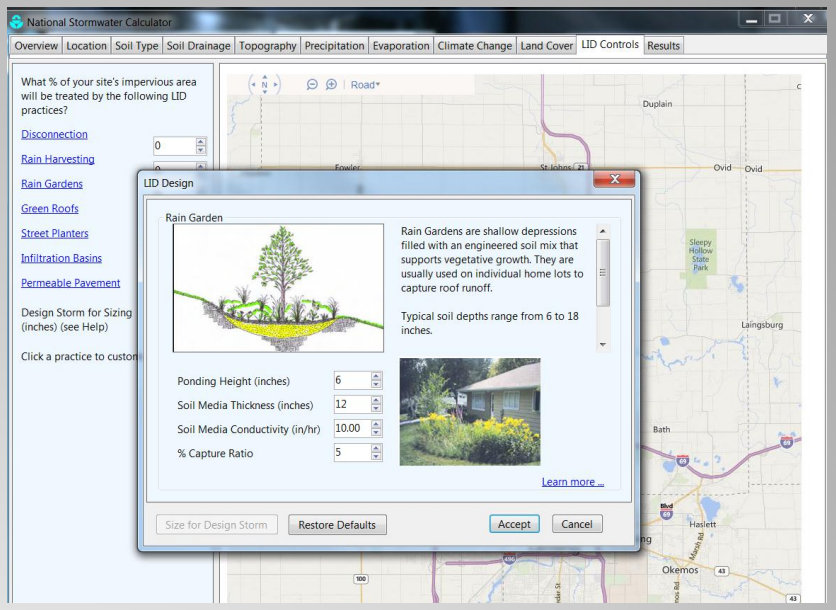
(Center for Neighborhood Technology)

- Comparing a conventional storm sewer system to a green solution (SCMs)
  - What is the cost savings?
  - What is the water quantity benefit?

Example Applications

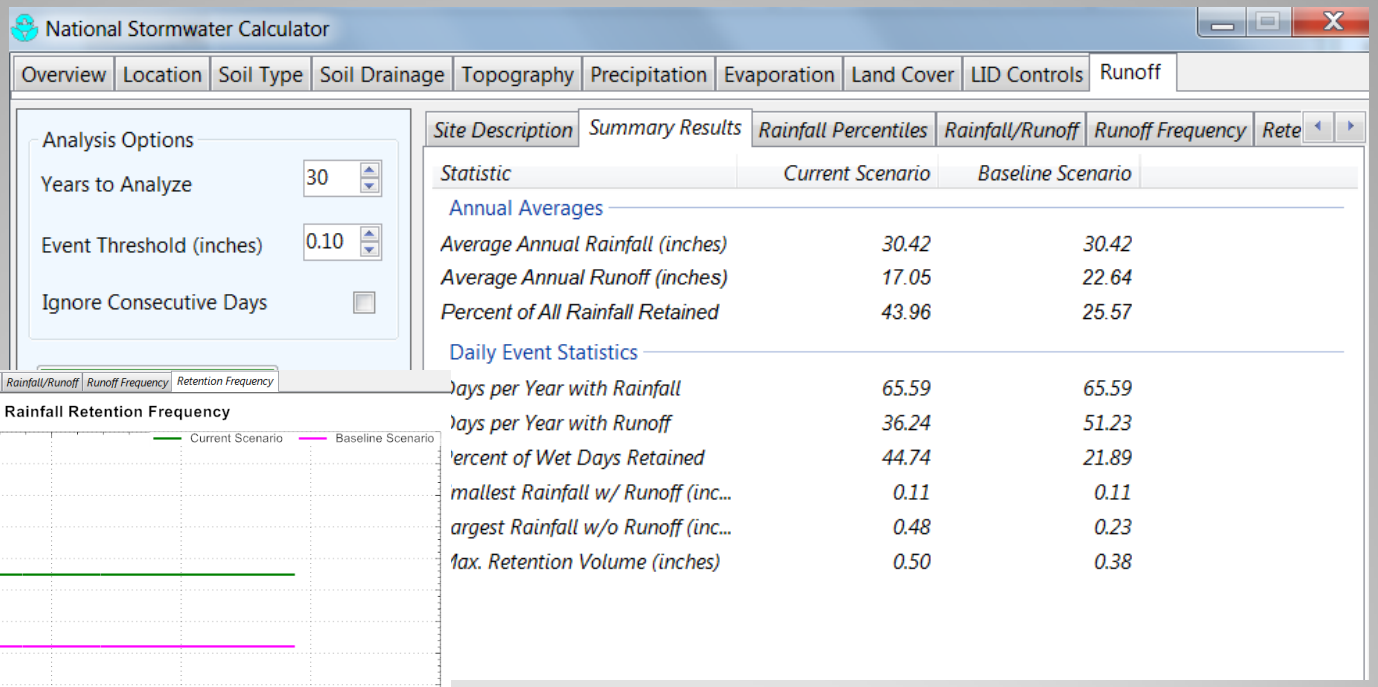
Green Values

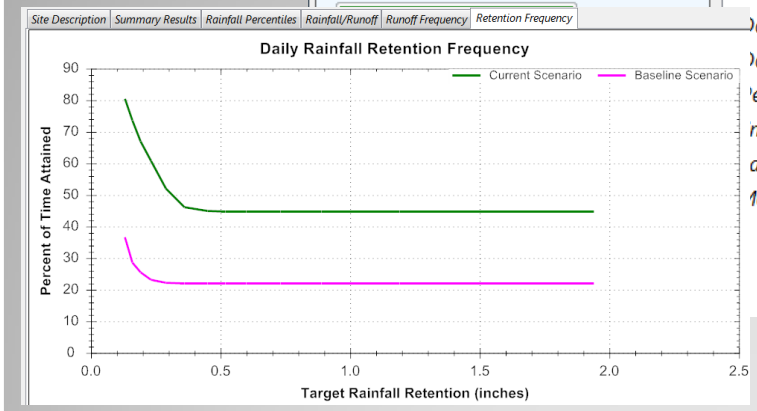
- Estimates annual amount and frequency of runoff from a site
- Based on:
  - Local soil conditions
  - Land cover
  - Historic rainfall records
- Quick and easy
- Calculations from EPA SWMM v5



Green Roofs
Permeable Pavement
Rain Gardens
Water Harvesting
Street Planters
Infiltration Basins
Downspout Disconnection

National Stormwater Calculator (USEPA)

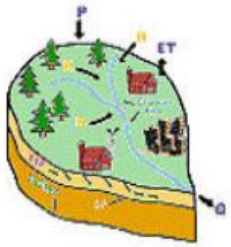




- Annual volume reduction with proposed SCMs
- Climate change impacts

Example Applications

National Stormwater Calculator



AVGWLF

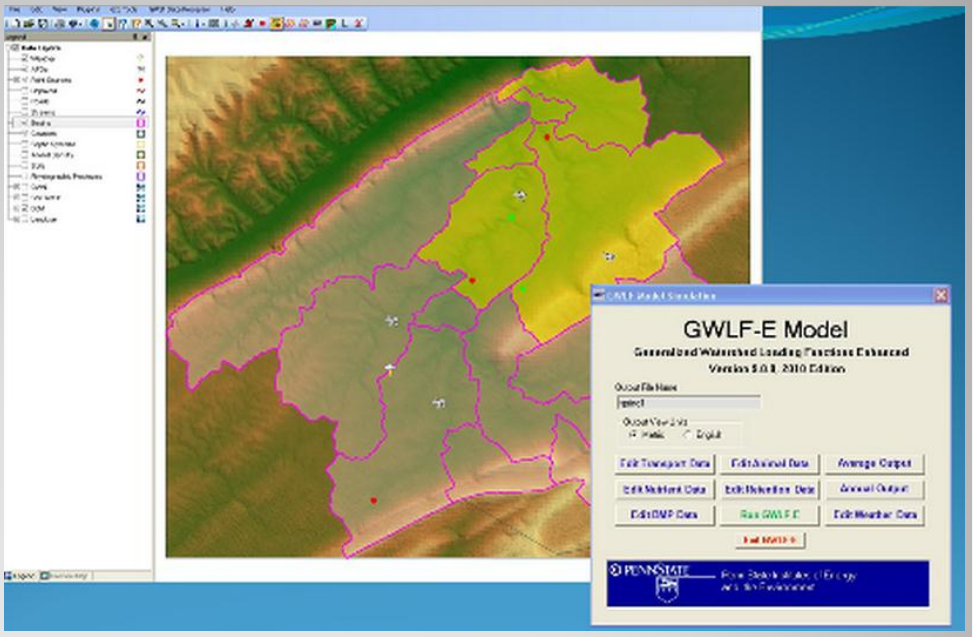
- Models runoff, sediment and nutrient transport within a watershed
- Based on:
  - Local soil type
  - Land cover
  - Weather/rain data
  - Topography
- SCS CN approach, USLE

Green Roofs
Permeable Pavement
Rain Gardens
Water Harvesting
Street Planters
Infiltration Basins
Downspout Disconnection

Mapshed/AVGWLF

(Penn State PA DEP/Cornell University)

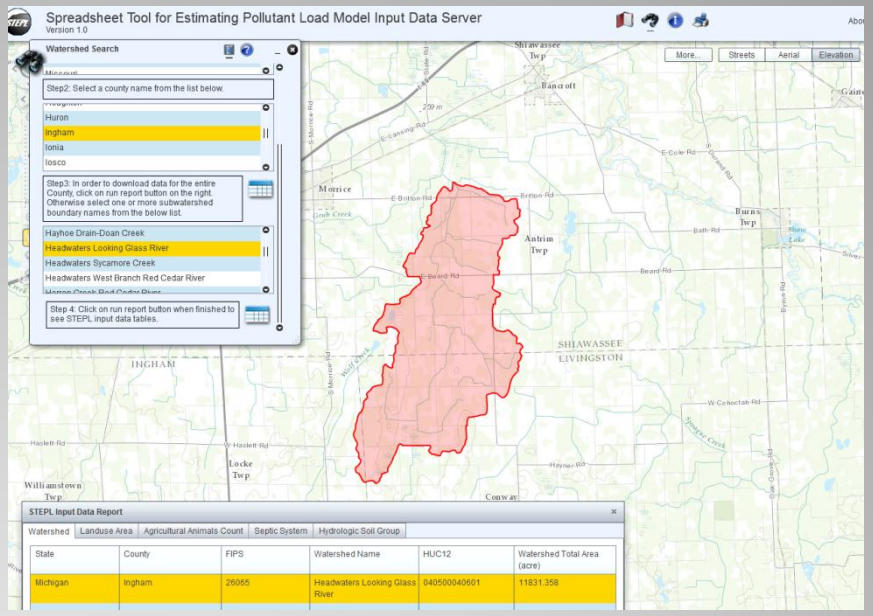
- Watershed analysis to meet TMDL requirements
  - Runoff
  - Sediment Loading
  - Nutrient Loading
- Streambank erosion calculations



Example Applications

Mapshed/AVGWLF

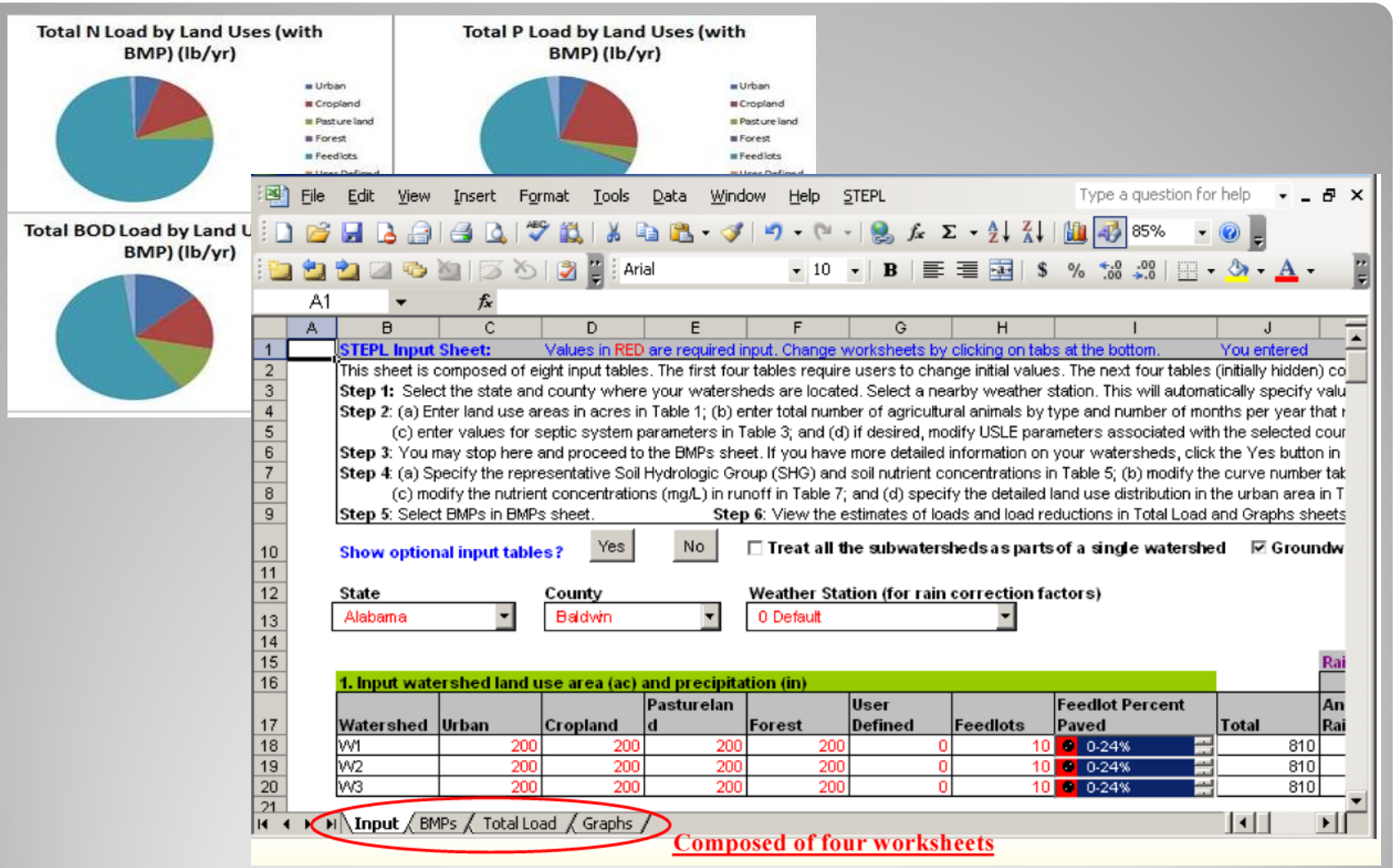
- Estimates the reduction in nutrient/sediment loads from various land uses using SCMs
- Based on:
  - Rain depth and rain days
  - Land cover
  - SCM Tributary Areas
- USLE, Research-based SCM pollutant removal efficiencies, HUC-12 data



Green Roofs
Permeable Pavement
Rain Gardens
Water Harvesting
Street Planters
Infiltration Basins
Downspout Disconnection
....many more

Spreadsheet Tool for Estimating Pollutant Load (STEPL)

(EPA)



Example Application

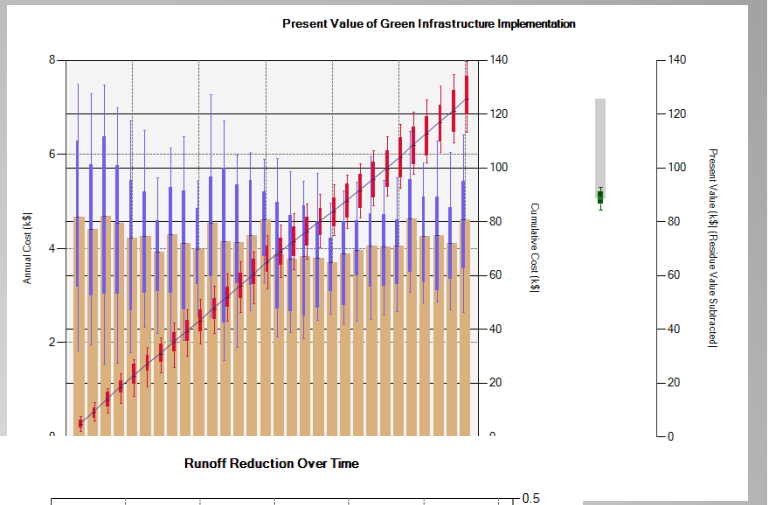
STEPL

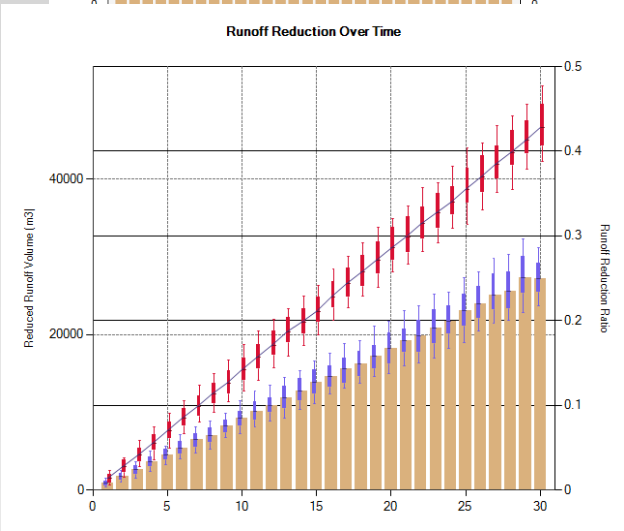
- Web-enabled tool
- Quantifies cost effectiveness of reducing runoff with LID/SCM
- Based on:
  - Precipitation & ET data
  - Land use descriptions
  - SCM options to be considered
- Monte-carlo simulations
- User's manual and supporting documentation not accessible

Low Impact Development Rapid Assessment (LIDRA)

(Drexel University)

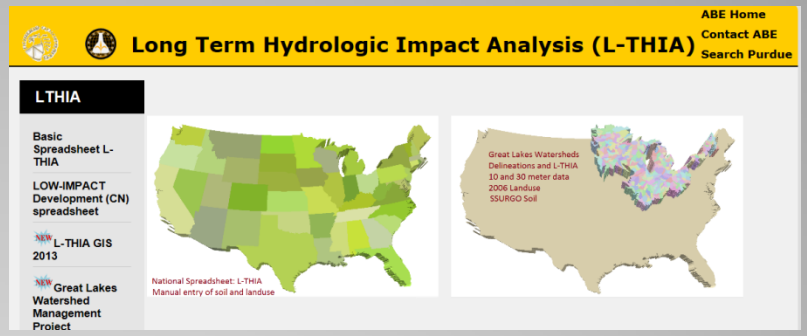
- Determine if a proposed SCM will provide the annual runoff reduction necessary
  - Annual and cumulative cost
  - Present value





Example Application

LIDRA

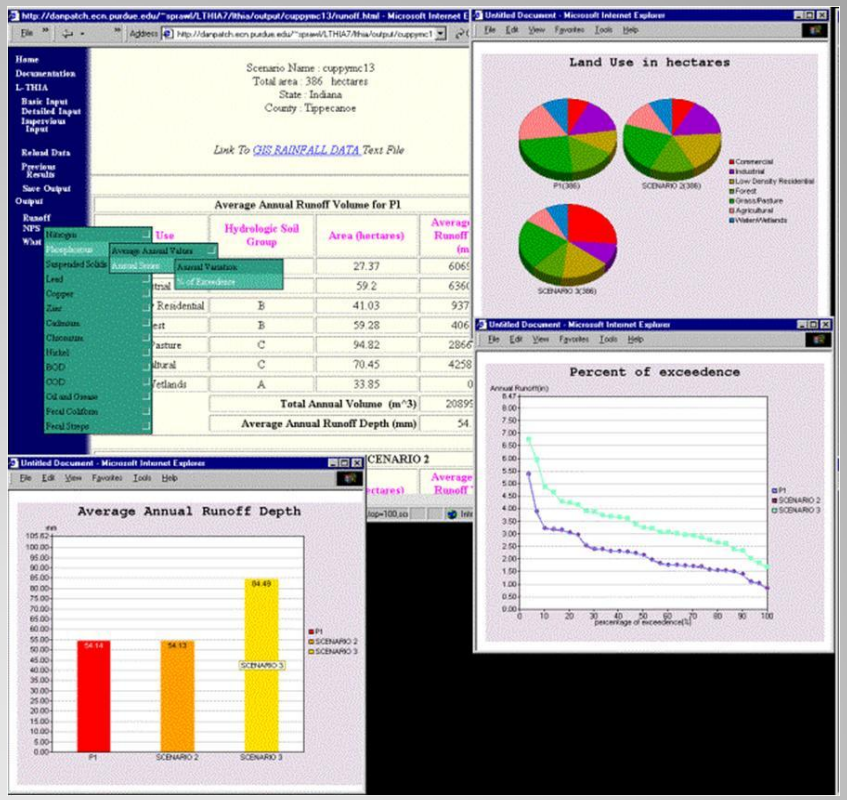


- Web-enabled screening level tool
- Quantifies impact of land use change on water quantity and quality
- Based on:
  - Runoff Curve Number approach
  - 30 years of precipitation data
  - Event Mean Concentrations for pollutant loading estimation
- Provides graphical and tabular runoff volumes and associated pollutant loads

Long-Term Hydrologic Impact Assessment Model (L-THIA)

(Purdue University)

- Estimate changes in recharge and runoff from existing or future land use
  - Site
  - Watershed



Example Application

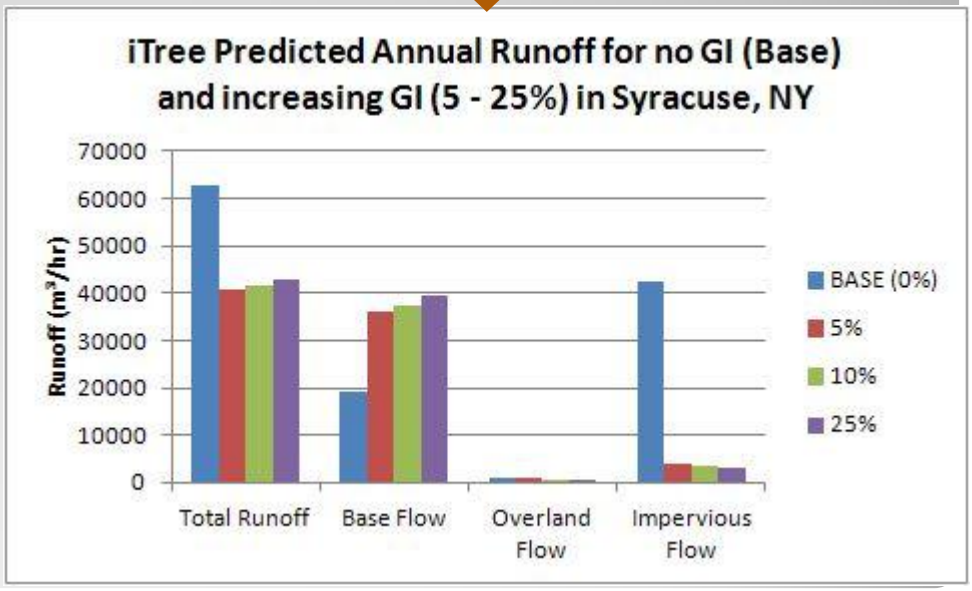
L-THIA

- GIS interface
- Watershed scale
- Analyzes changes in stream flow and water quality
- Based on:
  - Tree canopy
  - Impervious cover
  - USGS gauging station
- Cumbersome to hand delineate polygons
- Target audience is urban planners and natural resource managers

i-Tree Hydro

(USDA Forest Service/SUNY-ESF)

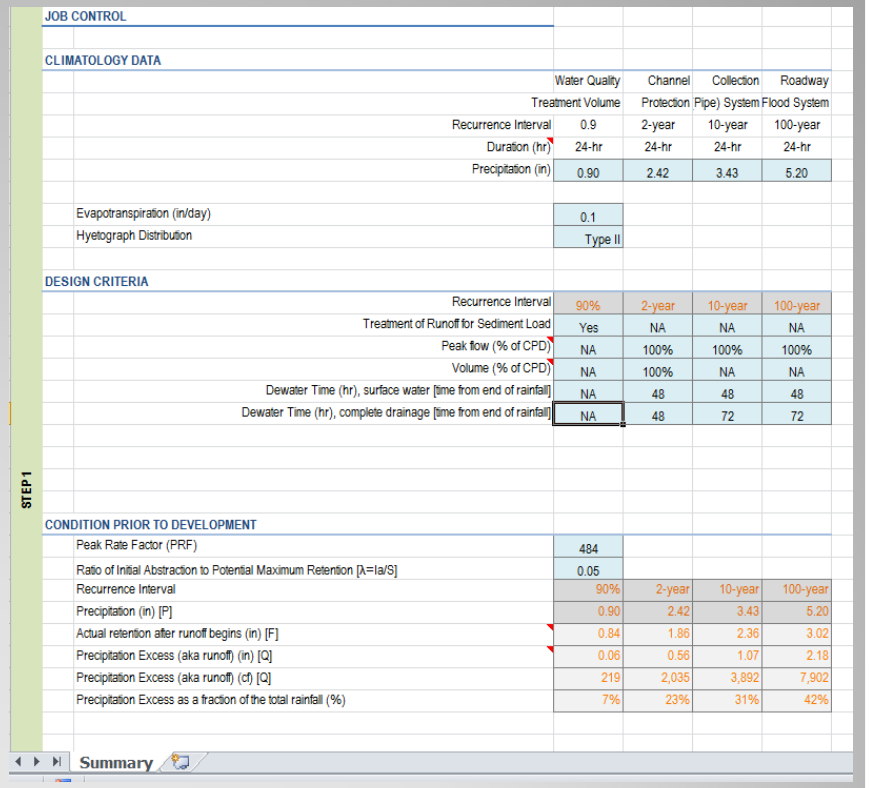
- How does the city-wide tree planting effort affect annual runoff volumes?
- What is the pollutant load downstream from the current land use?



Example Application

i-Tree Hydro

- Excel based
- Site-scale design tool
- Generates surface runoff hydrograph and routes through user defined SCMs
- Analysis of peak flow, volume, and shape of the hydrograph
- Discrete storm events only
- Target audience: design and municipal engineers



STEP 1

JOB CONTROL

CLIMATOLOGY DATA

	Water Quality Treatment Volume	Channel Protection	Collection Pipe) System	Roadway Flood System
Recurrence Interval	0.9	2-year	10-year	100-year
Duration (hr)	24-hr	24-hr	24-hr	24-hr
Precipitation (in)	0.90	2.42	3.43	5.20
Evapotranspiration (in/day)	0.1			
Hyetograph Distribution	Type II			

DESIGN CRITERIA

Recurrence Interval	90%	2-year	10-year	100-year
Treatment of Runoff for Sediment Load	Yes	NA	NA	NA
Peak flow (% of CPD)	NA	100%	100%	100%
Volume (% of CPD)	NA	100%	NA	NA
Dewater Time (hr), surface water [time from end of rainfall]	NA	48	48	48
Dewater Time (hr), complete drainage [time from end of rainfall]	NA	48	72	72

CONDITION PRIOR TO DEVELOPMENT

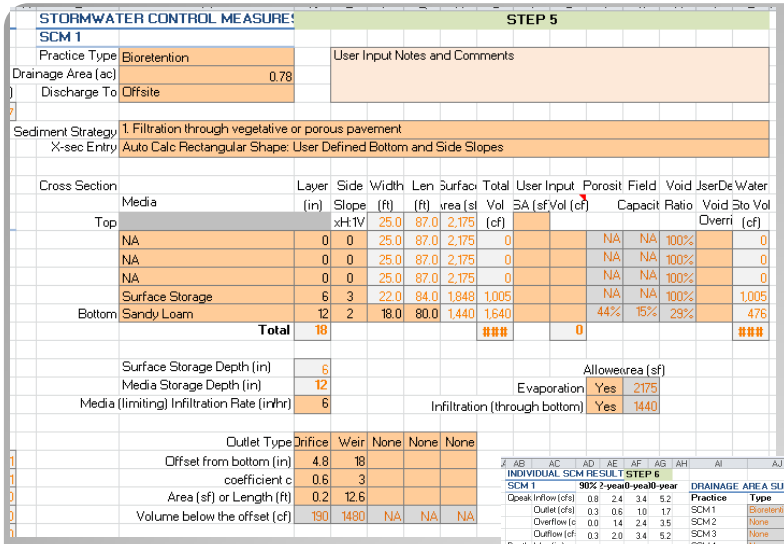
Peak Rate Factor (PRF)	484			
Ratio of Initial Abstraction to Potential Maximum Retention [λ=Ia/S]	0.05			
Recurrence Interval	90%	2-year	10-year	100-year
Precipitation (in) [P]	0.90	2.42	3.43	5.20
Actual retention after runoff begins (in) [F]	0.84	1.86	2.36	3.02
Precipitation Excess (aka runoff) (in) [Q]	0.06	0.56	1.07	2.18
Precipitation Excess (aka runoff) (cf) [Q]	219	2,035	3,892	7,902
Precipitation Excess as a fraction of the total rainfall (%)	7%	23%	31%	42%

Summary

Site Development Spreadsheet Tool (SDST)

(Tetra Tech)

- Design and evaluate SCMs for a site redevelopment project for multiple design criteria



STORMWATER CONTROL MEASURES — STEP 5

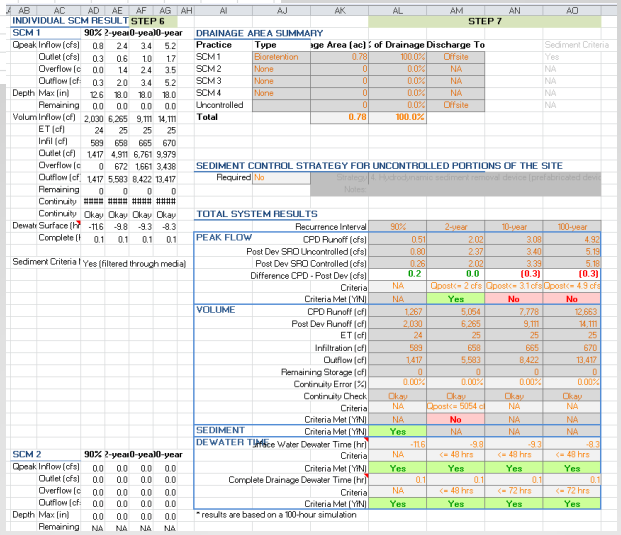
SCM 1

Practice Type	Bioretention	User Input Notes and Comments
Drainage Area (ac)	0.78	
Discharge To	Offsite	
Sediment Strategy	1. Filtration through vegetative or porous pavement	
X-sec Entry	Auto Calc Rectangular Shape: User Defined Bottom and Side Slopes	

Cross Section	Media	Layer (in)	Side Slope xH:1V	Width (ft)	Len (ft)	Surface Area (sf)	Total Vol (cf)	User Input SA (sf)	User Input Vol (cf)	Porosity	Field Capacity	Void Ratio	User Defined Void Ratio Overrid	Water Sto Vol (cf)
Top				25.0	87.0	2,175								
	NA	0	0	25.0	87.0	2,175	0			NA	NA	100%		0
	NA	0	0	25.0	87.0	2,175	0			NA	NA	100%		0
	NA	0	0	25.0	87.0	2,175	0			NA	NA	100%		0
	Surface Storage	6	3	22.0	84.0	1,848	1,005			NA	NA	100%		1,005
Bottom	Sandy Loam	12	2	18.0	80.0	1,440	1,640			44%	15%	29%		476
	Total	18					###		0					###

Surface Storage Depth (in)	6		Allowed area (sf)
Media Storage Depth (in)	12	Evaporation	Yes 2175
Media (limiting) Infiltration Rate (in/hr)	6	Infiltration (through bottom)	Yes 1440

Outlet Type	Orifice	Weir	None	None	None
Offset from bottom (in)	4.8	18			
coefficient c	0.6	3			
Area (sf) or Length (ft)	0.2	12.6			
Volume below the offset (cf)	190	1480	NA	NA	NA



INDIVIDUAL SCM RESULTS — STEP 6

SCM 1		90%	2-year	10-year	100-year
Qpeak	Inflow (cfs)	0.8	2.4	3.4	5.2
	Outlet (cfs)	0.3	0.6	1.0	1.7
	Overflow (c	0.0	1.4	2.4	3.5
	Outflow (cf	0.3	2.0	3.4	5.2
Depth	Max (in)	12.6	18.0	18.0	18.0
	Remaining	0.0	0.0	0.0	0.0
Volum	Inflow (cf)	2,030	6,265	9,111	14,111
	ET (cf)	24	25	25	25
	Infil (cf)	589	658	665	670
	Outlet (cf)	1,417	4,911	6,761	9,979
	Overflow (c	0	672	1,661	3,438
	Outflow (cf	1,417	5,583	8,422	13,417
	Remaining	0	0	0	0
	Continuity	#####	#####	#####	#####
	Continuity	Okay	Okay	Okay	Okay
Dewat	Surface (hr	-11.6	-9.8	-9.3	-8.3
	Complete (h	0.1	0.1	0.1	0.1
Sediment Criteria		Yes (filtered through media)			

SCM 2		90%	2-year	10-year	100-year
Qpeak	Inflow (cfs)	0.0	0.0	0.0	0.0
	Outlet (cfs)	0.0	0.0	0.0	0.0
	Overflow (c	0.0	0.0	0.0	0.0
	Outflow (cf	0.0	0.0	0.0	0.0
Depth	Max (in)	0.0	0.0	0.0	0.0
	Remaining	NA	NA	NA	NA

DRAINAGE AREA SUMMARY — STEP 7

Practice	Type	Drainage Area (ac)	% of Drainage	Discharge To	Sediment Criteria
SCM 1	Bioretention	0.78	100.0%	Offsite	Yes
SCM 2	None	0	0.0%	NA	NA
SCM 3	None	0	0.0%	NA	NA
SCM 4	None	0	0.0%	NA	NA
Uncontrolled		0	0.0%	Offsite	NA
Total		0.78	100.0%		

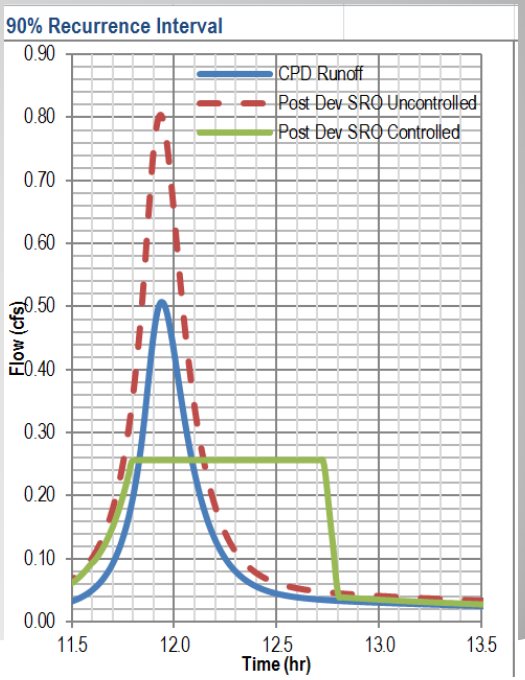
SEDIMENT CONTROL STRATEGY FOR UNCONTROLLED PORTIONS OF THE SITE

Required	No	Strategy	4. Hydrodynamic sediment removal device (prefabricated devi
		Notes:	

TOTAL SYSTEM RESULTS

	Recurrence Interval	90%	2-year	10-year	100-year
PEAK FLOW	CPD Runoff (cfs)	0.51	2.02	3.08	4.92
	Post Dev SRO Uncontrolled (cfs)	0.80	2.37	3.40	5.15
	Post Dev SRO Controlled (cfs)	0.26	2.02	3.39	5.18
	Difference CPD - Post Dev (cfs)	0.2	0.0	(0.3)	(0.3)
	Criteria	NA	Qpost<= 2 cfs	Qpost<= 3.1 cfs	Qpost<= 4.9 cfs
	Criteria Met (Y/N)	NA	Yes	No	No
VOLUME	CPD Runoff (cf)	1,267	5,054	7,778	12,653
	Post Dev Runoff (cf)	2,030	6,265	9,111	14,111
	ET (cf)	24	25	25	25
	Infiltration (cf)	589	658	665	670
	Outflow (cf)	1,417	5,583	8,422	13,417
	Remaining Storage (cf)	0	0	0	0
	Continuity Error (%)	0.00%	0.00%	0.00%	0.00%
	Continuity Check	Okay	Okay	Okay	Okay
	Criteria	NA	Qpost<= 5054 cf	NA	NA
	Criteria Met (Y/N)	NA	No	NA	NA
SEDIMENT	Criteria Met (Y/N)	Yes	NA	NA	NA
DEWATER TIME	Surface Water Dewater Time (hr)	-11.6	-9.8	-9.3	-8.3
	Criteria	NA	<= 48 hrs	<= 48 hrs	<= 48 hrs
	Criteria Met (Y/N)	Yes	Yes	Yes	Yes
	Complete Drainage Dewater Time (hr)	0.1	0.1	0.1	0.1
	Criteria	NA	<= 48 hrs	<= 72 hrs	<= 72 hrs
	Criteria Met (Y/N)	Yes	Yes	Yes	Yes

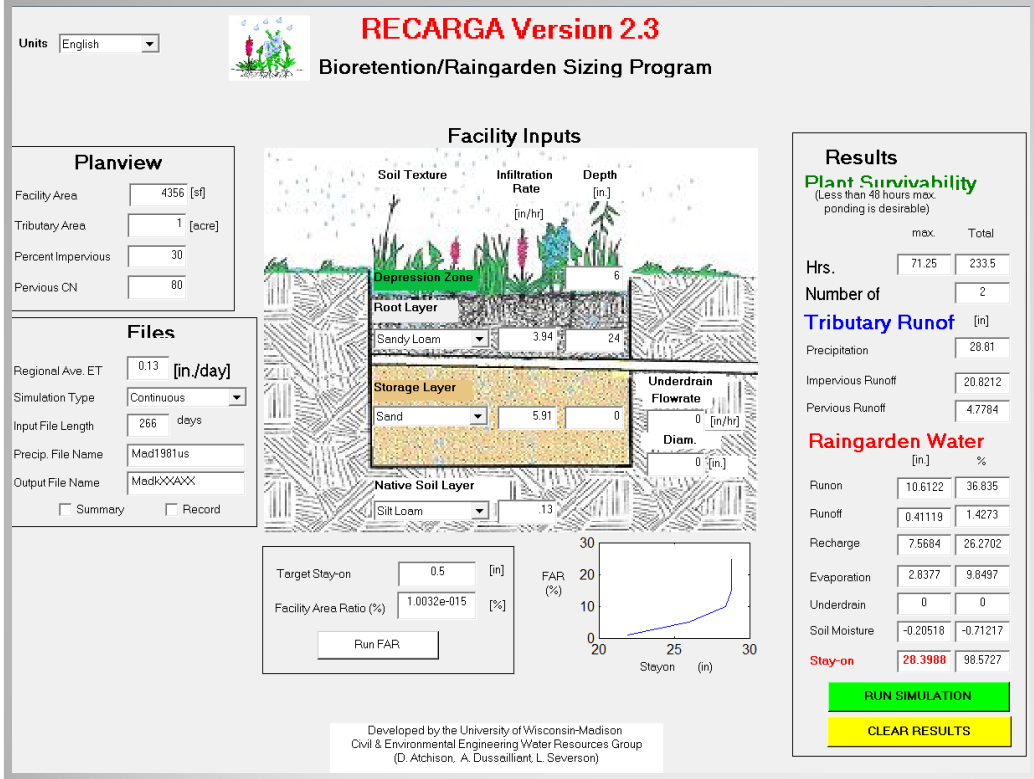
* results are based on a 100-hour simulation



Example Application

SDST

- Based on:
  - Rainfall and evaporation file
  - Drainage area characteristics
  - Cross-section characteristics

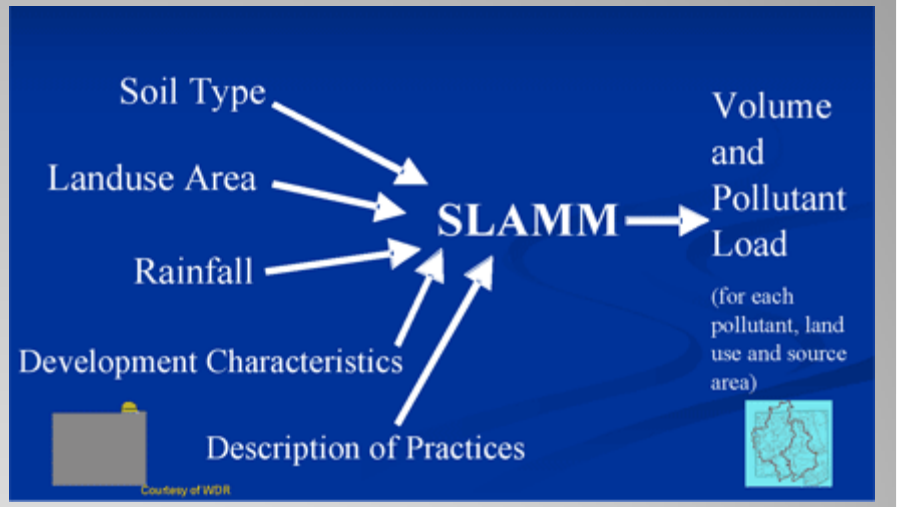


- MATLAB application
- Design tool for evaluating performance of bioretention facilities and infiltration basins
- Model can simulate continuous rainfall, a single-event, or user specified volume
- Can target "stay-on" volume

RECARGA

(University of Wisconsin-Madison)

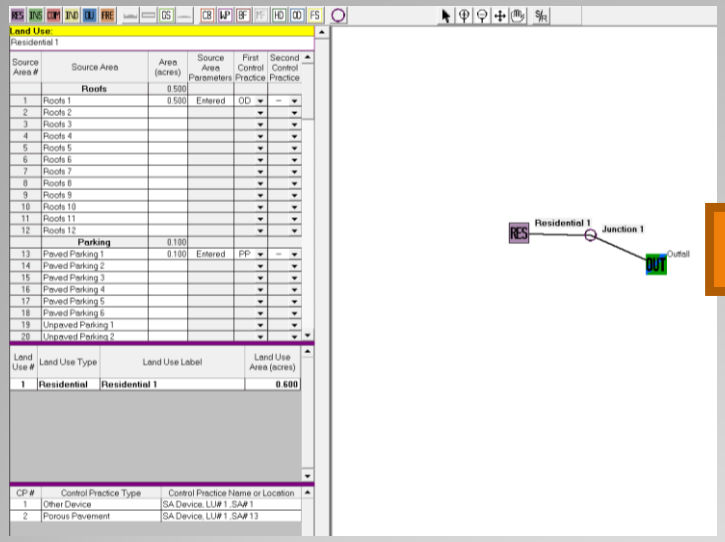
- Graphical interface
- Tool to evaluate runoff volume and pollutant loading from different sources
- Based on:
  - Hydrologic characteristics
  - Land use characteristics
  - Control characteristics

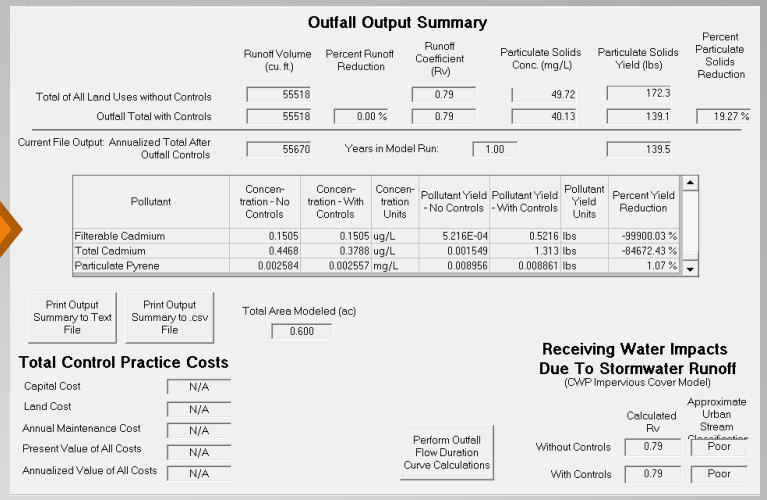


- Design SCMs based on source of pollutant
- Based on Dr. Robert Pitt's research
- Long-term simulations
- Model includes cost data
- ArcSLAMM is under development

Source Loading and Management Model for Windows (WinSLAMM)

(University of Alabama/PV & Associates)



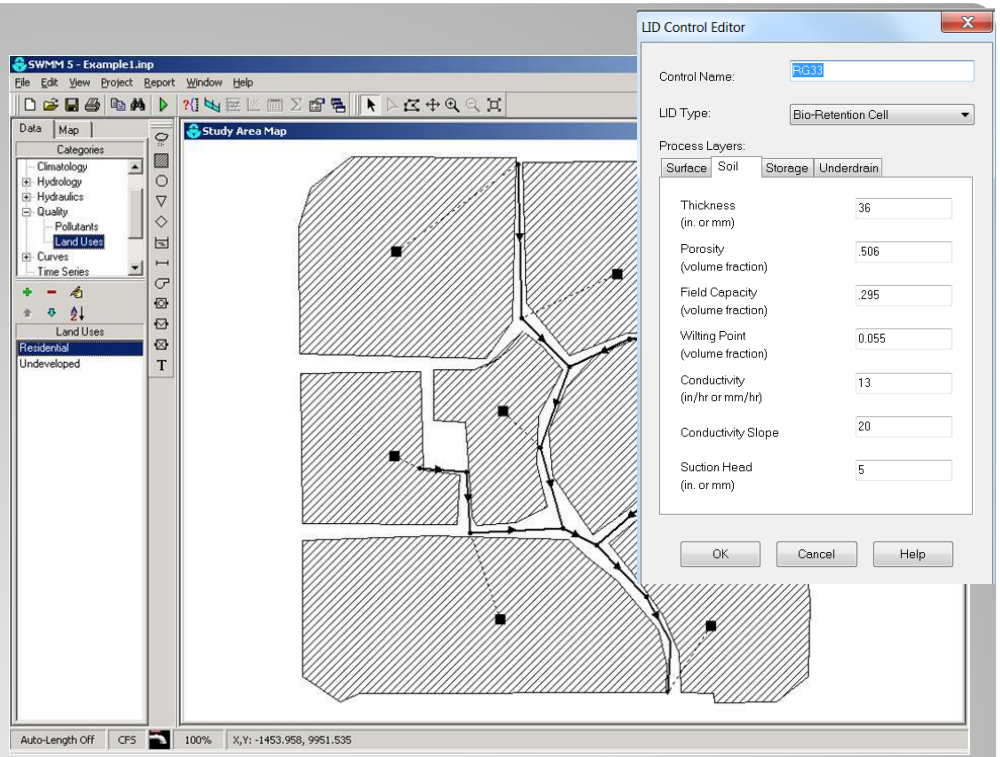


- How often should street sweeping be performed to reduce sediment load by 40%?
- Comparing BMP effectiveness for different land use scenarios

Example Application

WinSLAMM

- Graphical interface
- Complex model
- New controls for SCM evaluation
- Based on:
  - Cross-section
  - SCM specifications
  - Initial soil conditions
  - Hydrologic data
- Limitless # of permutations
- Graphical and tabular output

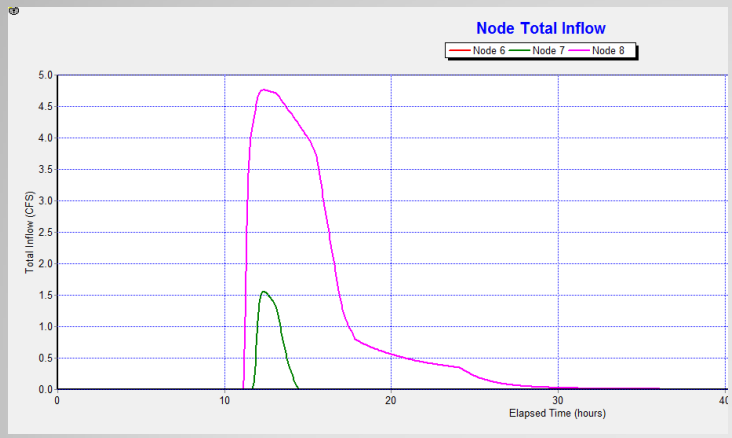


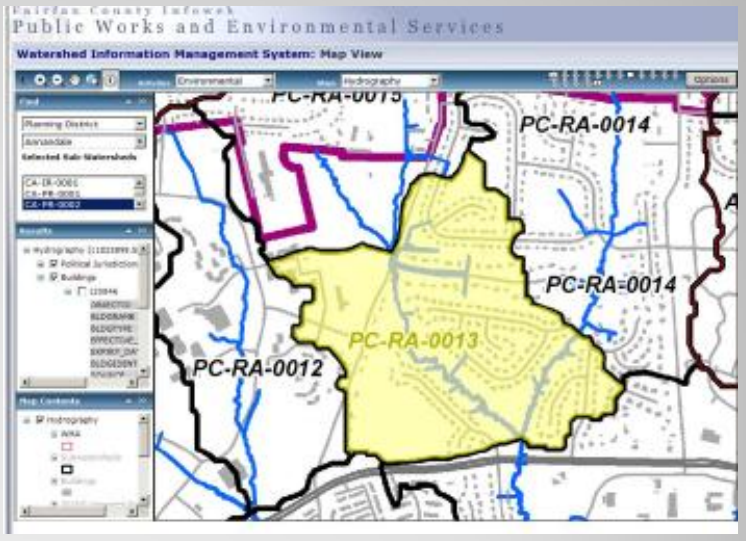
Bioretention
Infiltration Trenches
Permeable Pavement
Rain Barrels
Vegetative Swales
Detention Basins

Stormwater Management Model (SWMM)

(EPA)

- Create a prioritization strategy to maximize stormwater benefits
- Evaluate if proposed SCMs will provide CSO reduction benefits





Example Application

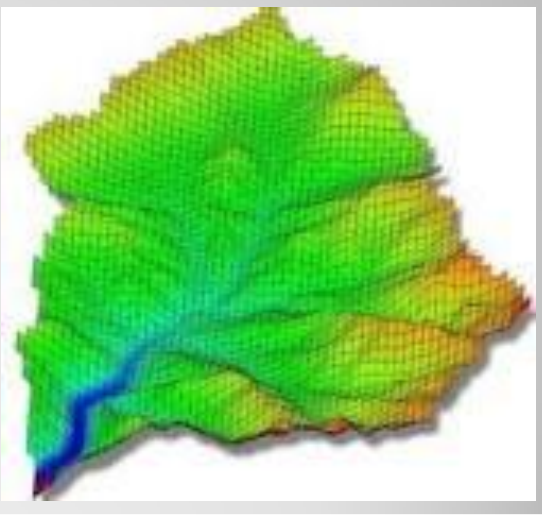
SWMM

	Water Quality	Volume	Costing	User Interface	Complexity	Public Domain	Site-Scale	Watershed-Scale	Planning	Design
GREEN VALUES	X	X	X	WEB	SIMPLE	X	X		X	
EPA SW CALC		X		WEB	SIMPLE	X	X		X	
WERF SELECT	X	X	X	EXCEL	MODERATE	X	X	X	X	
MAPSHED/GWLF	X	X		GIS	MODERATE	X		X	X	
STEPL	X	X		EXCEL	MODERATE	X		X	X	
LIDRA		X	X	WEB	MODERATE	X	X		X	
L-THIA	X	X		WEB	MODERATE	X	X	X	X	
i-TREE HYDRO	X	X		GIS	COMPLEX	X		X	X	
SDST		X		EXCEL	MODERATE	*				X
RECARGA		X		WEB	MODERATE	X	X			X
WinSLAMM	X		X	WEB	MODERATE		X			X
SWMM	X	X		GRAPHICAL	COMPLEX	X	X	X	X	X

Model Summary Table

Tool selection depends on the **objective** you are trying to achieve and the **questions** you are trying to answer

- Comprehensive tool that combines site design with cost effectiveness and construction cost information
- Modeling the fate of pollutants that stormwater transports into SCMs
- 2D-modeling of surface runoff and routing through SCMs



What's Next…

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Thank You!