BMP-Decision Support System (BMP-DSS) Phase II

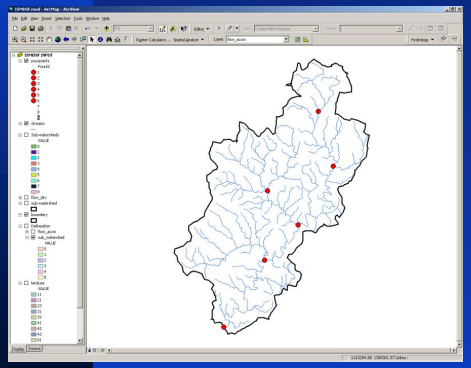
In

Prince George's County Maryland

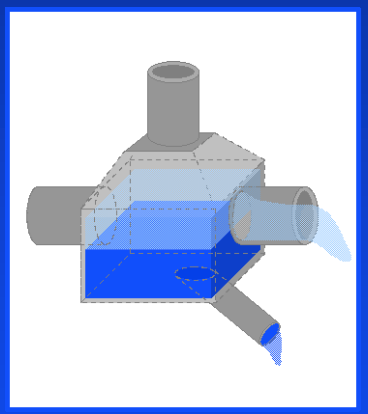
PRINCE GEORGE'S COUNTY
Department of Environmental Resources

BMP Decision Support System for Watershed-based Stormwater Management

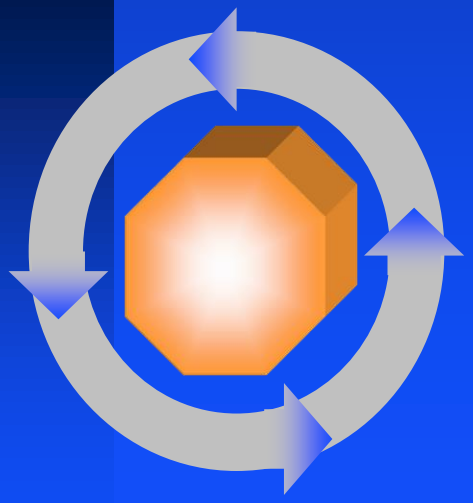
Major Module Enhancements



GIS Linkage



LID – CSO Linkage



Optimization

Project Team Members

Prince George's Co.

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USEPA – ORD

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University of Virginia

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- Sam Zhai

Wright Water Engineers, Inc.

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Tetra Tech, Inc.

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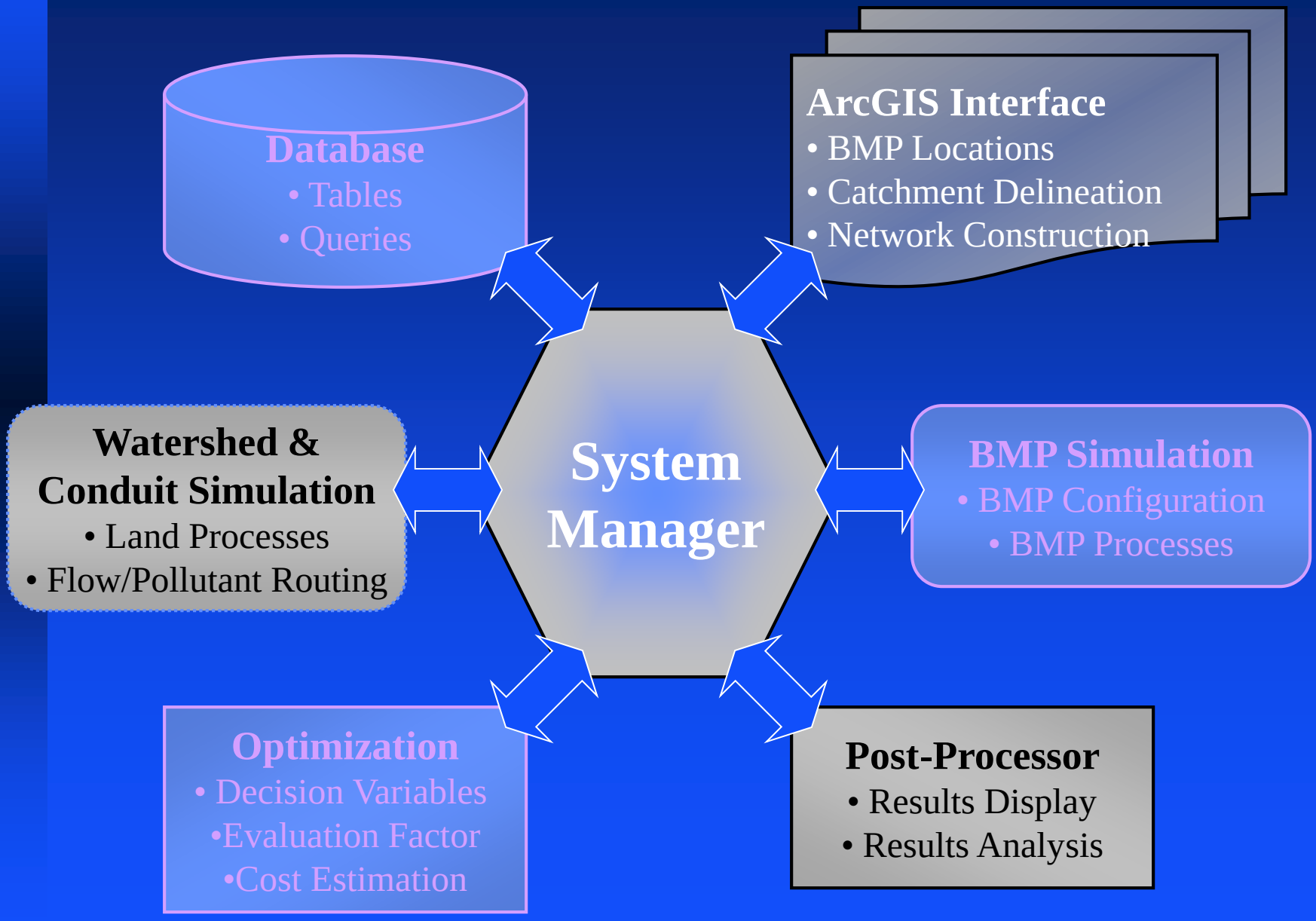
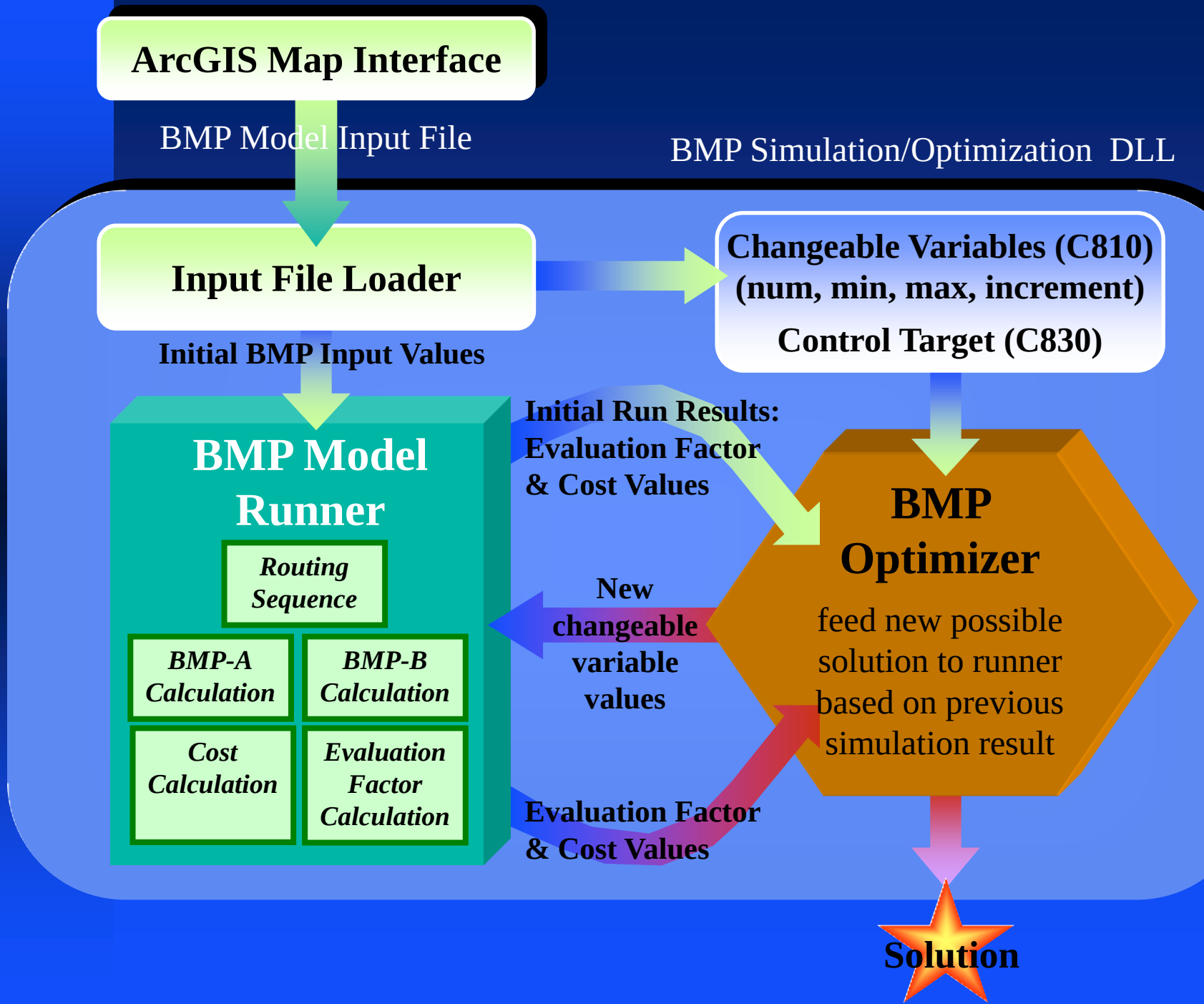
- Dr. Leslie Shoemaker
- Dr. Ting Dai
- Khalid Alvi
- Haihong Yang
- Mira Chokshi
- Dr. Sabu Paul
- Priya Krishnan

System Overview




ArcGIS Map Interface
BMP Model Input File
BMP Simulation/Optimization DLL
Input File Loader
Changeable Variables (C810)
(num, min, max, increment)
Control Target (C830)
Initial BMP Input Values
BMP Model Runner
Routing Sequence
BMP-A Calculation
BMP-B Calculation
Cost Calculation
Evaluation Factor Calculation
Initial Run Results:
Evaluation Factor
& Cost Values
New
changeable
variable
values
BMP Optimizer
feed new possible solution to runner based on previous simulation result
Evaluation Factor
& Cost Values
Solution

Minimum Software Requirements:

- Microsoft Office 2000 Professional
- ArcView 9.x
- ArcGIS Spatial Analyst

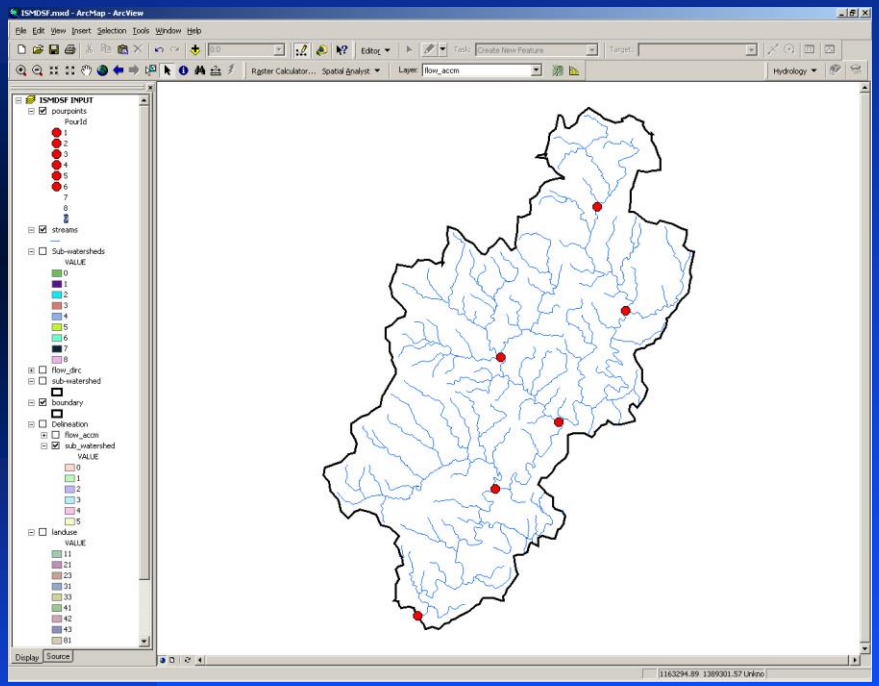
Watershed & Conduit Module

System uses externally generated land use-associated time series

System applies SWMM TRANSPORT algorithms for conduit routing simulation

Accesses all subroutines and functions through a DLL (dynamic link library)

BMP Module – GIS Linkage



Land use Functions

- Reclassify or group land use
- Time series association

BMP Functions

- Add/Remove BMP
- Modify existing BMP
- Select from list

GIS/System Functions

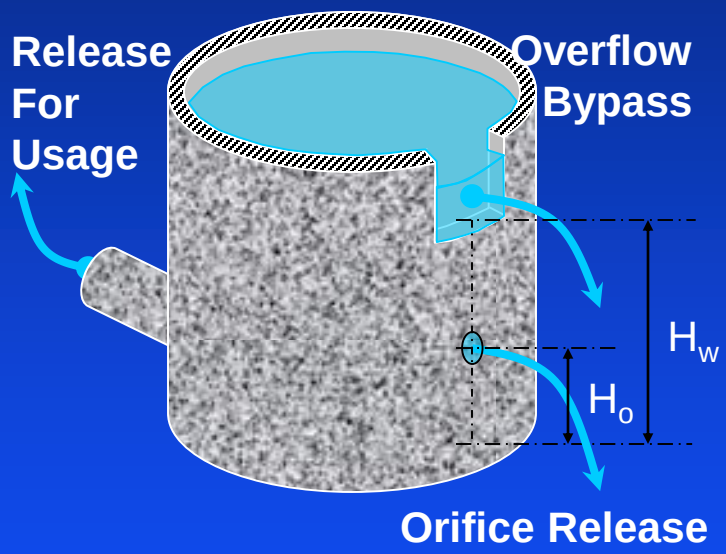
- Delineate watershed or BMP drainage area
- Generate network
- Run model scenario(s)

BMP Options


Define BMP Templates
BMP Templates
Bioretention Basin
Dry Pond
Rain Barrels
Cistern
Wet Pond / Wet Land
Infiltration Trench
Vegetative Swale
Green Roof
Porous Pavement
Set Dimensions
Cancel

Additional BMPs: Cistern/Rain Barrel Functionality

- Function of stored volume, release rates, and water level
- Variable time step calculation



Output:

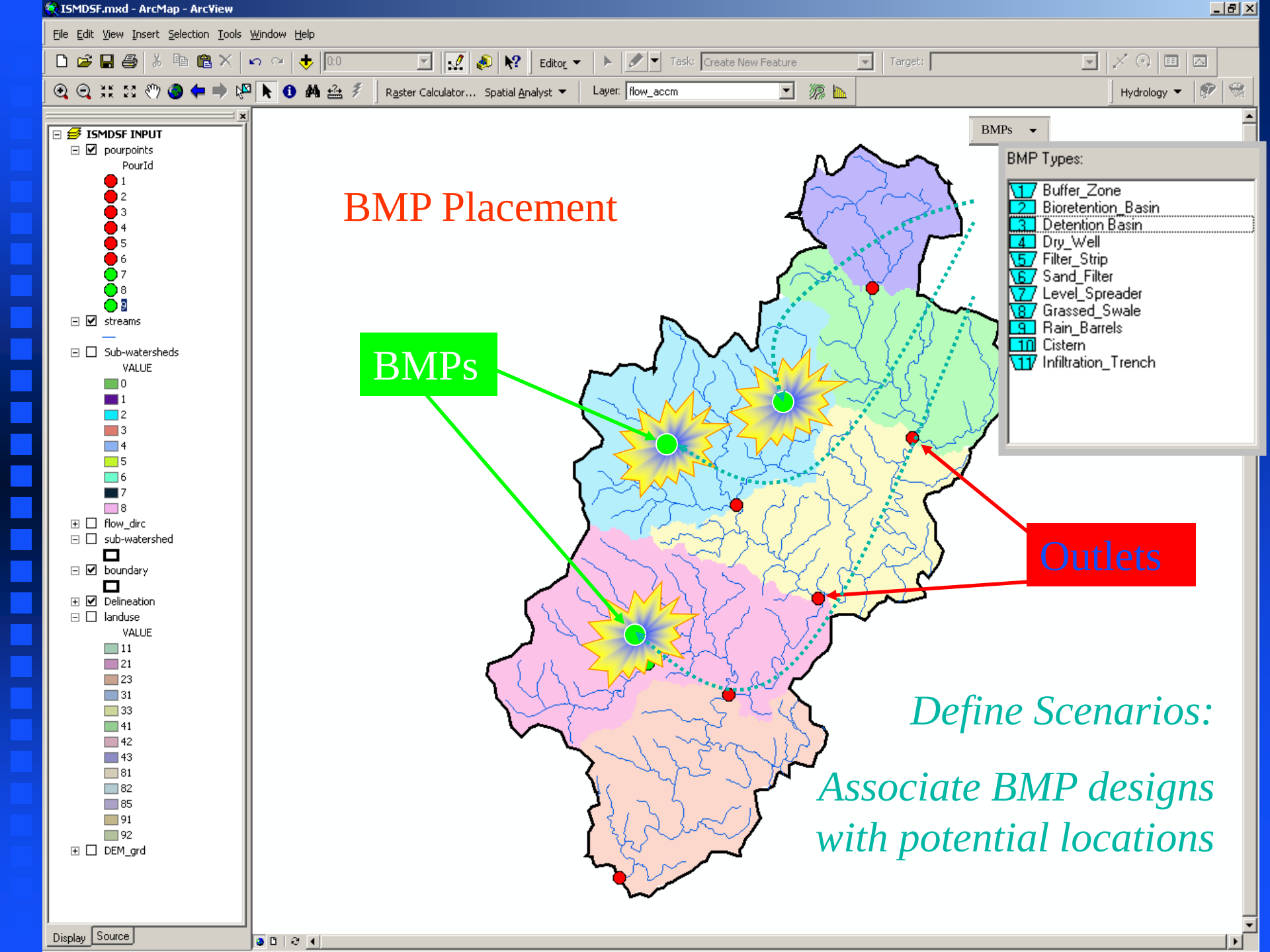
Weir Overflow
Orifice Release

Release For Usage

When cistern water is pumped for domestic use, the modeler can define an hourly per-capita usage rate and the number of people

Orifice Release

The modeler defines the number of dry days following a storm event, after which water from a rain-barrel is released.


ISMDSF.mxd - ArcMap - ArcView
File Edit View Insert Selection Tools Window Help
Editor
Task: Create New Feature
Target:
Raster Calculator...
Spatial Analyst
Layer: flow_accm
Hydrology
ISMDSF INPUT
pourpoints
PourId
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4
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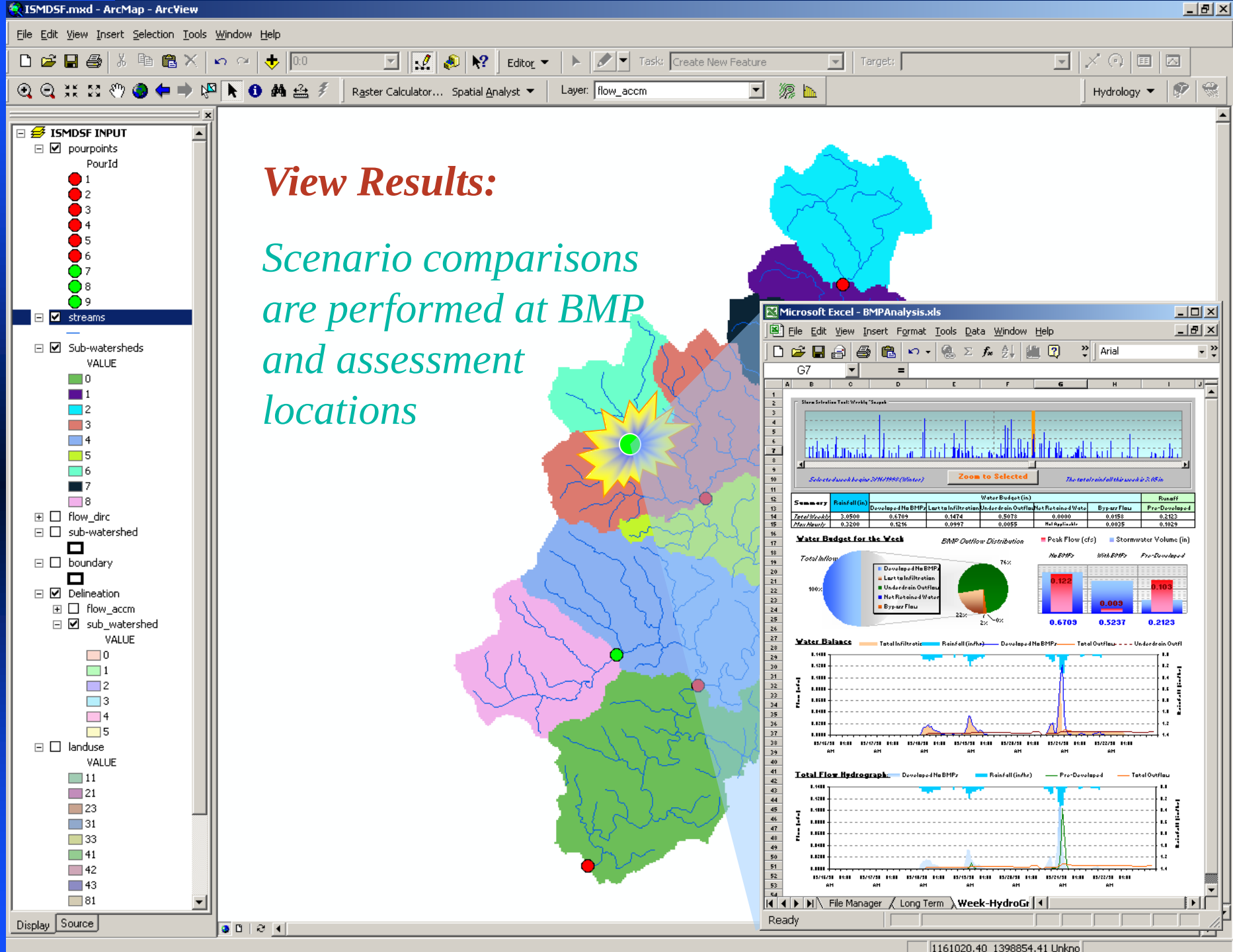
7
8
9
streams
Sub-watersheds
VALUE
0
1
2
3
4
5
6
7
8
flow_dirc
sub-watershed
boundary
Delineation
landuse
VALUE
11
21
23
31
33
41
42
43
81
82
85
91
92
DEM_grd
Display
Source
BMP Placement
BMPs
Outlets
BMPs
BMP Types:
1 Buffer_Zone
2 Bioretention_Basin
3 Detention Basin
4 Dry_Well
5 Filter_Strip
6 Sand_Filter
7 Level_Spreader
8 Grassed_Swale
9 Rain_Barrels
10 Cistern
11 Infiltration_Trench
Define Scenarios:
Associate BMP designs
with potential locations


ISMDSF.mxd - ArcMap - ArcView
File Edit View Insert Selection Tools Window Help
Editor
Task: Create New Feature
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Raster Calculator...
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pourpoints
PourId
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streams
Sub-watersheds
VALUE
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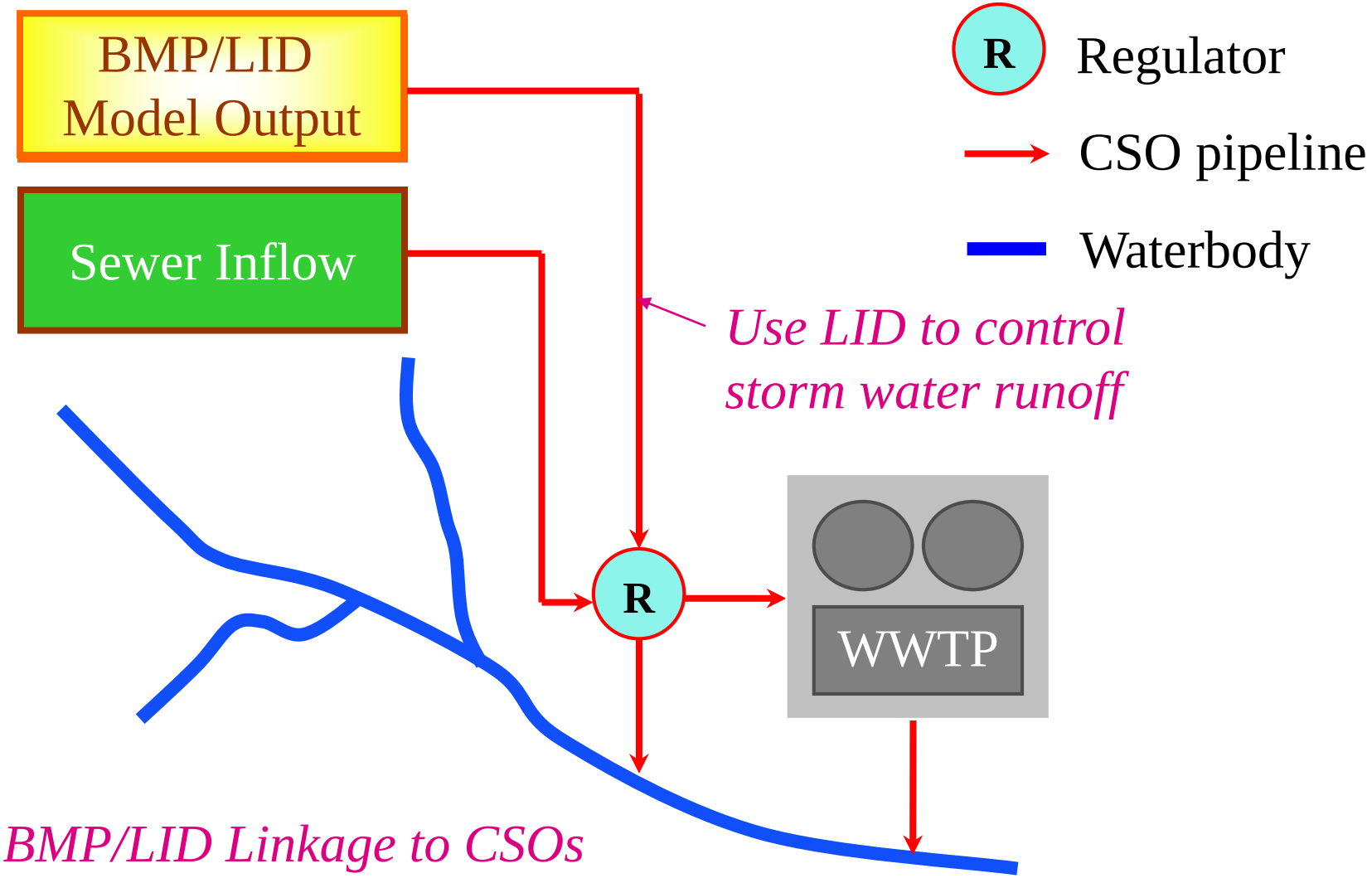
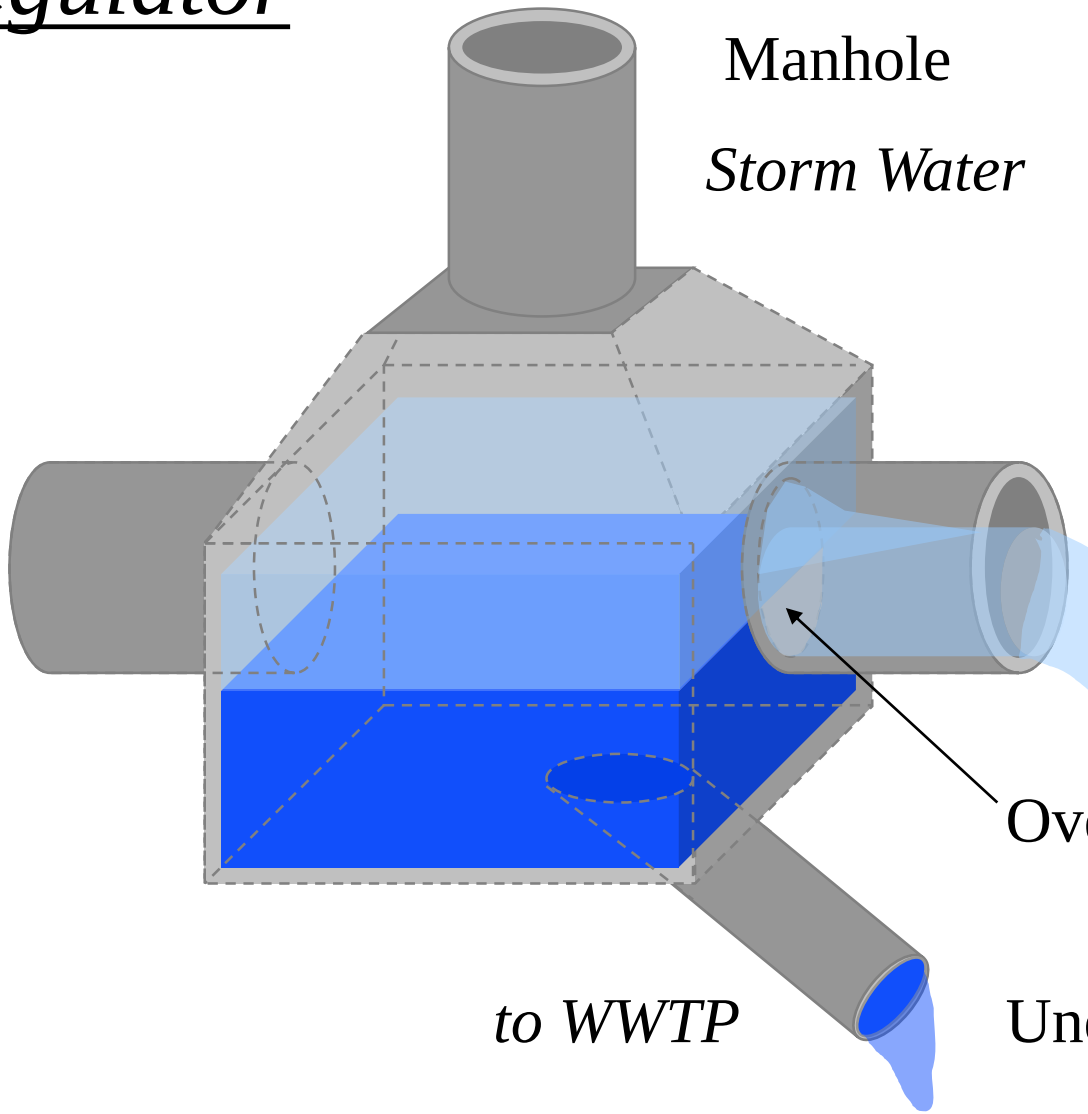
6
7
8
flow_dirc
sub-watershed
boundary
Delineation
flow_accm
sub_watershed
VALUE
0
1
2
3
4
5
landuse
VALUE
11
21
23
31
33
41
42
43
81
Display
Source
View Results:
Scenario comparisons are performed at BMP and assessment locations
Microsoft Excel - BMPAnalysis.xls
File Edit View Insert Format Tools Data Window Help
Arial
G7
Zoom to Selected
Summary
Rainfall (in)
Water Budget (in)
Developed No BMPs
Last to Infiltration
Underdrain Outflow
Not Retained Water
Bypass Flow
Runoff
Pre-Developed
Water Budget for the Week
BMP Outflow Distribution
Peak Flow (cfs)
Stormwater Volume (in)
No BMPs
With BMPs
Pre-Developed
0.122
0.009
0.103
0.6709
0.5237
0.2123
Water Balance
Total Flow Hydrograph
File Manager
Long Term
Week-HydroGr
Ready
1161020.40 1398854.41 Unkno

The Effects of LID on CSOs

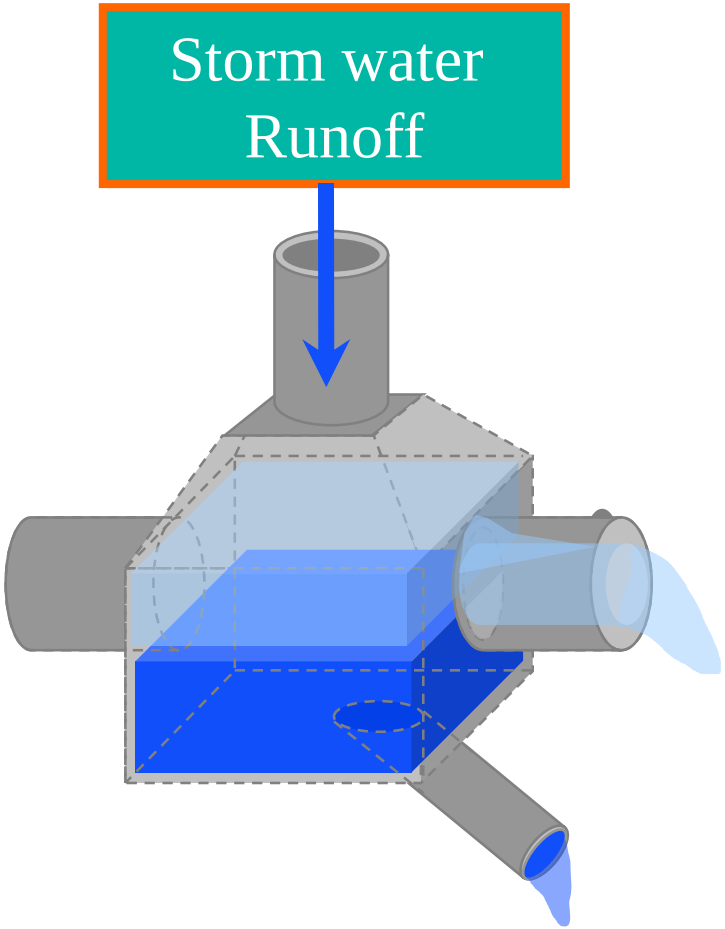


BMP/LID Linkage to CSOs

CSO Regulator

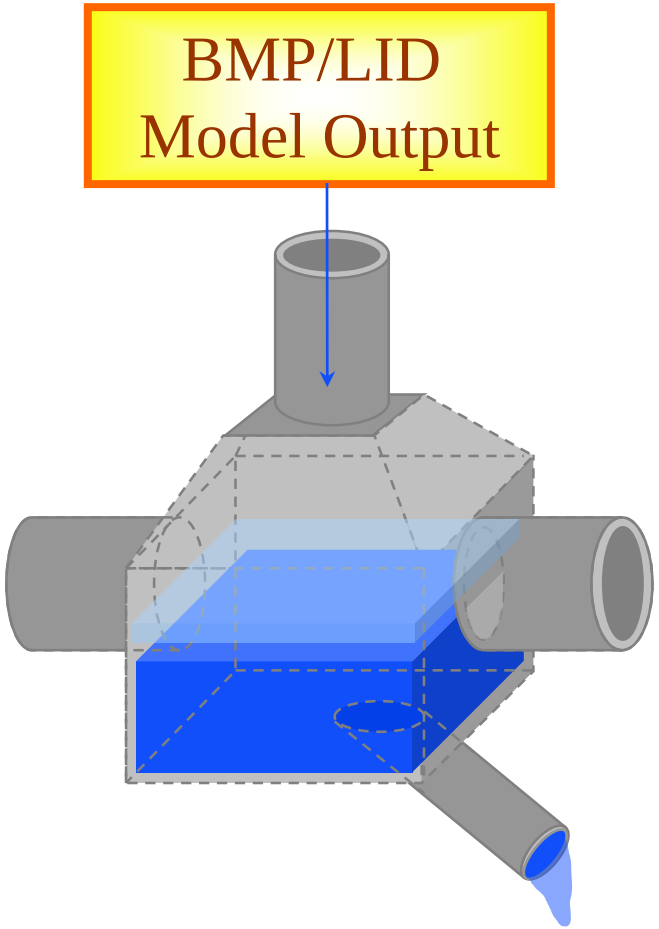


Existing CSO Model



Sewer Overflows Observed

BMP/LID Linkage to CSOs



CSOs Reduced or Eliminated

Optimization

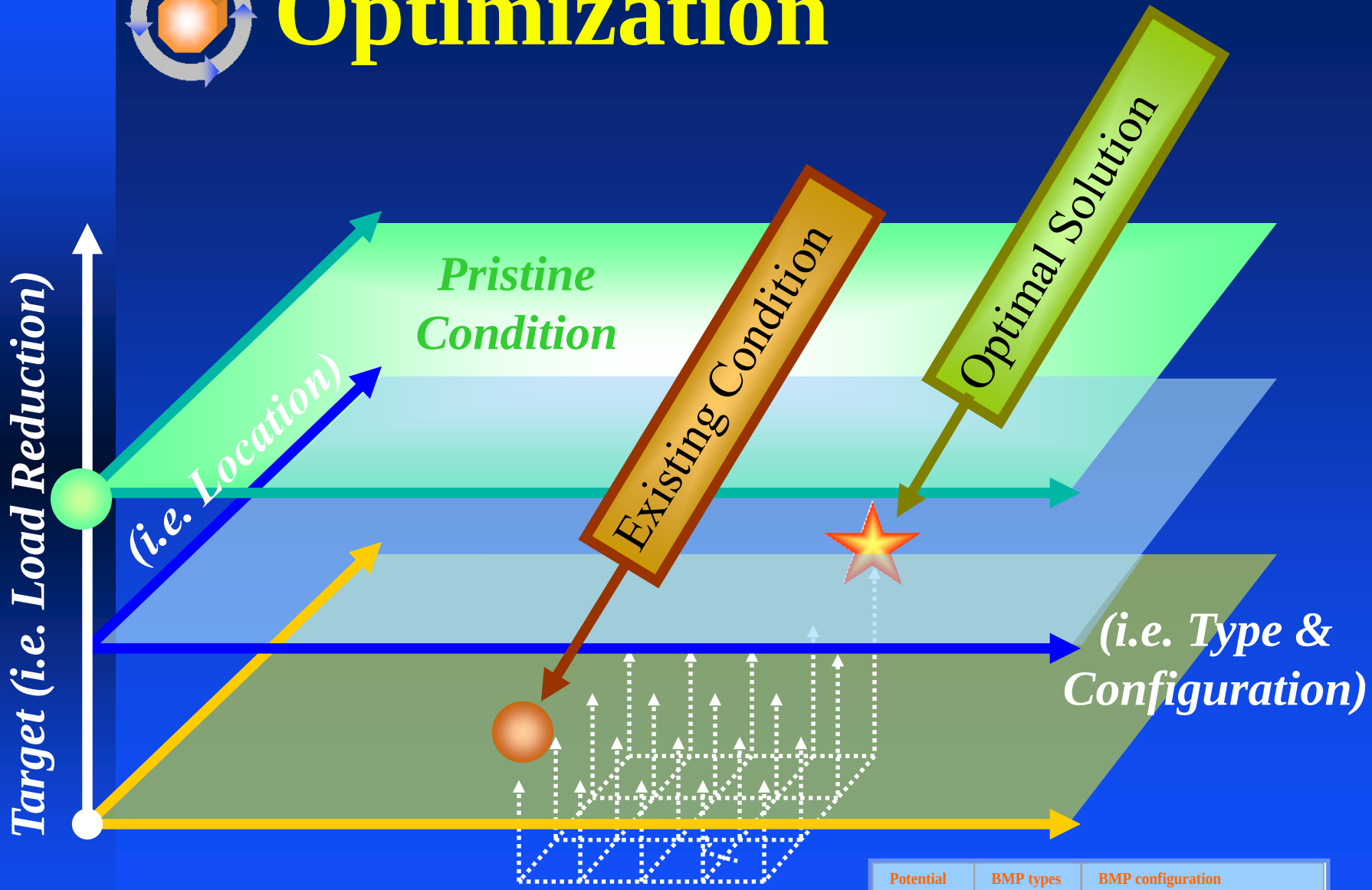
Problem Formulation

- Objectives & constraints
- Evaluation factors & assessment points
- Potential BMP types and locations

Solution Techniques

- Scatter search
- Genetic algorithm

Optimization



Potential Location	BMP types	BMP configuration		
1 (0-1)	A, B, C…	Depth	Surface area	…
2 (0-1)	A, B, C…	Depth	Surface area	…

Feasible Alternatives

Defining BMP Optimization

Find *optimum* BMP placement and selection strategies based on pre-selected potential sites and applicable BMP types.

What is optimum? (Problem Formulation)

- Minimize water quantity and pollutant load (same cost)
- Minimize total cost (same load reduction)

How does one measure optimum?

- Evaluation Criteria: (using continuous simulation)
- Minimum long-term flows and pollutant loads with an pre-defined budget
- Lowest cost among various alternatives to yield the same load reductions

Optimization Procedure

*Two common methods, **Genetic Algorithms** and **Scatter Search**, are both **population-based** approaches that select alternatives from within a set range of attributes present within the population.*

Genetic Algorithm – *Stochastic Method*

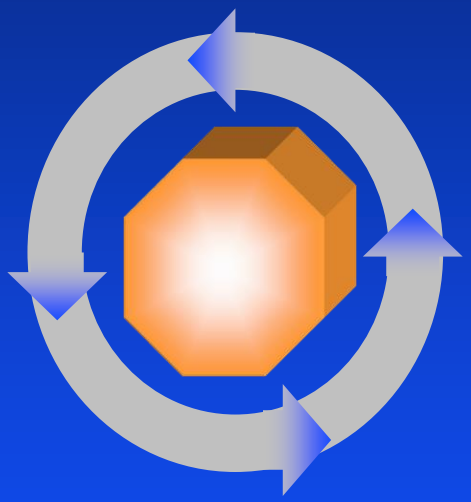
- Uses **probabilistic** rather than **deterministic** search rules.
- Uses **randomization** to select which "elements" of "parent" alternatives are combined to generate "offspring."
- Strongest "offspring" elements are used in the "next generation"

Scatter Search – *Strategic Method*

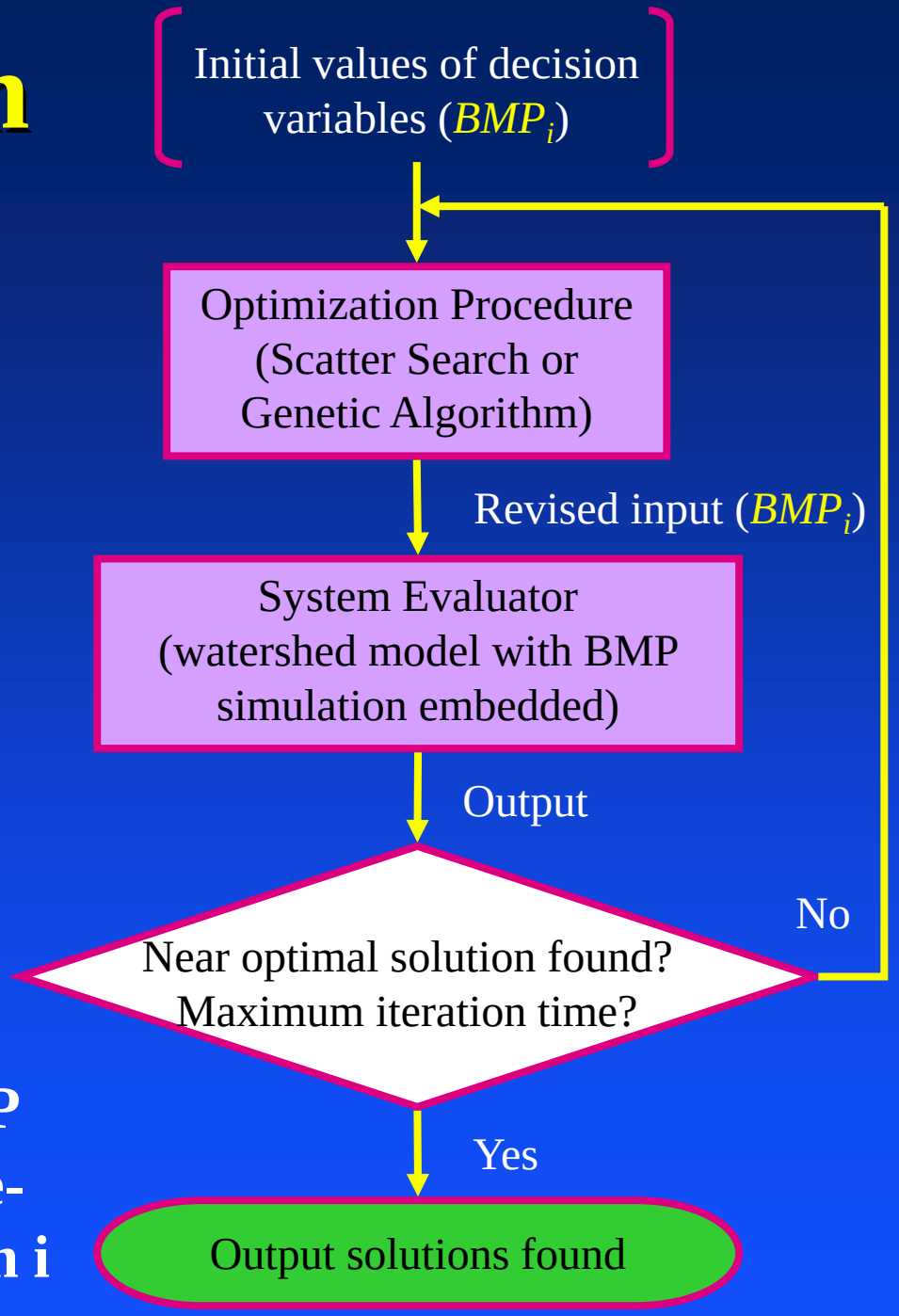
- Uses both deterministic and probabilistic search rules
- Not **randomized** – treats all alternatives equal at the start
- Narrows search based on system response and history

Optimization Flow Chart

For BMP_i *



* BMP_i is a set of BMP decision variables for pre-selected potential location i

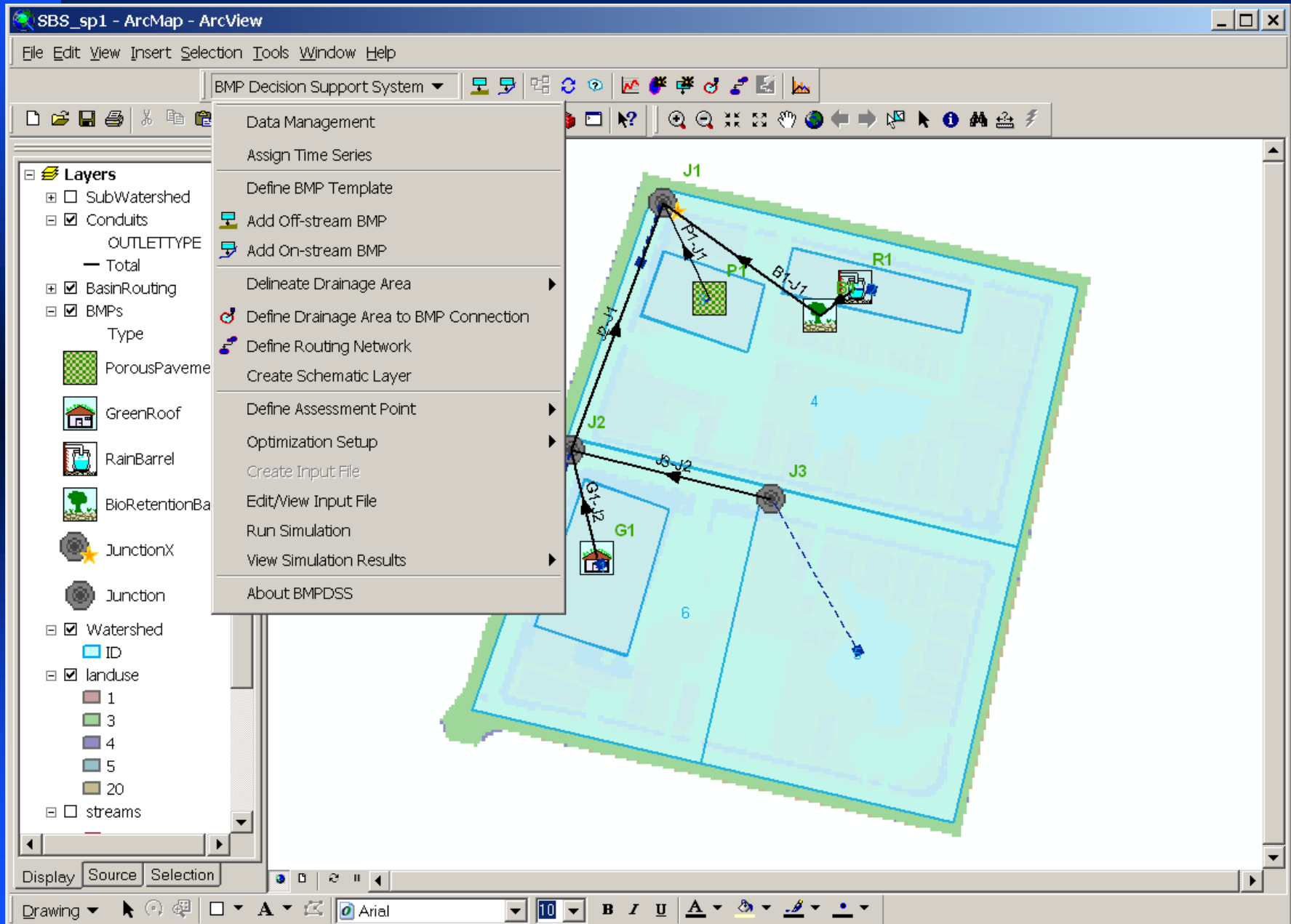


Optimization Decision Matrix

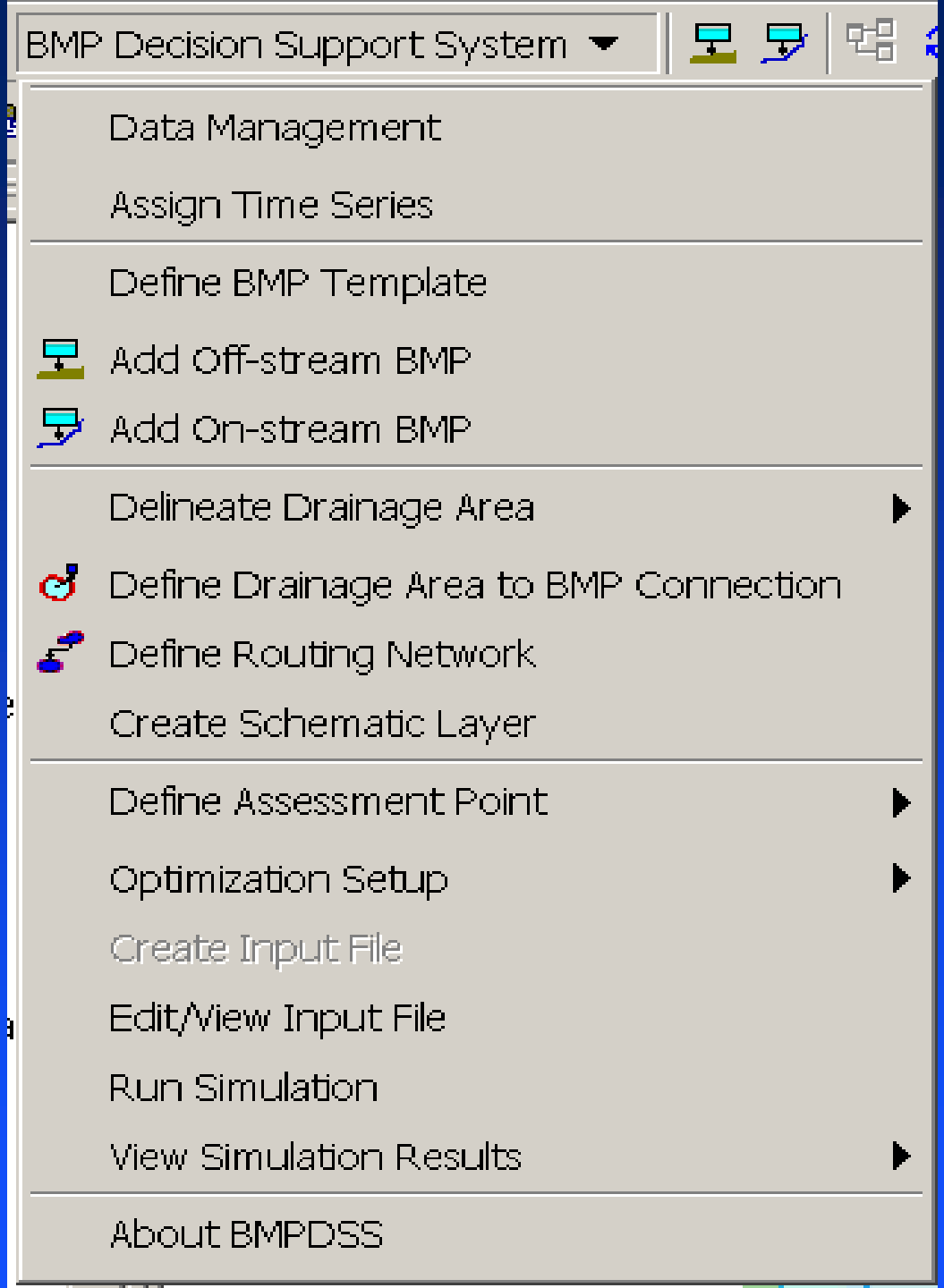
A group of BMP_i ($i = 1,\ldots, n$) forms the decision matrix, which defines the optimization engine's search domain:

Potential Location	BMP Type	BMP Configuration Parameters				
		1	2	3	…	m
1	A1 (wet pond)	Surface area	Pool depth	Outlet structure		
	A2 (Bio-retention)	Surface area	Outlet structure	Soil column depth	Surface infiltration rate	Final infiltration rate
2	C (buffer strip)	Length	Width	Slope	Vegetation height	Overland manning's n
…						
n	B1 (swale)	Length	Width	Slope	Manning's n	

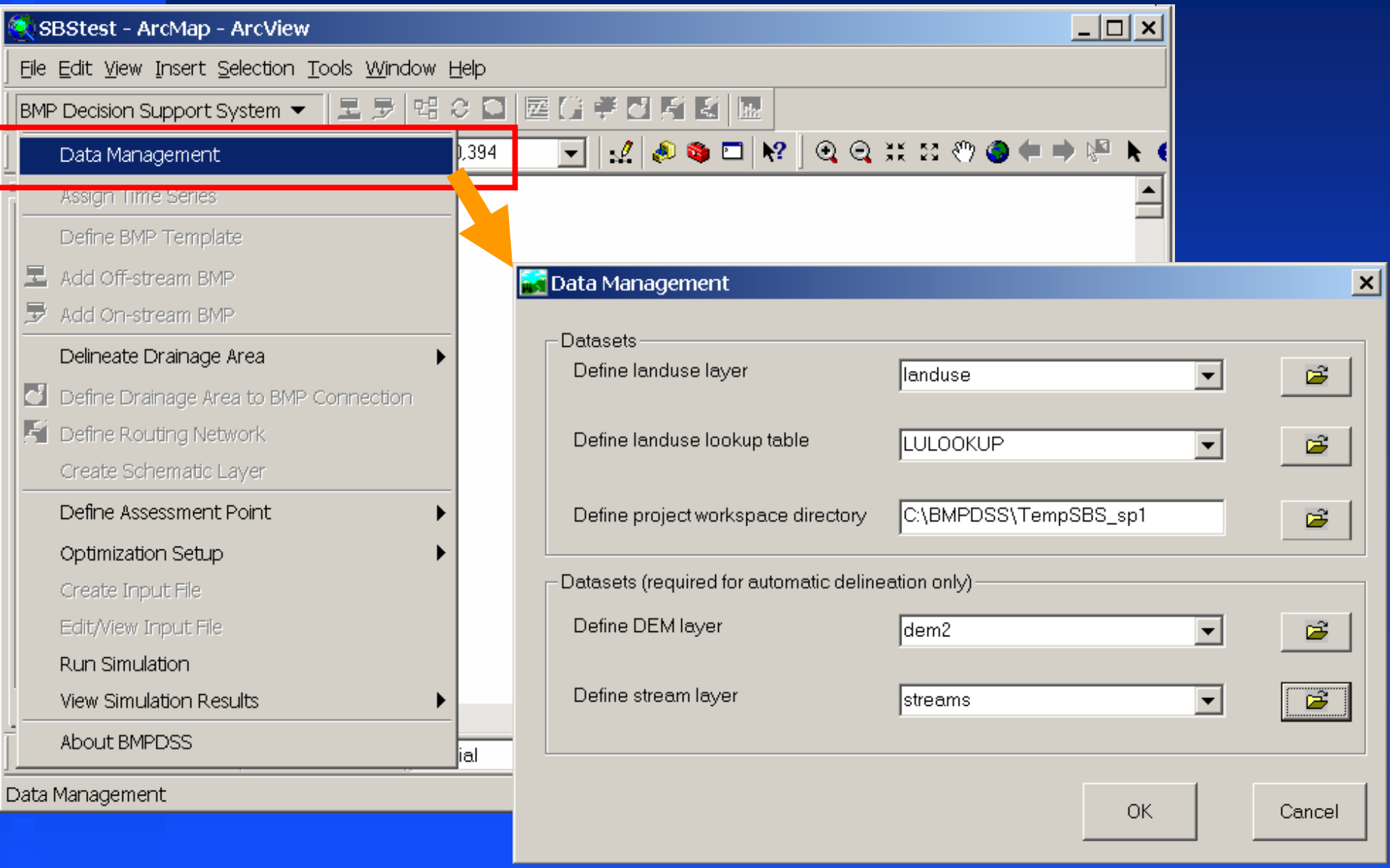
GIS Interface



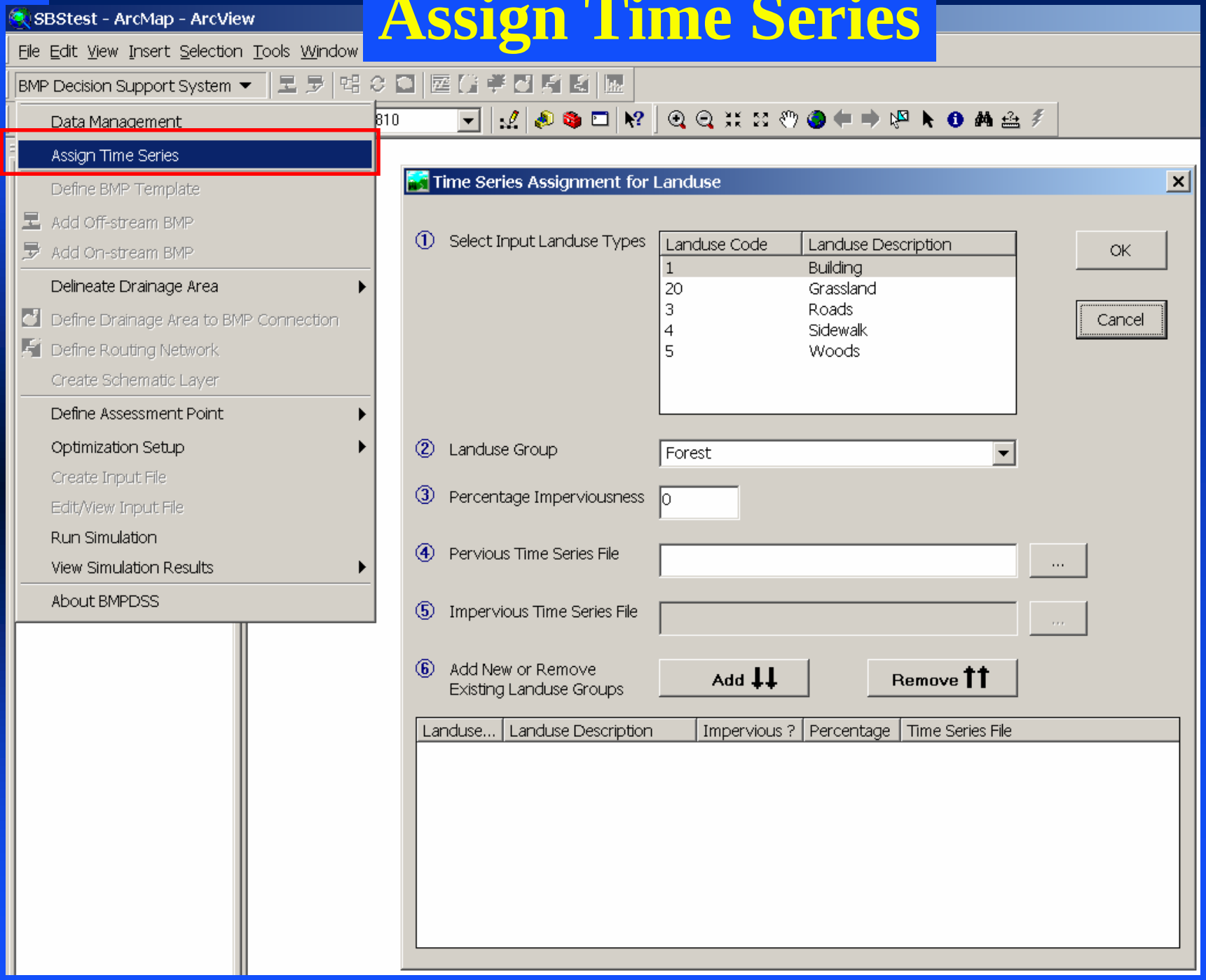
GIS Interface Functions



Data Management

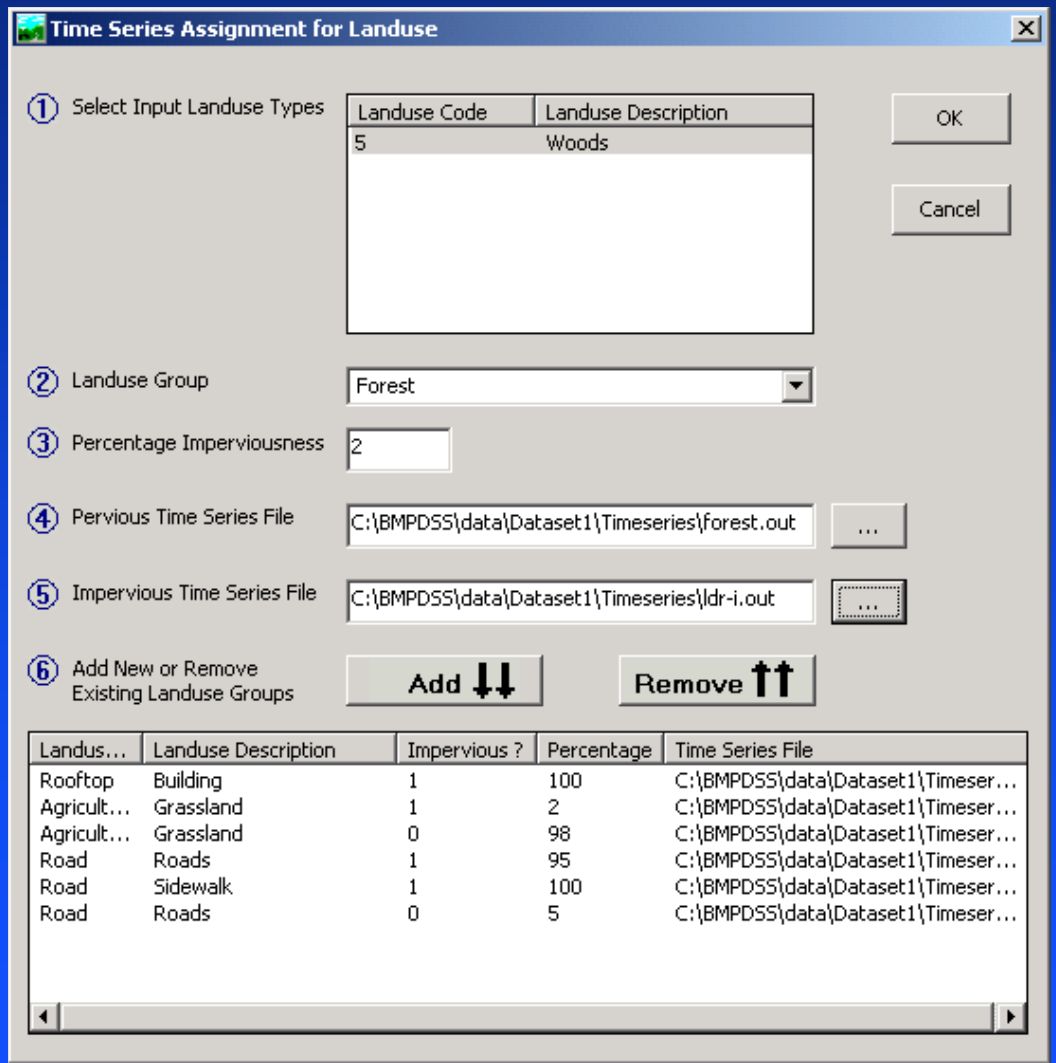


Assign Time Series

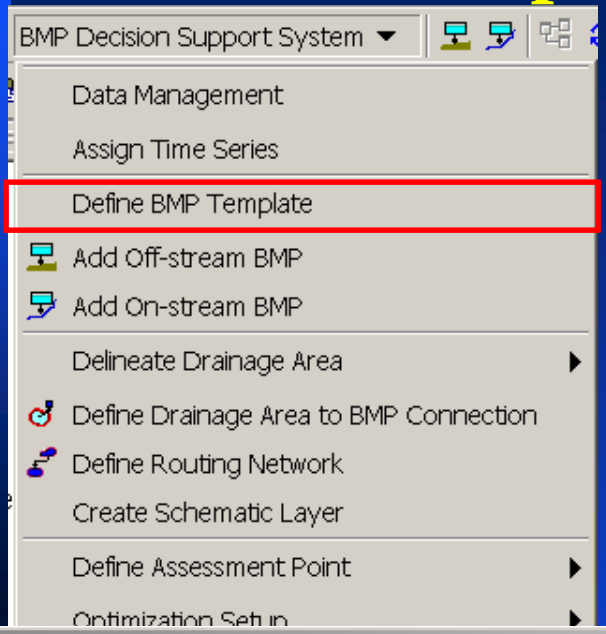


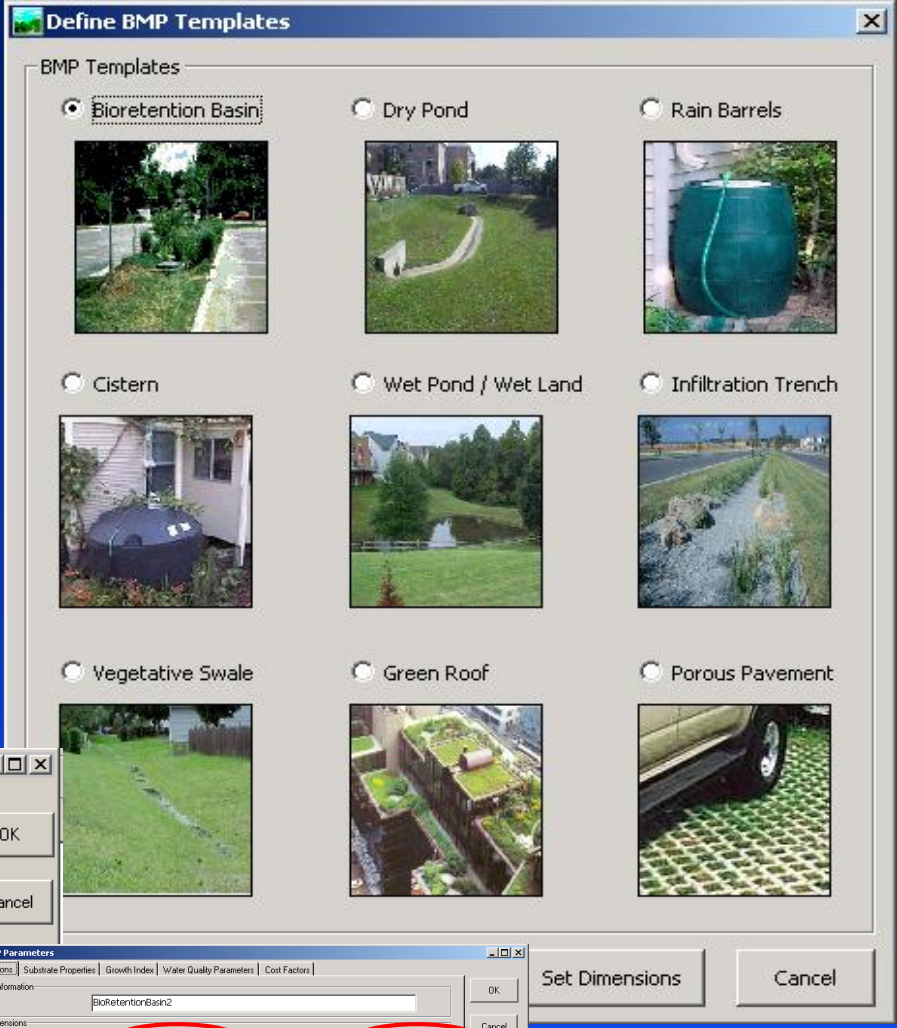
LAND SIMULATION

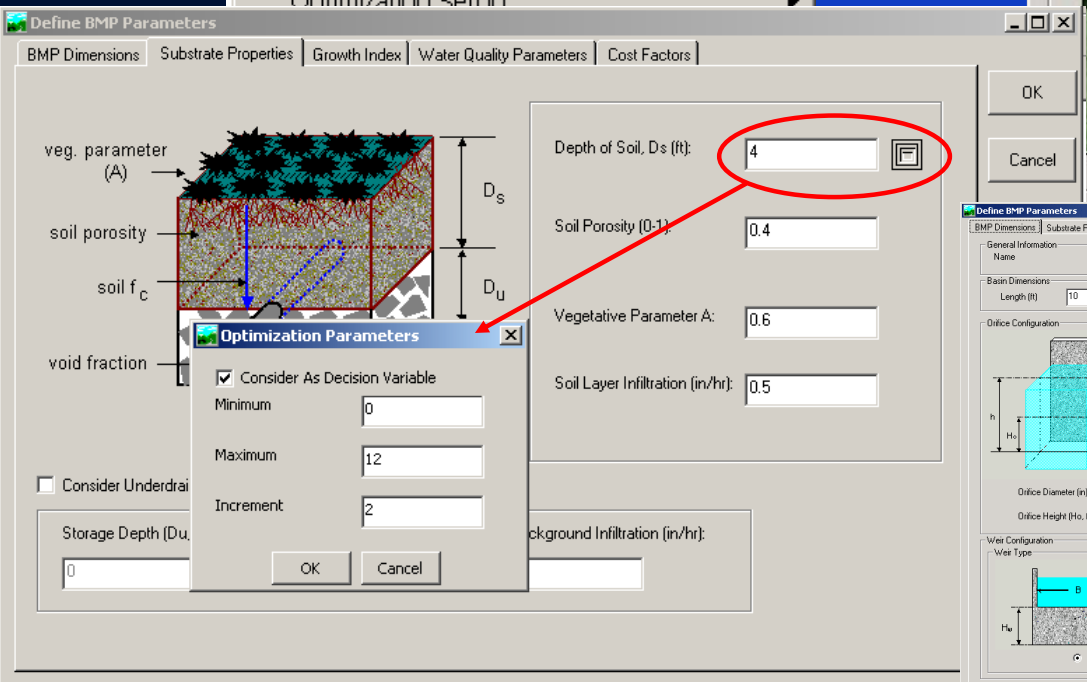
- ✓ External time series generated using HSPF

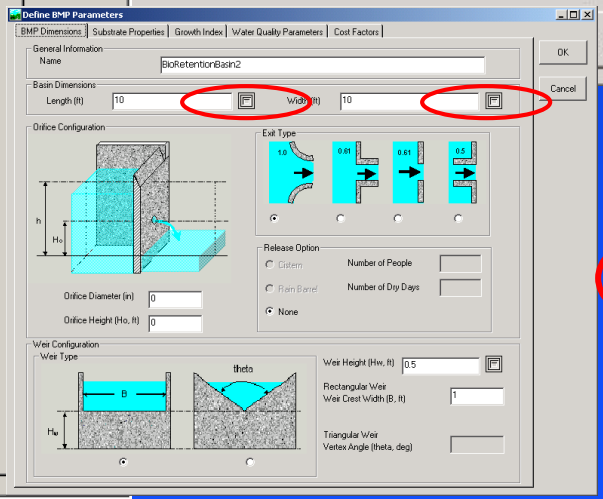


Define BMP Template





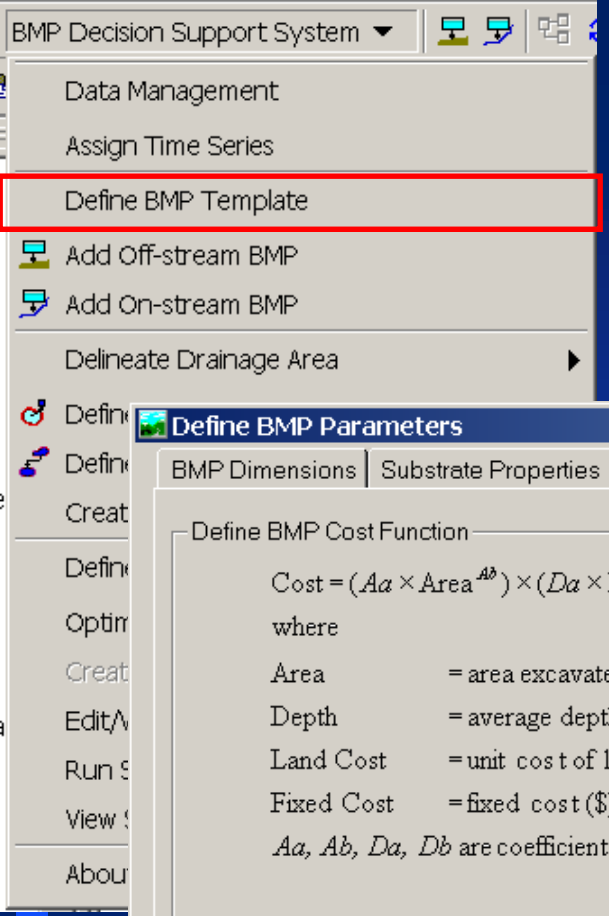


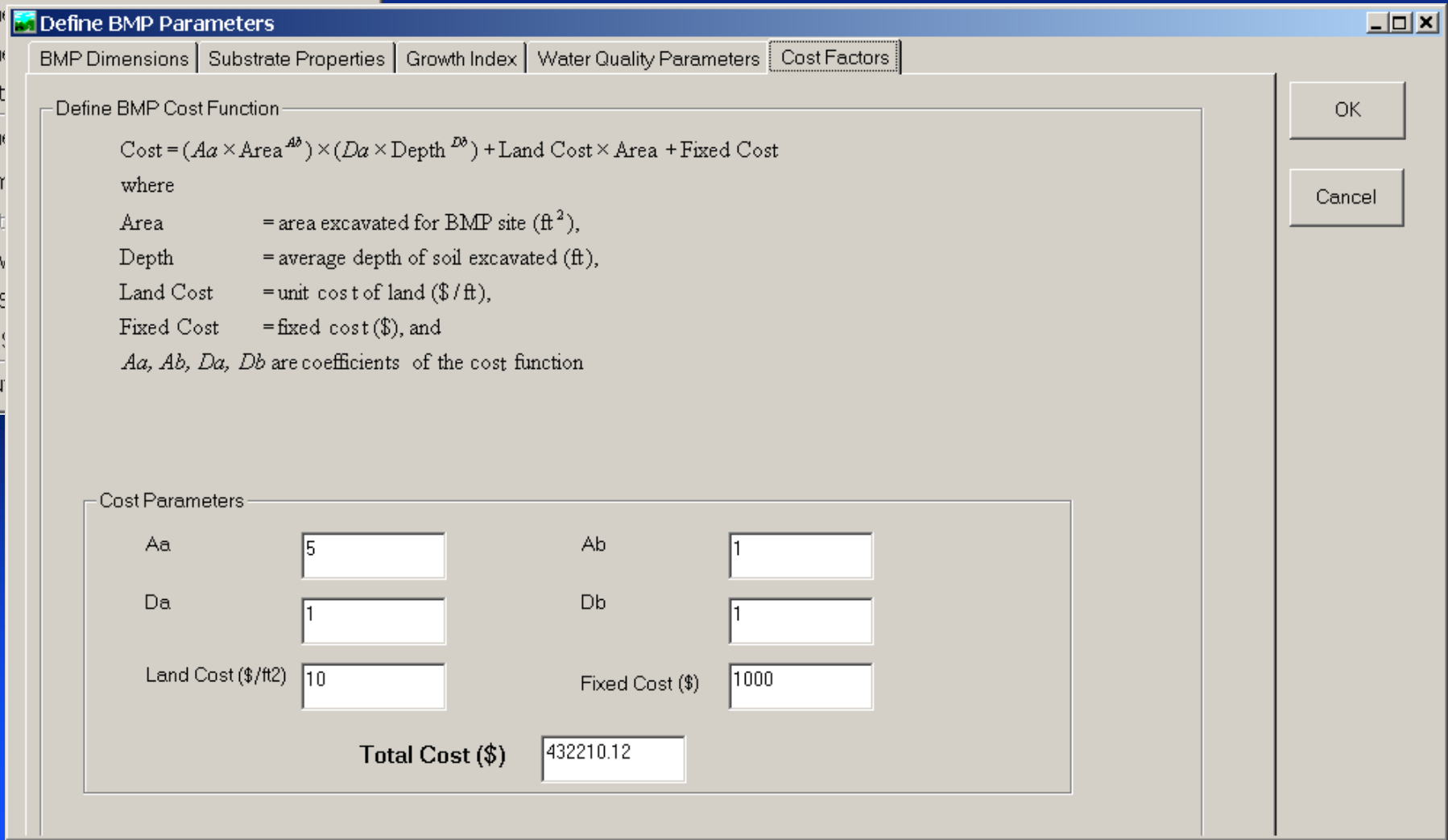


Optimization Parameters

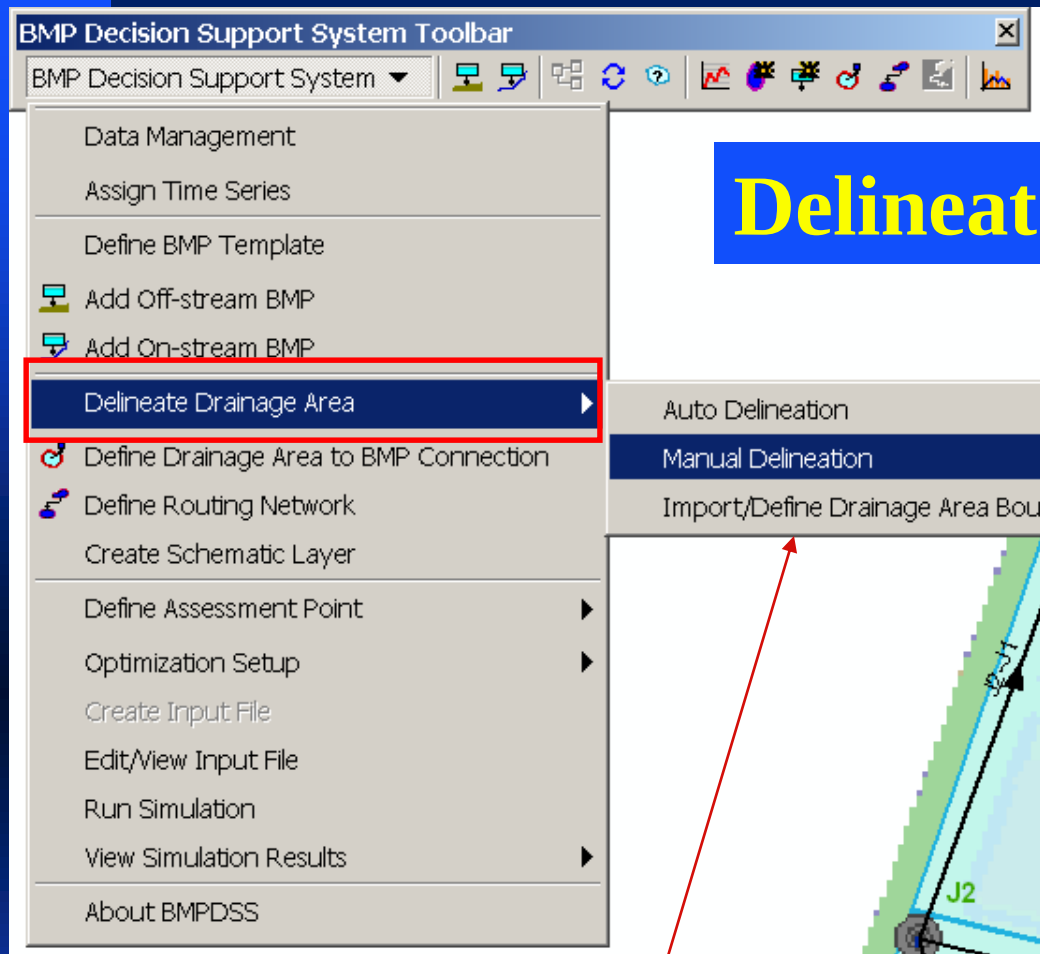
Define BMP Template (Cont)

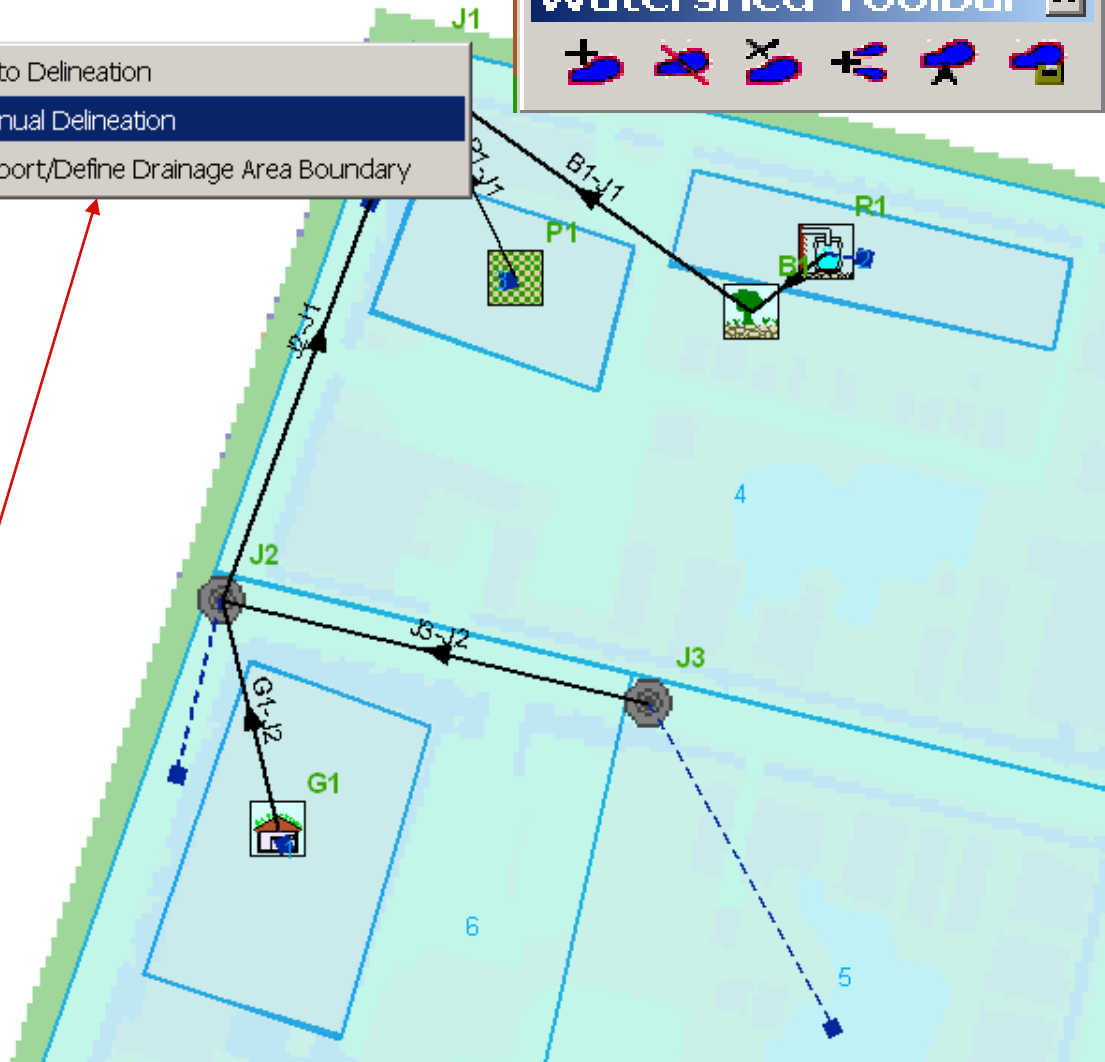
(Define Growth Index, Water Quality, and Cost Parameters)





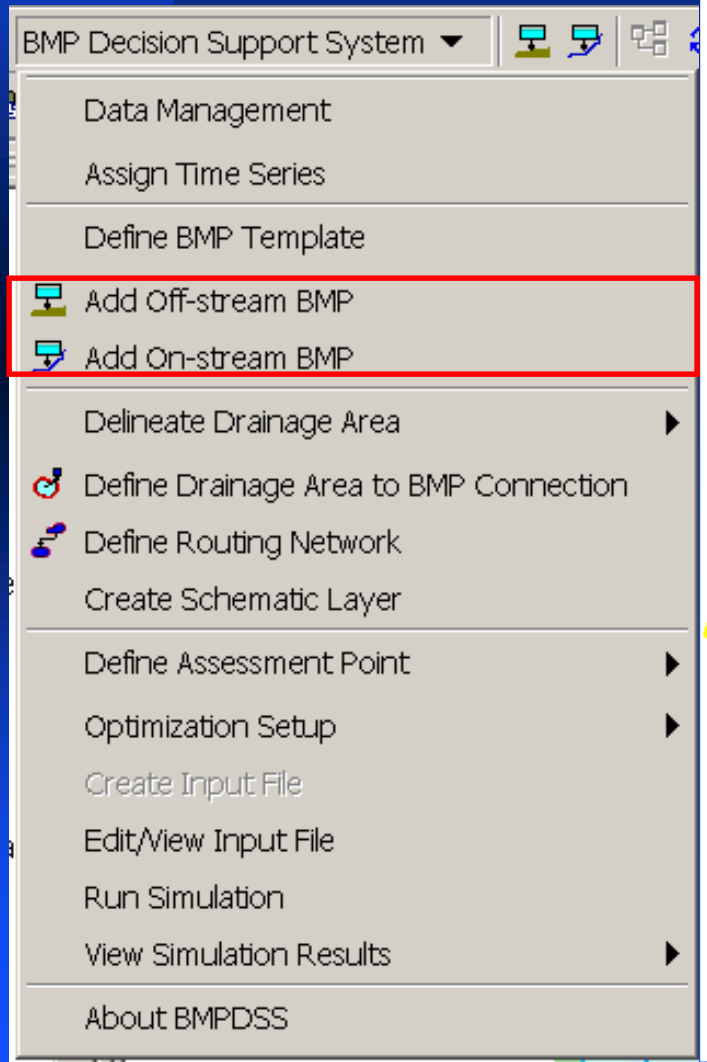
Delineate Drainage Areas

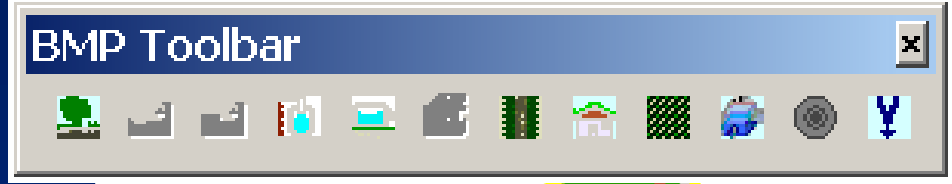


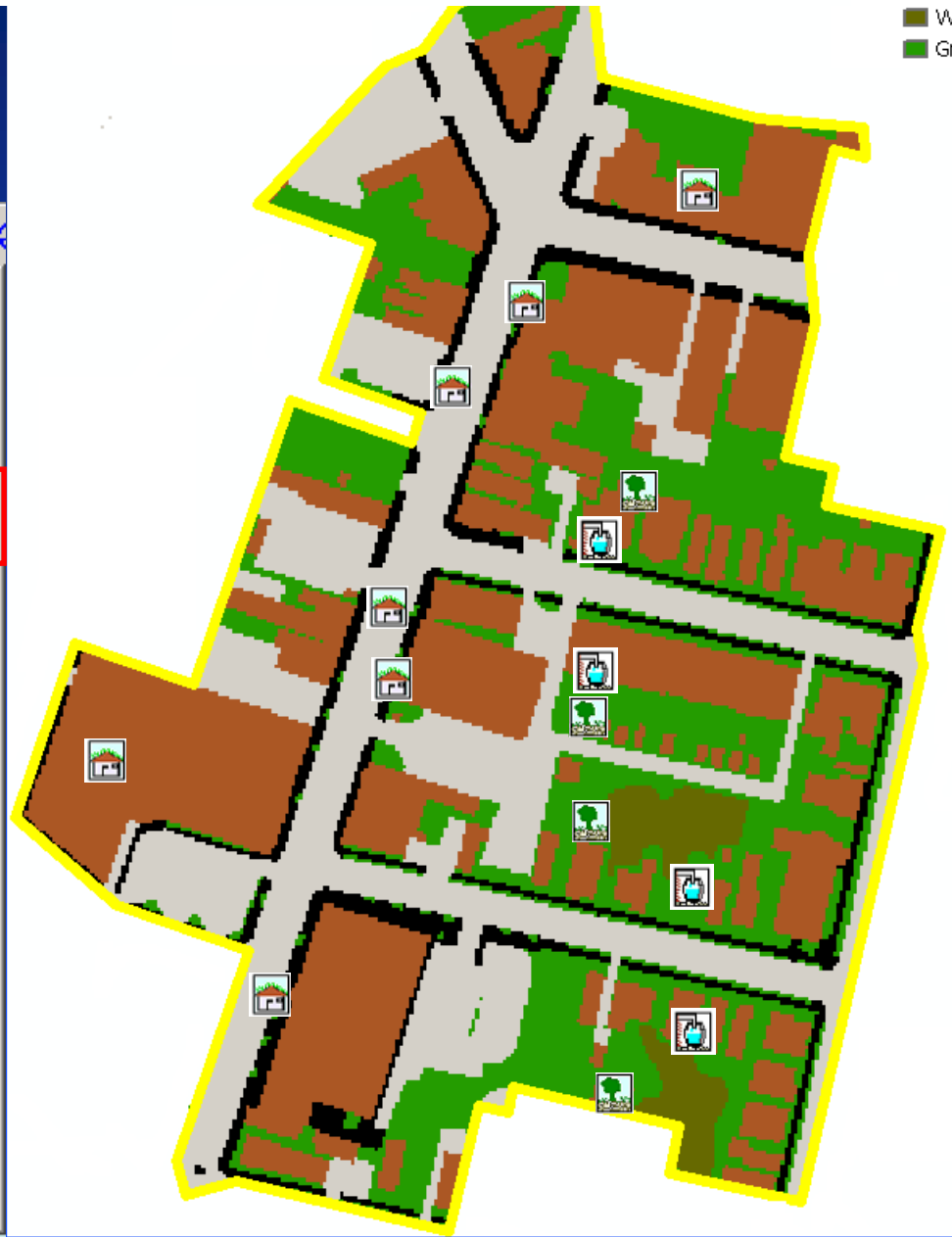


Three Options

Add Off-Stream BMPs
Add On-stream BMPs

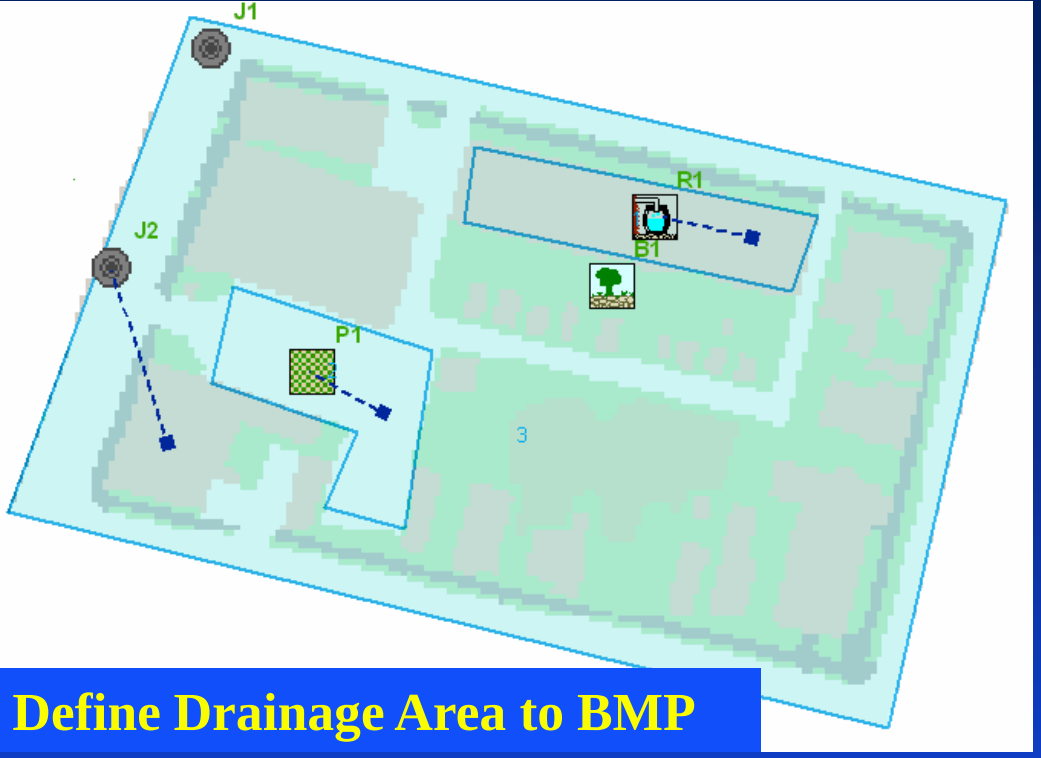




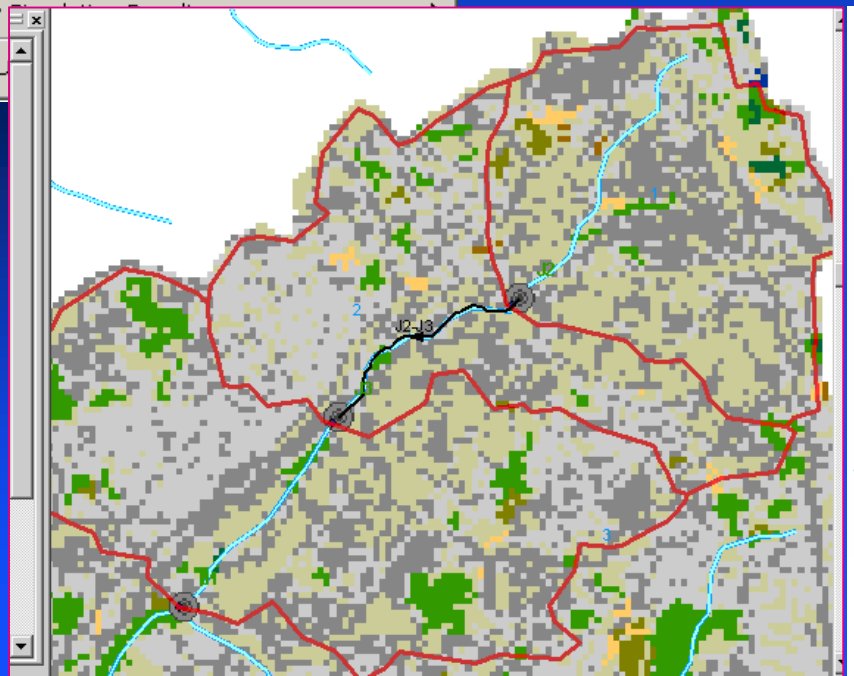


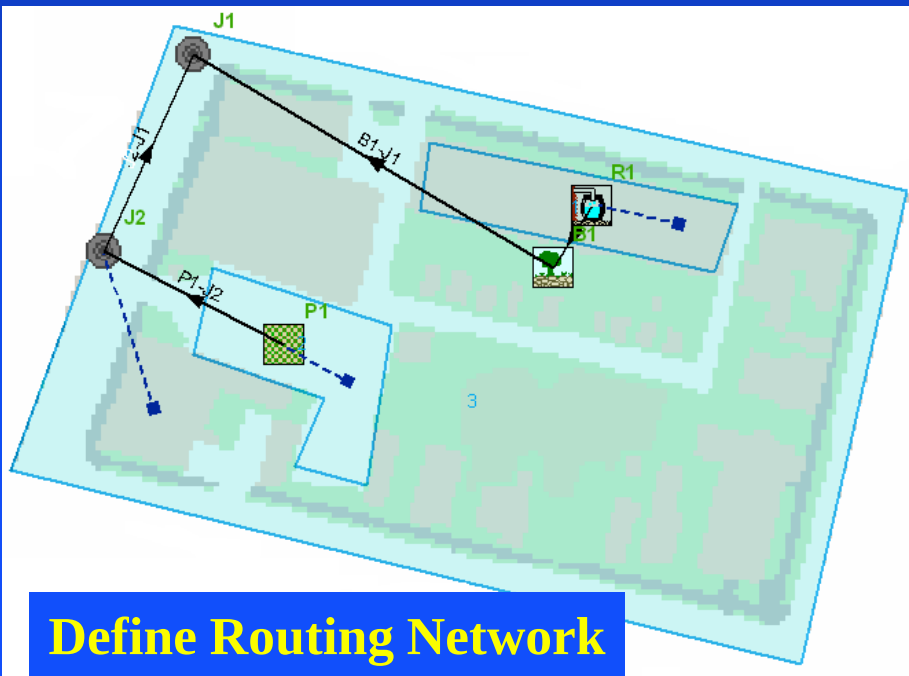
BMP Decision Support System

- Data Management
- Assign Time Series
- Define BMP Template
- Add Off-stream BMP
- Add On-stream BMP
- Delineate Drainage Area
- Define Drainage Area to BMP Connection
- Define Routing Network
- Create Schematic Layer
- Define Assessment Point
- Optimization Setup
- Create Input File
- Edit/View Input File
- Run Simulation
- View
- Abou



Define Drainage Area to BMP

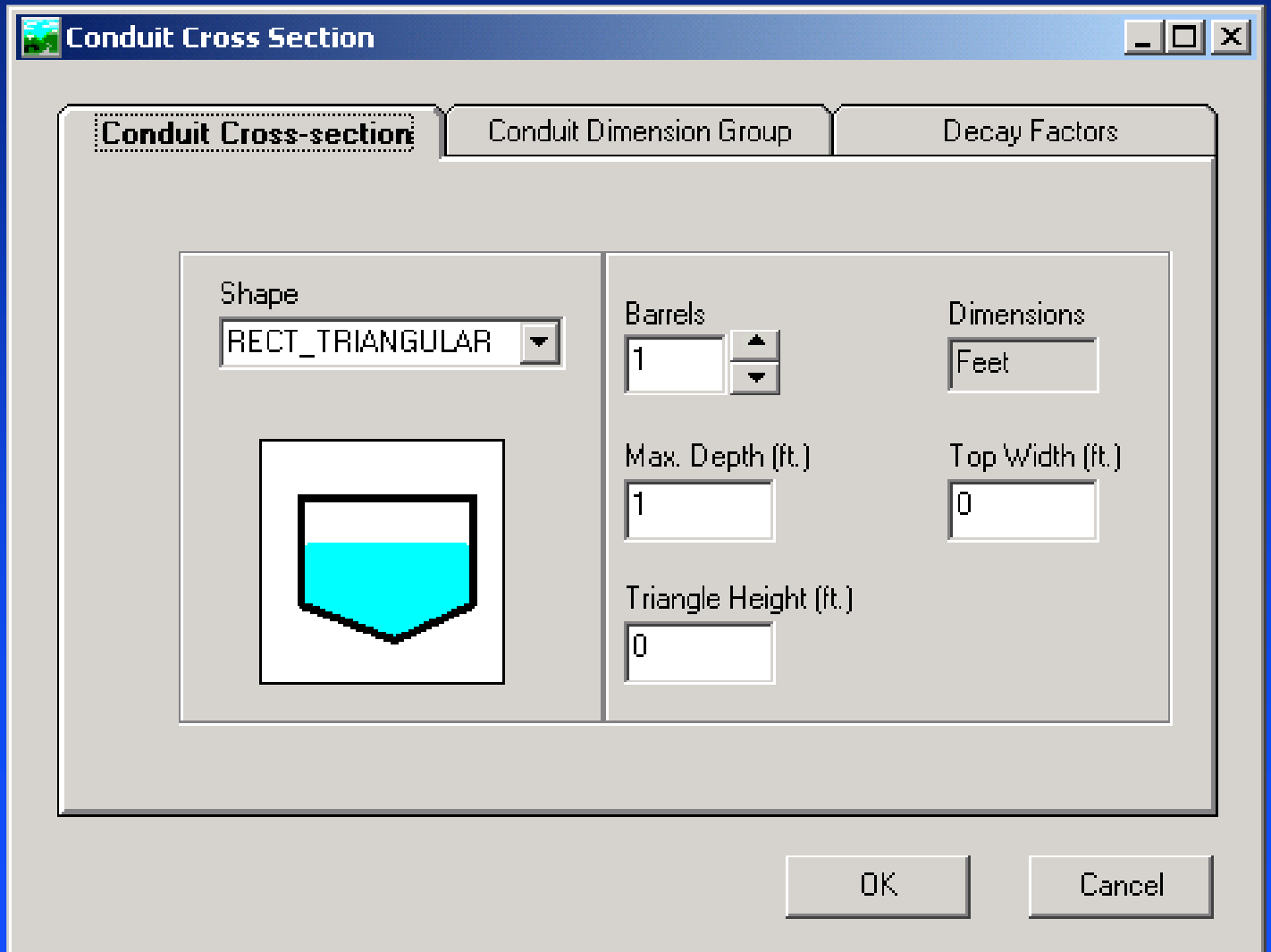




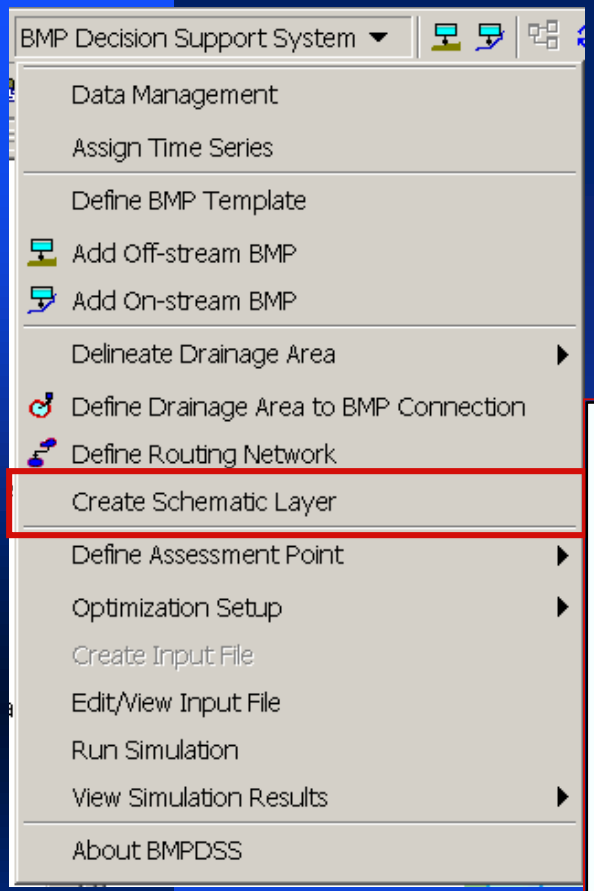
Define Routing Network

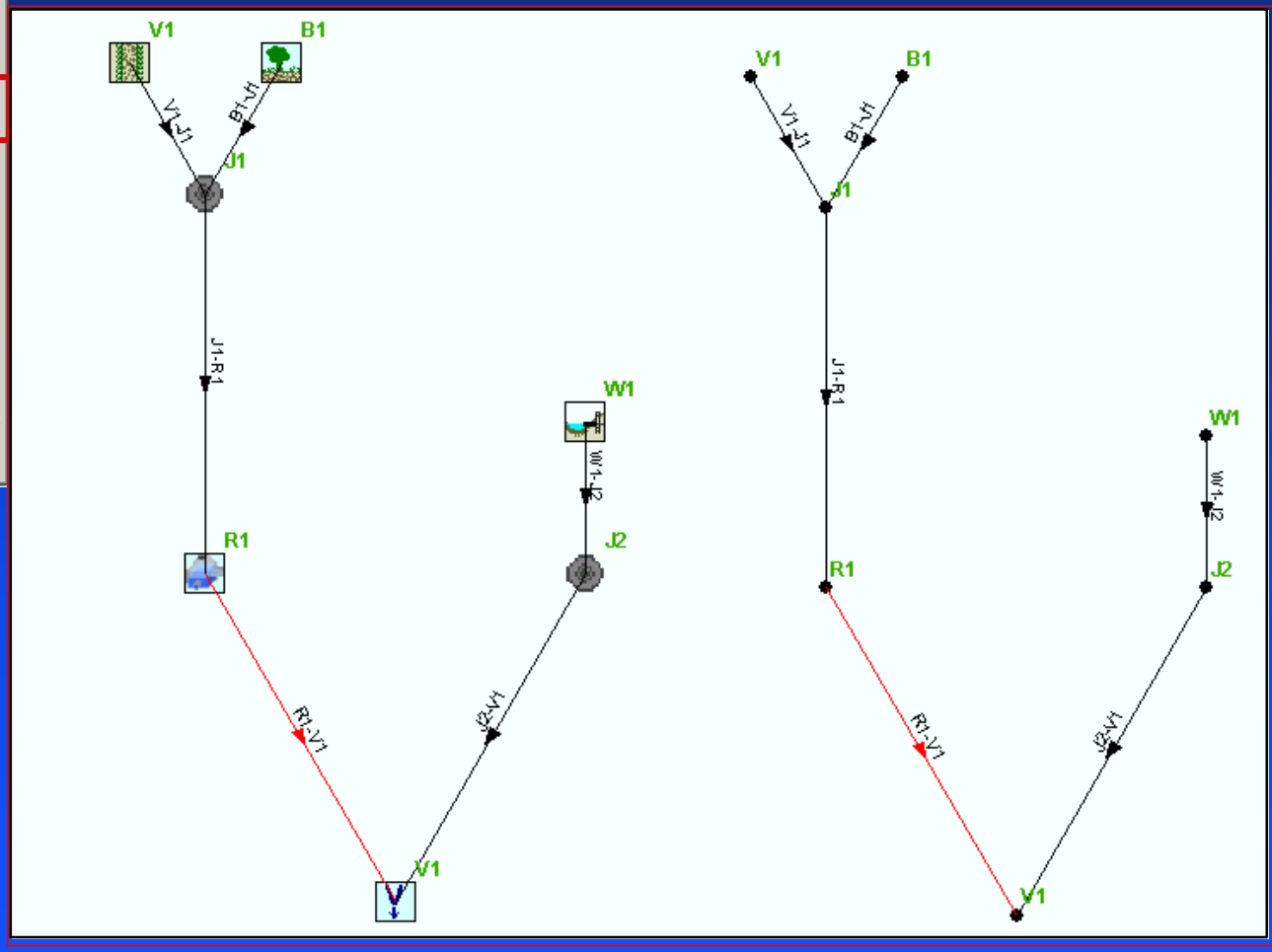
CONVEYANCE SIMULATION

- ✓ **SWMM TRANSPORT Module**

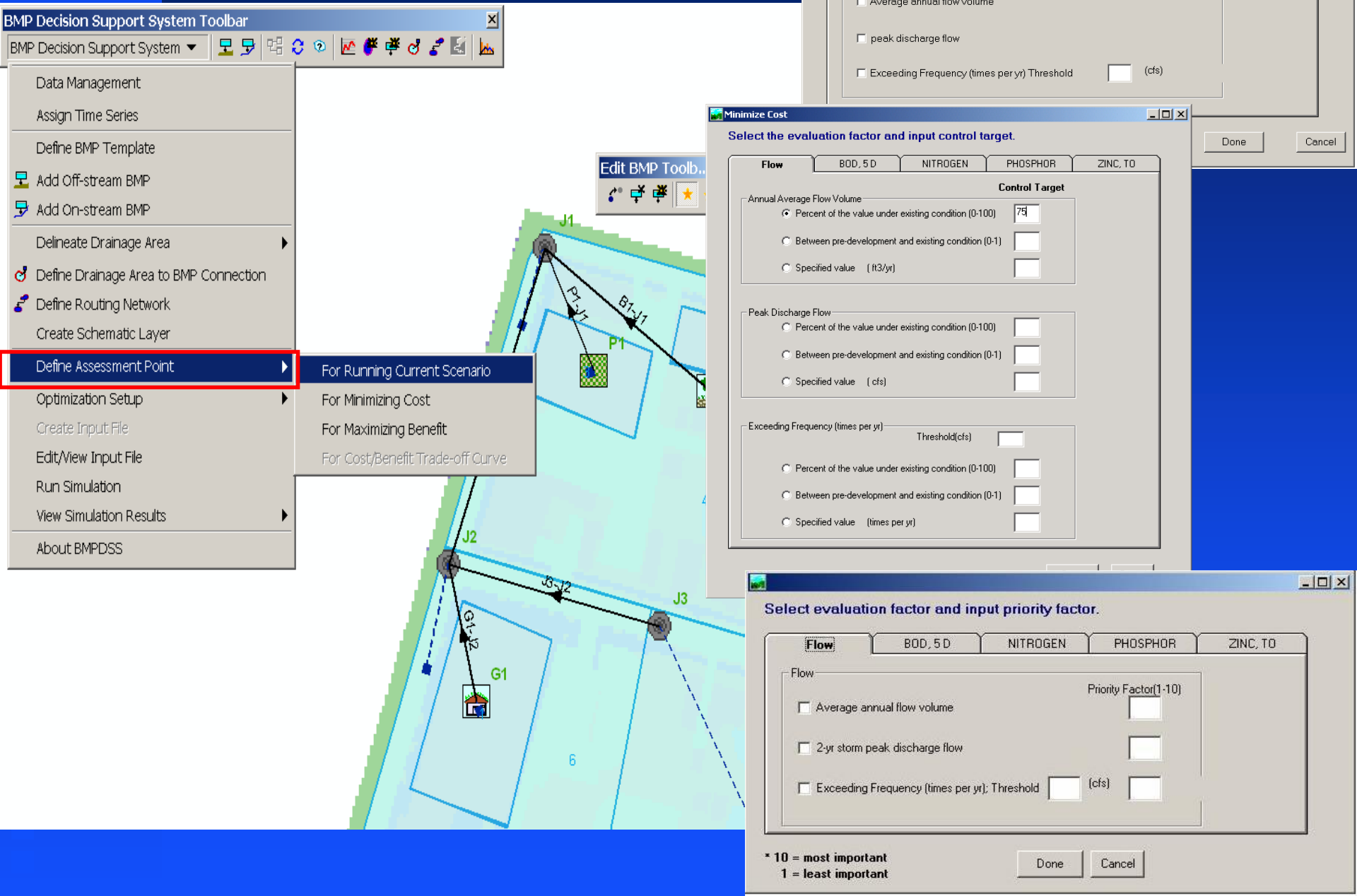


Create Schematic Layer

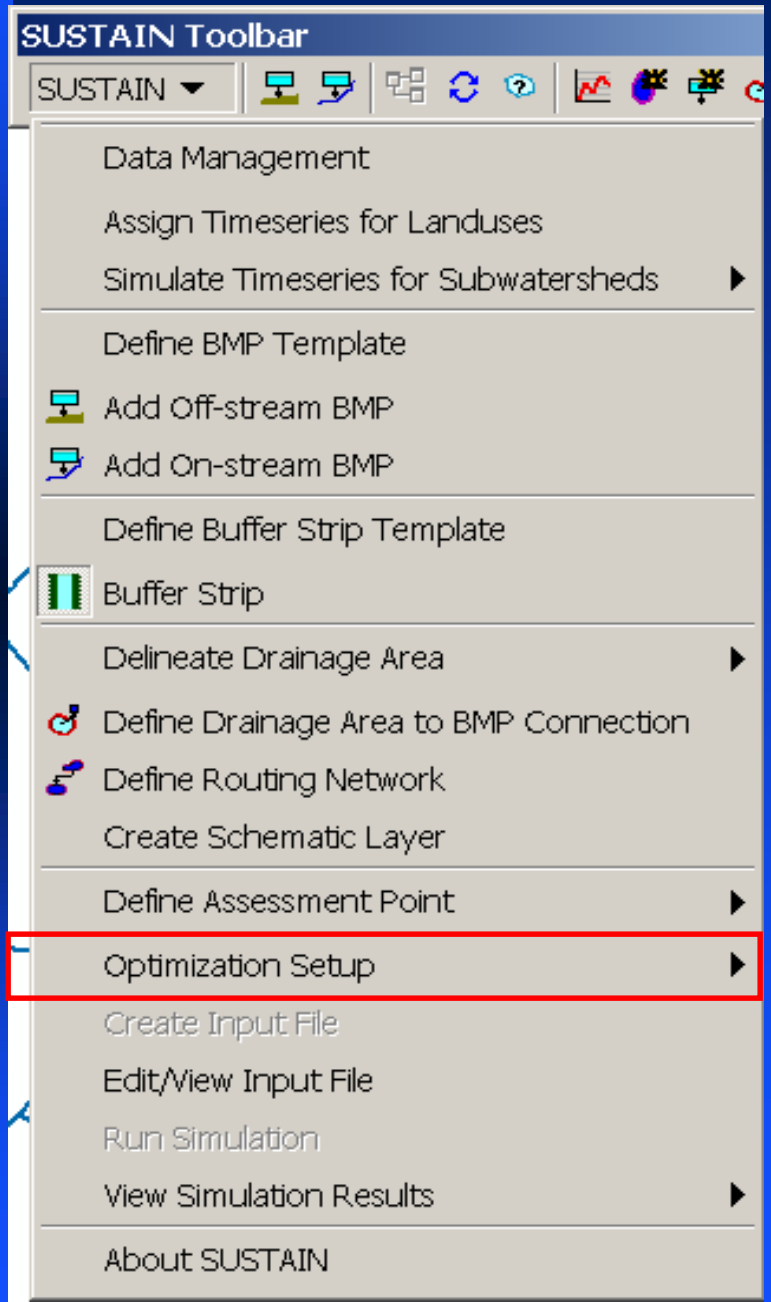


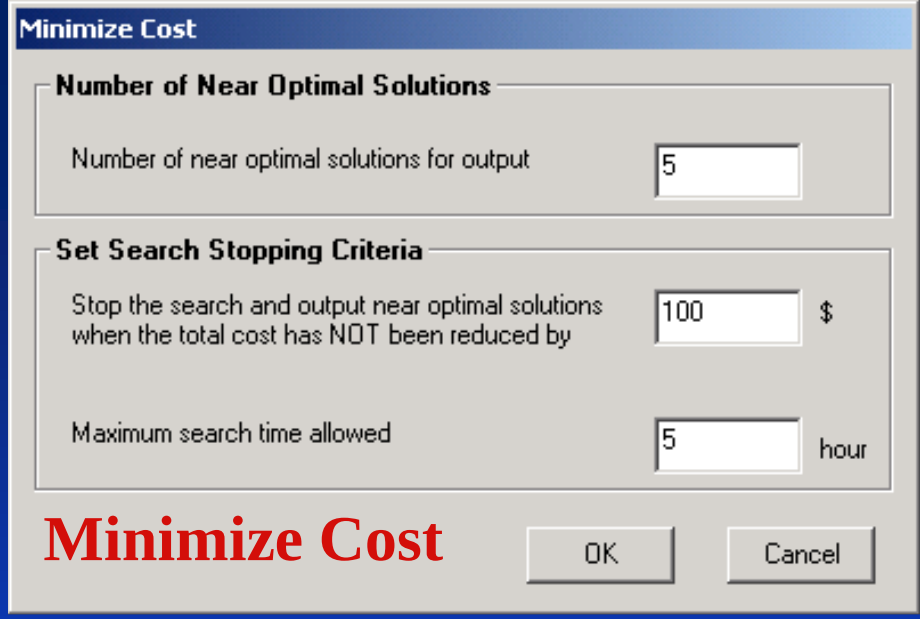


Define Assessment Points

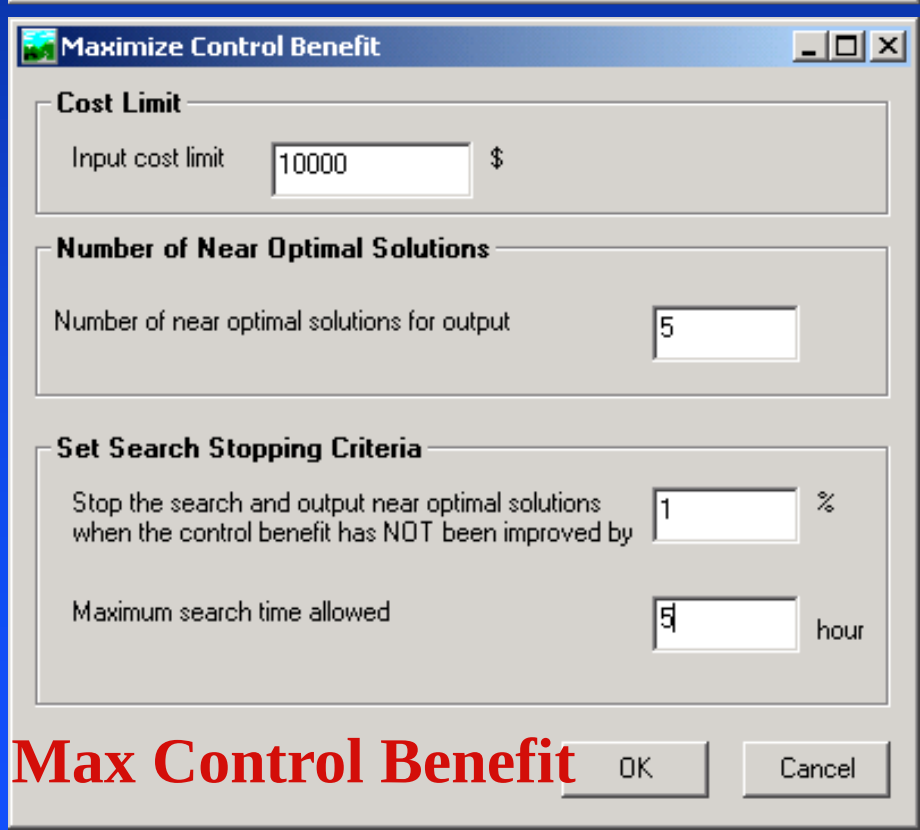


Optimization Setup





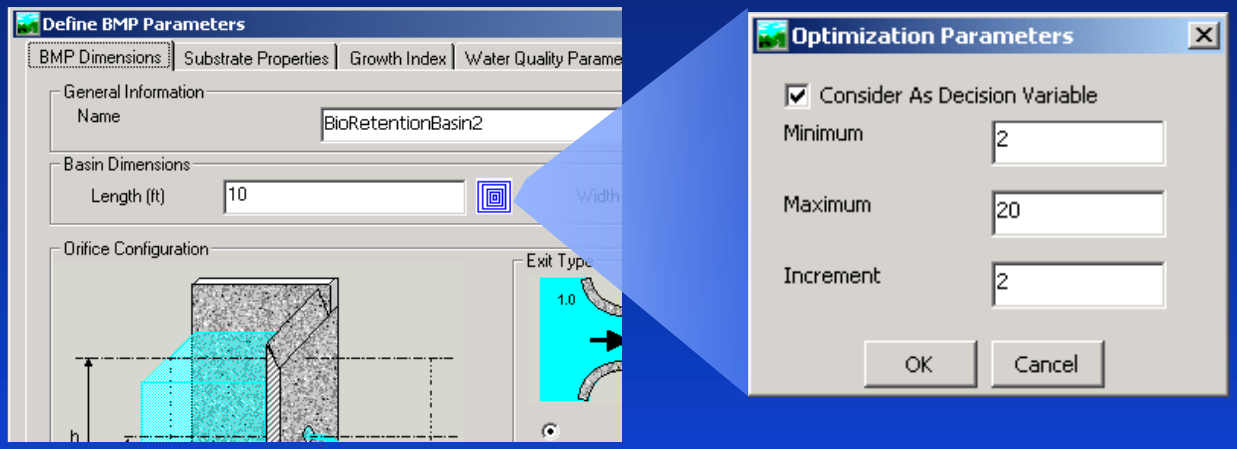
Minimize Cost



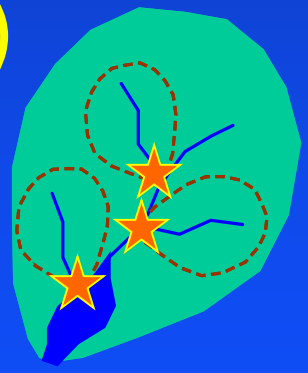
Max Control Benefit

BMP OPTIMIZATION

- ✓ BMP Decision Variables

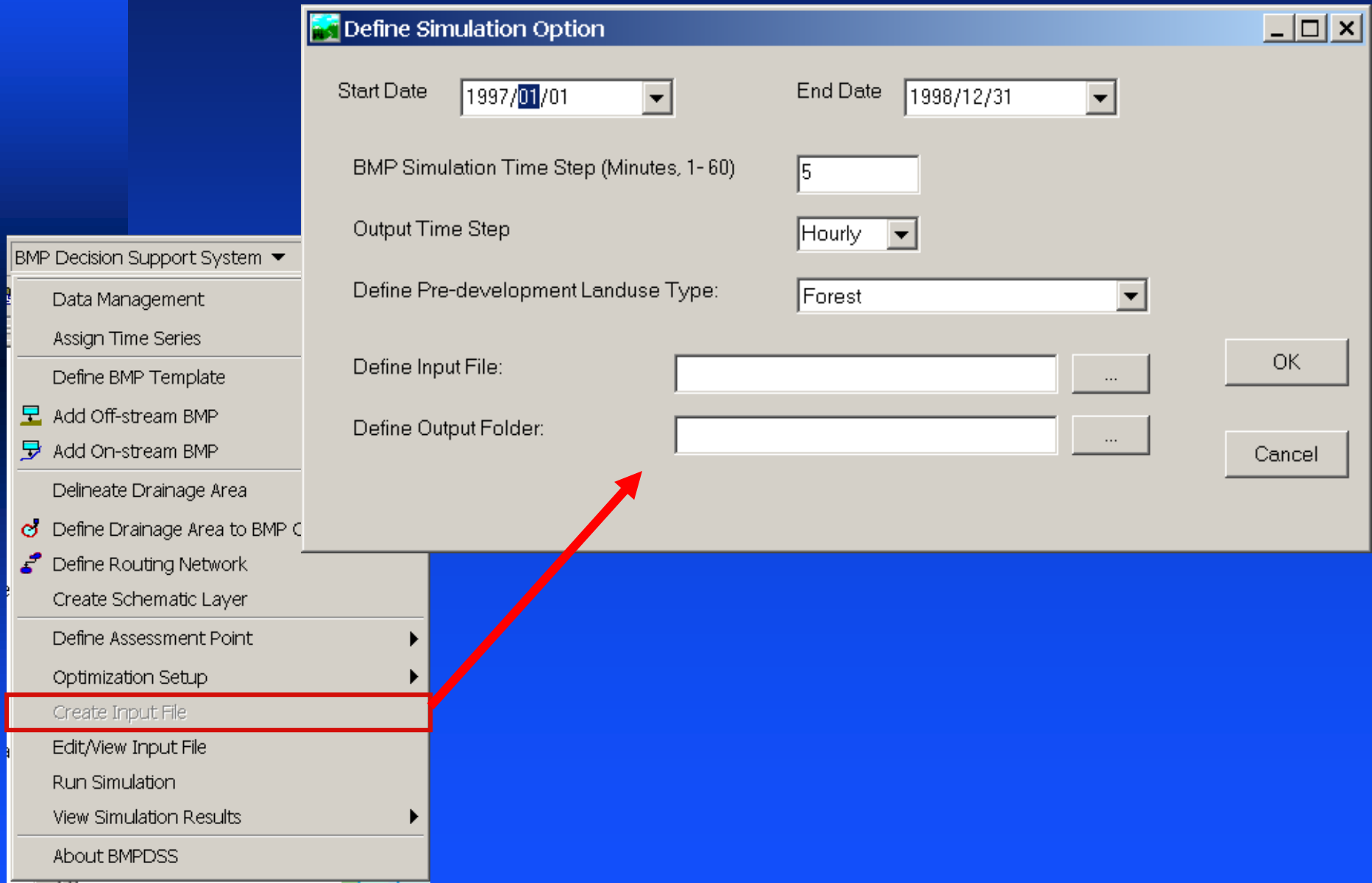


- ✓ Assessment Point(s)

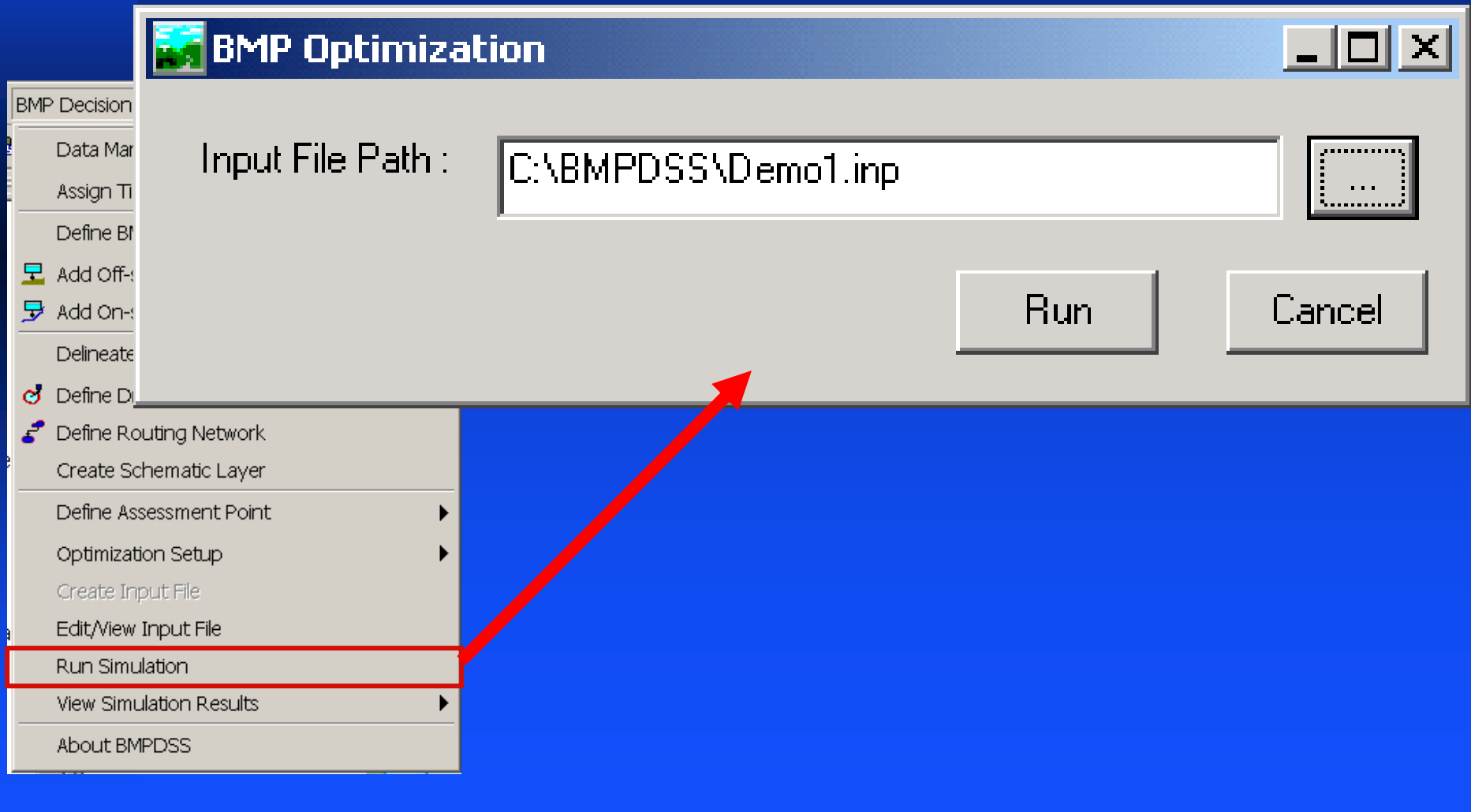


- ✓ Objective and Constraints

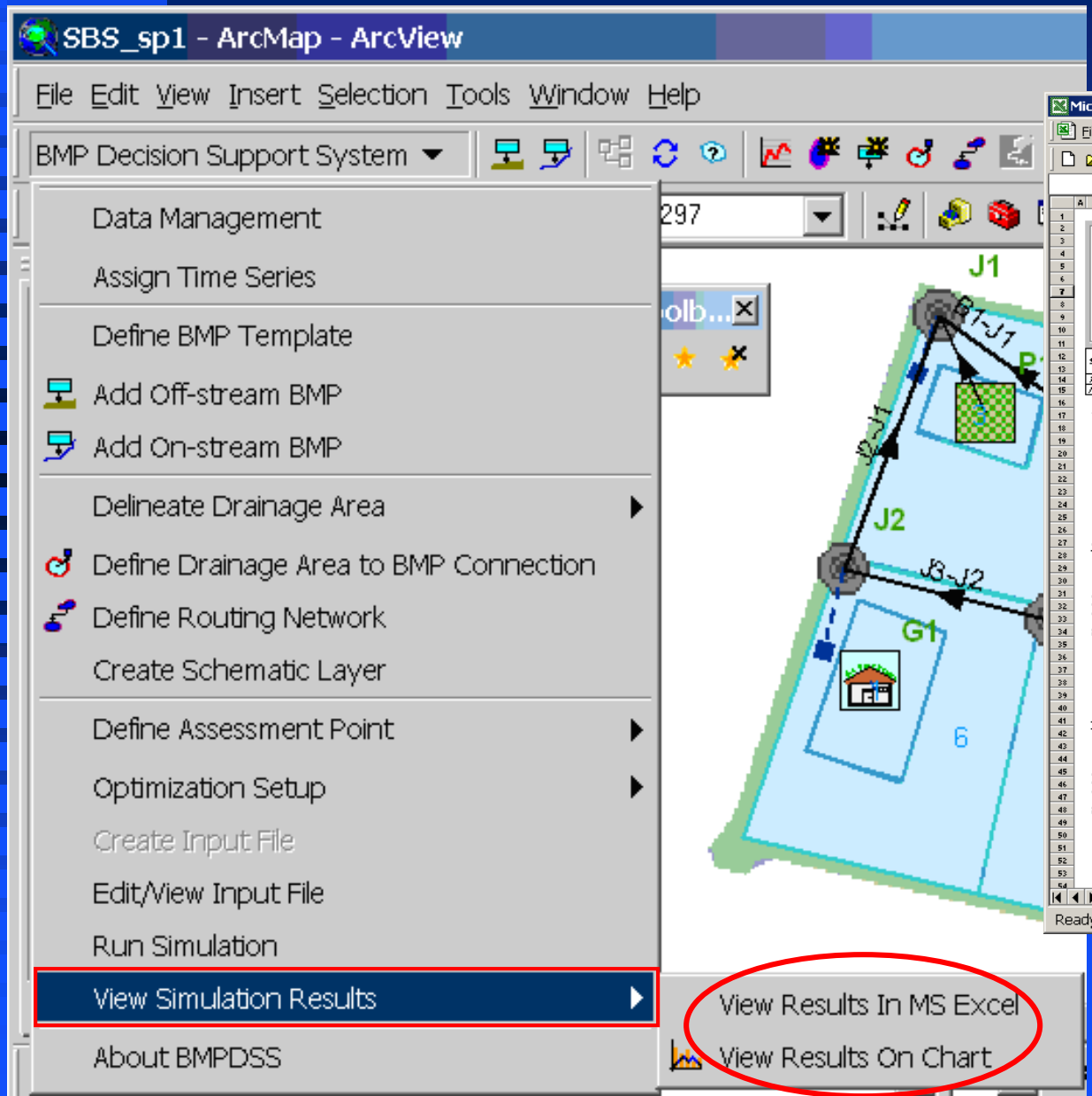
Create Input Files

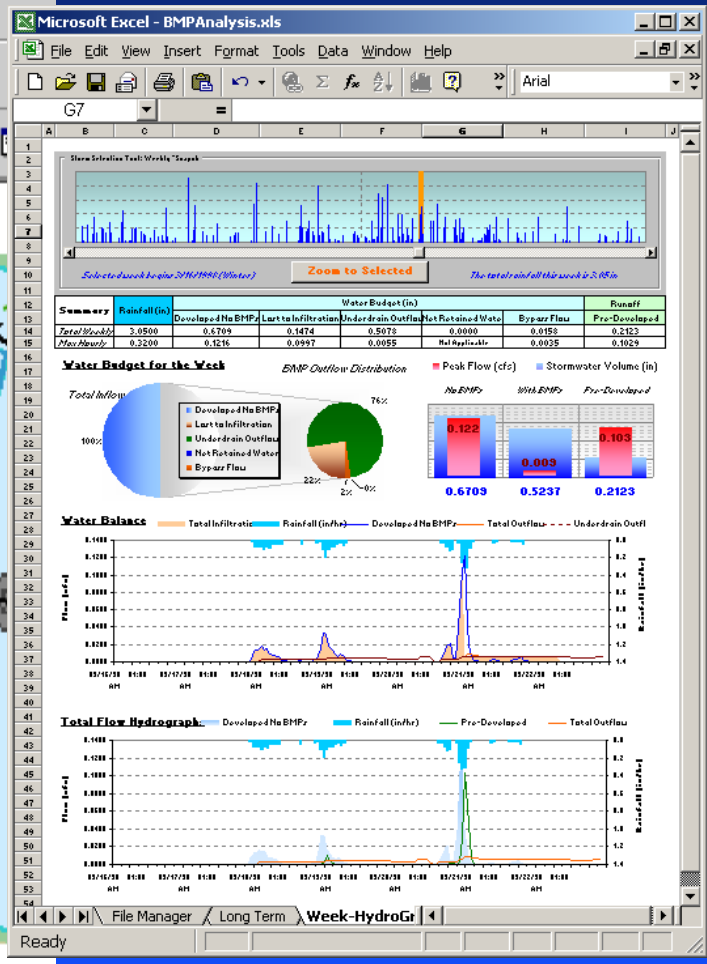


Run Simulation



View Simulation Results





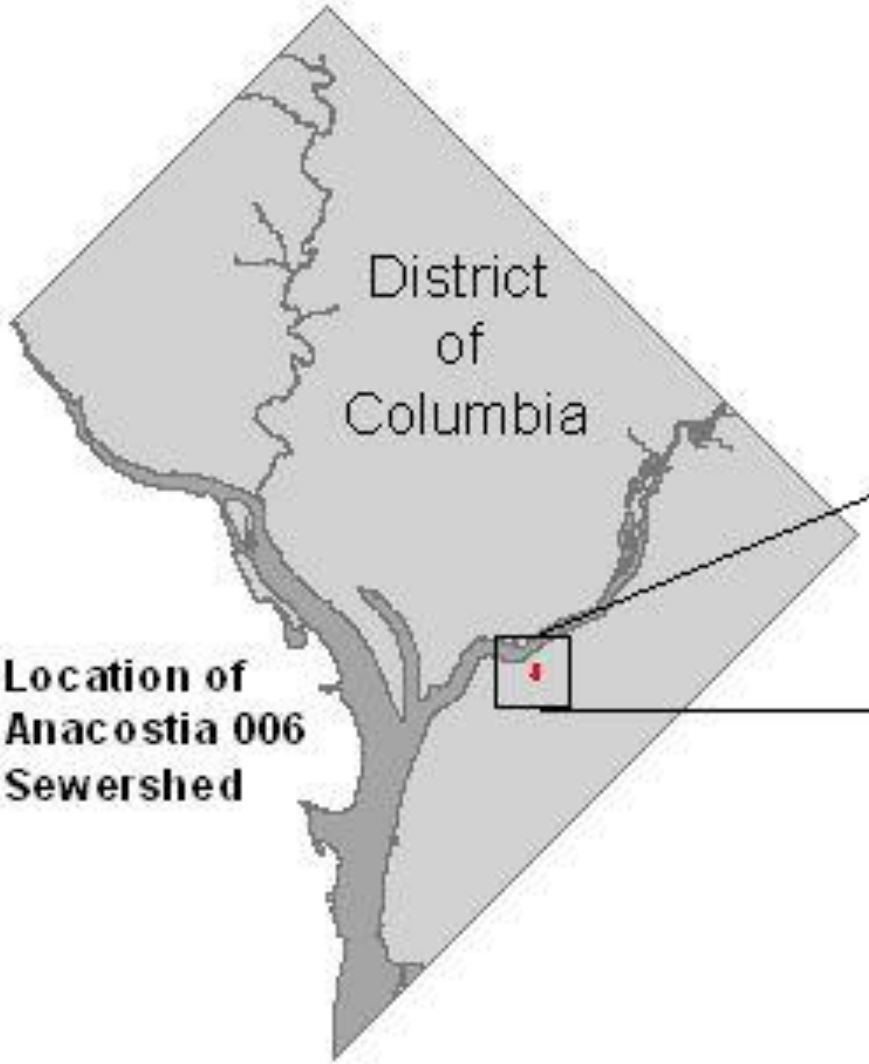
What can the system be used for

- Area of Interest: Control Objectives
- Potential BMP Sites
- Cost Concerns
  - What is the benefit of management?
  - What is the difference between management options/scenarios including one or more practices?
  - Are they cost effective?

Case Study Application

- Incorporate data from existing D.C. WASA CSS Model for a few city blocks in Anacostia Watershed.
- Develop potential LID configuration scenarios
- Test BMP selection and placement optimization
- Summarize effect of potential LID configurations on runoff volume and CSO inflow reduction
- CSO storm water inflow reduction is associated with reduction of CSO overflow frequency

Case Study



Anacostia 006 Sewershed

Problem Formulation

Objectives

- Minimize CSO volume
- Minimize cost

Decision Variables

Porous Paving

- Size
- Location

Rain Barrel

- Sizes
- Location

Bioretention

- Size
- Soil Depth
- Location

Green Roof

- Size
- Depth of Soils
- Locations

Cost Function

$$Cost = (Aa \times Area^{Ab}) \times (Da \times Depth^{Db}) + Land\,Cost \times Area + Fixed\,Cost$$

where

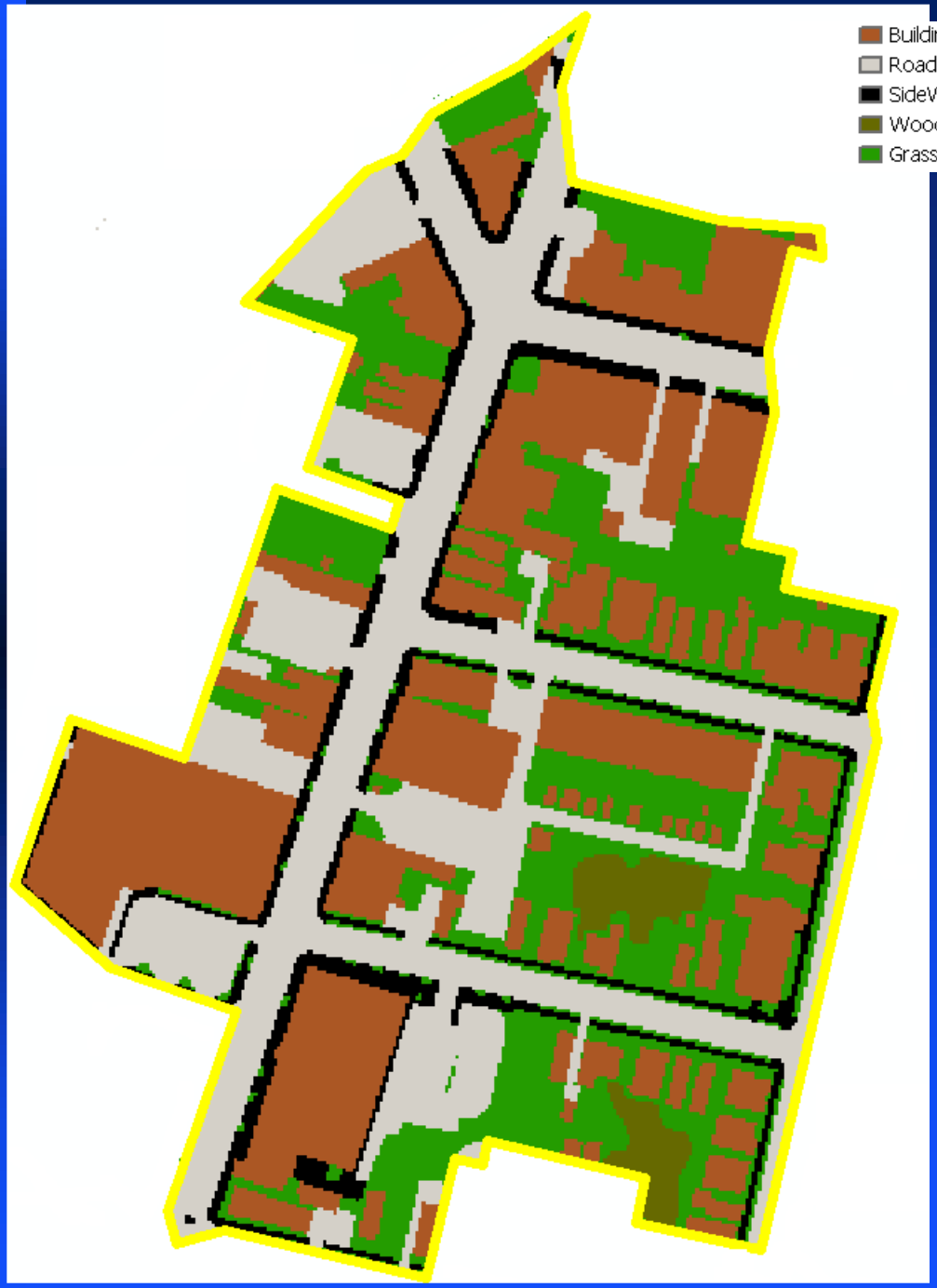
$Area$ $= area\,excavated\,for\,BMP\,site\,(ft^2)$,

$Depth$ $= average\,depth\,of\,soil\,excavated\,(ft)$,

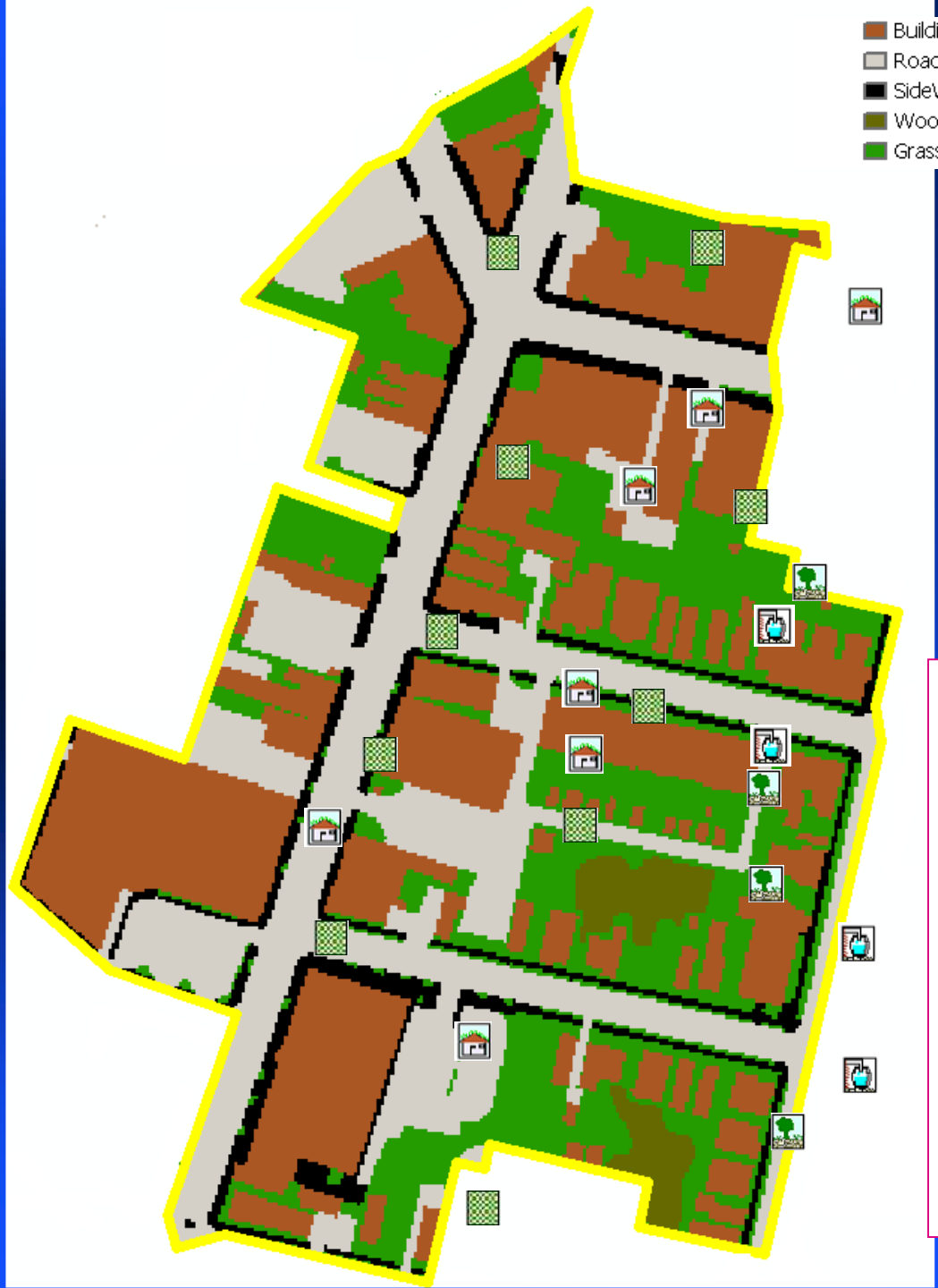
$Land\,Cost$ $= unit\,cost\,of\,land\,(\$/ft)$,

$Fixed\,Cost$ $= fixed\,cost\,(\$)$, *and*

Aa, Ab, Da, Db *are coefficients of the cost function*



Existing Site Condition
Land Uses



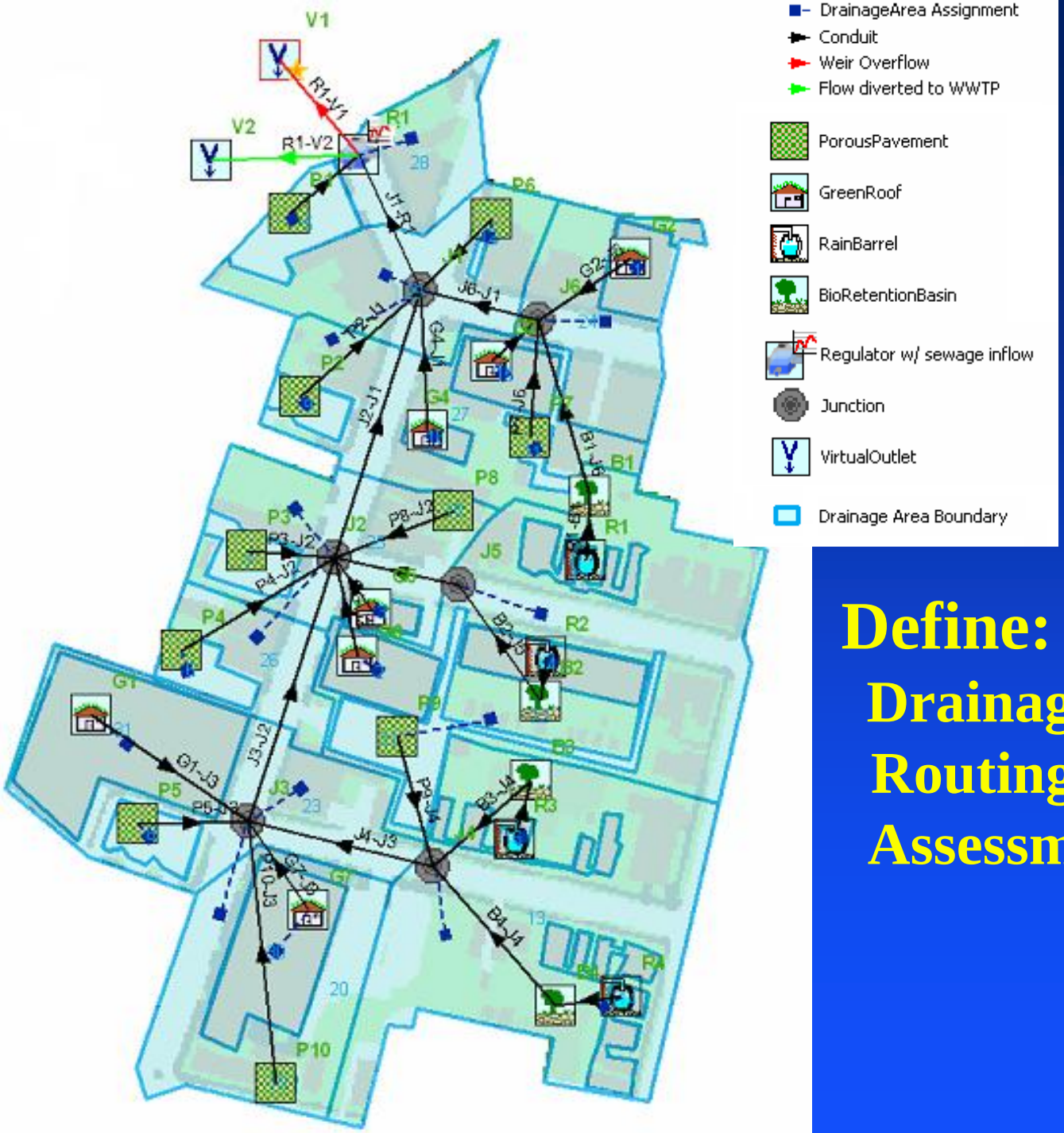
Selected BMP Alternatives

PorousPavement

GreenRoof

RainBarrel

BioRetentionBasin



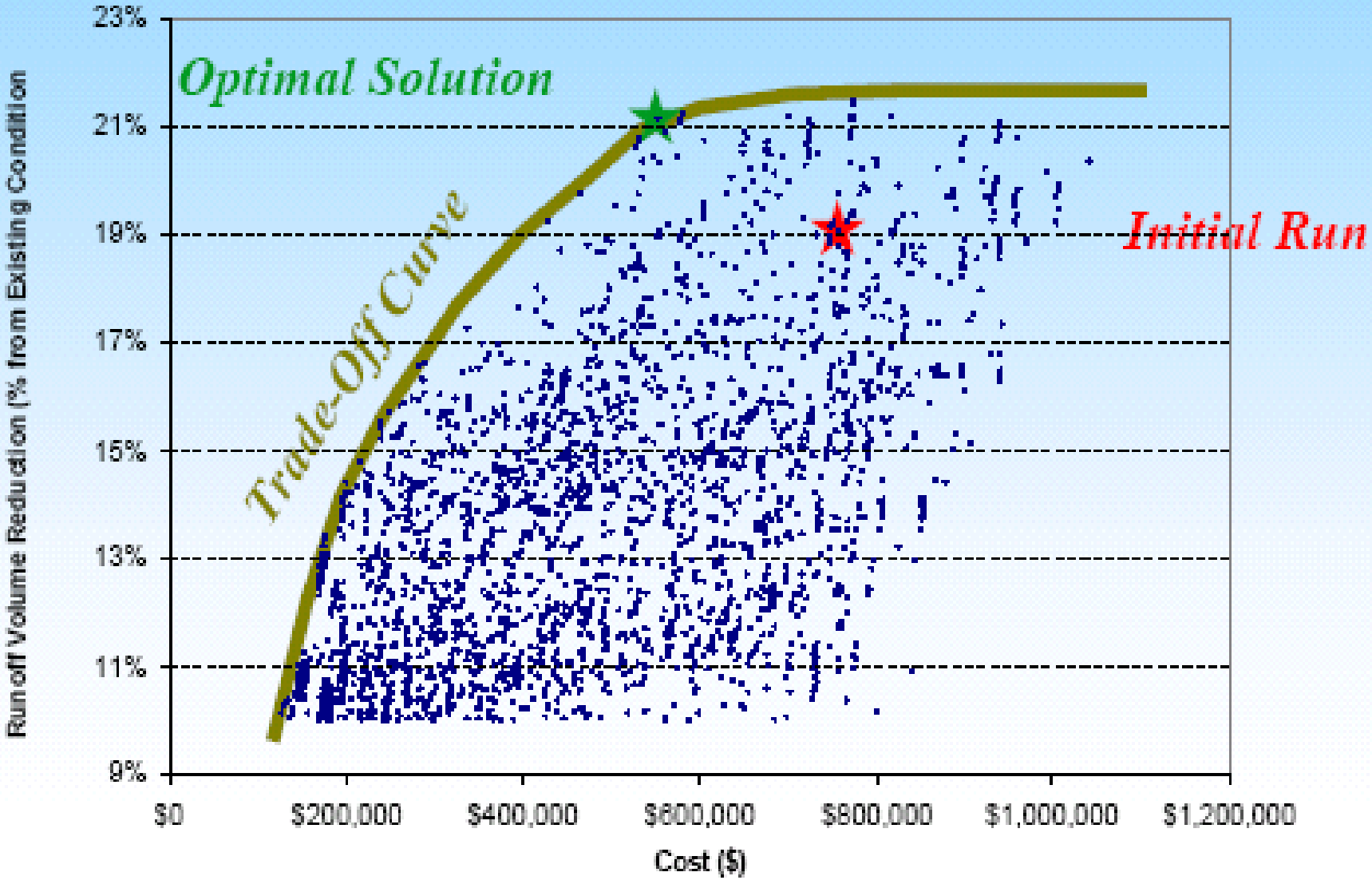
Define:

Drainage areas

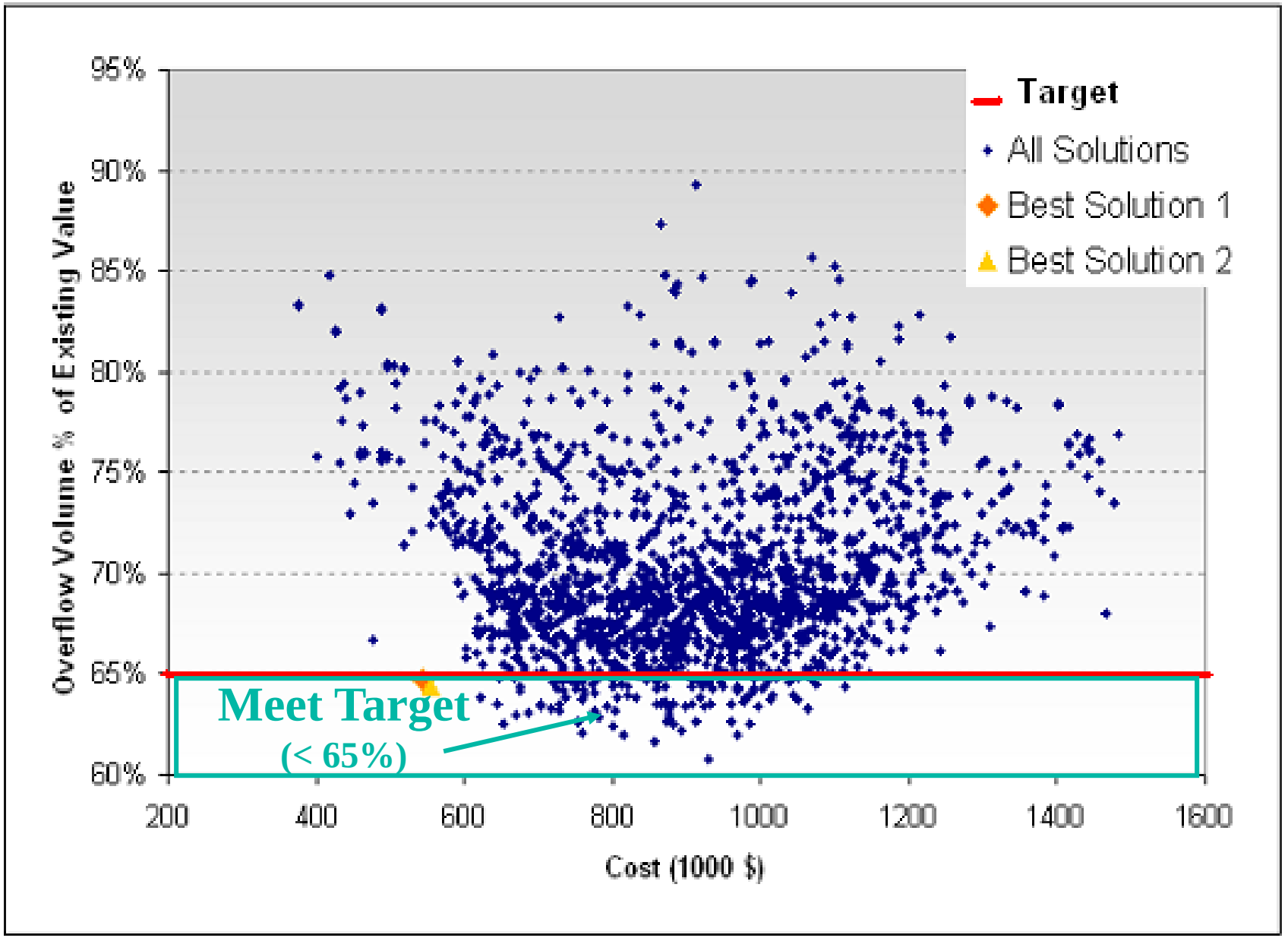
Routing network

Assessment points

Optimization Solutions

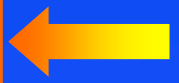


Optimization Solutions



Optimization Solution Details

BMP Type	BMP ID	Decision Variable Upper Limit	Best Solution 1 Overflow volume reduction = 35.3% cost = $544,124	Best Solution 1 Overflow volume reduction = 35.7% cost = $555,904
		Surface area (ft^2) or Rain Barrel Count	Surface area (ft^2) or Rain Barrel Count	Surface area (ft^2) or Rain Barrel Count
Bio-retention	B1	1800	1200	1200
	B2	900	675	675
	B3	2250	1500	1500
	B4	2700	1800	1800
Rain Barrel	R1	6	6	6
	R2	12	12	12
	R3	10	8	8
	R4	12	8	8
Porous Pavement	P1	8118	2706	2706
	P2	3534	2356	3534
	P3	5505	1835	1835
	P4	4343	1447.6	1447.6
	P5	5205	1735	1735
	P6	981	490.5	490.5
	P7	2310	1155	1155
	P8	380	0	0
	P9	11400	5705	5705
	P10	801	801	801
Green Roof	G1	26400	6596	6596
	G2	6144	0	0
	G3	6400	0	0
	G4	2340	2340	2340
	G5	2400	1200	1200
	G6	7812	0	0
	G7	15408	0	0



Discussions and Conclusions (from the case study)

Green Roofs

Relatively high-cost alternative when only runoff reduction is the primary objective

Rain Barrels

Are a cost-effective alternative for controlling runoff when open land is limited

Are less cost-effective than bioretention when sufficient open land is available for bioretention

Discussions and Conclusions

This is a *TOOL* for selecting and evaluating alternatives

This tool can be customized for local uses.