SUSTAIN - A BMP Process and Placement Tool for Urban Watersheds

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The Issue

Various structural and non-structural stormwater best management practices (BMPs) have become the national focus for the mitigation of stormwater pollution. Analytical tools are needed to help agencies evaluate management options and optimize cost. Currently there is no comprehensive modeling system available in the public domain for systemically evaluating the location, type, and cost of wet-weather flow BMPs.

- Urban land increased by 330% and paved road mileage by 280% between 1945 and 1997.
- When the percentage of impervious cover exceeds 25 to 30% of the watershed, streams tend to no longer support diverse fish and aquatic life.

Abstract

To assist stormwater management professionals in planning for best management practices (BMPs) and low-impact developments (LIDs) implementation, USEPA is developing a decision support system, called the **S**ystem for **U**rban **S**tormwater **T**reatment and **A**nalysis **IN**tegration (*SUSTAIN*). This tool will help develop, evaluate, select, and place BMP/LID options. *SUSTAIN*, a generic public domain framework, will provide a thorough, practical, and informative assessment of management alternatives considering the economic, environmental, and engineering factors. *SUSTAIN* supports evaluation of BMP placement at multiple scales from a few city blocks to large watersheds.

Objective

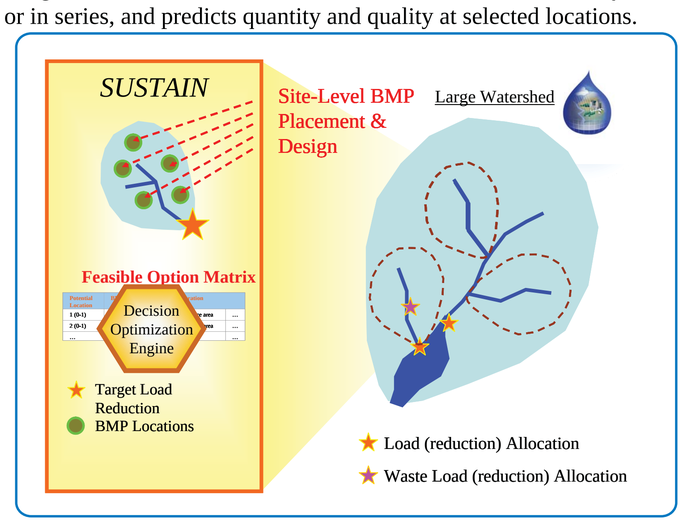
To develop methodologies and decision support tools that help develop, evaluate, select and place BMPs in urban watersheds based on sound science and consideration of cost and effectiveness.

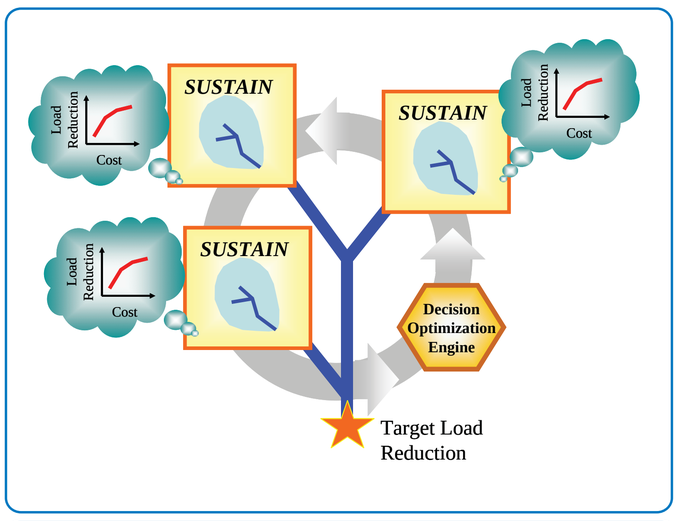
Intended Users

Those who have a fundamental understanding of watershed and BMP modeling processes – local and county government engineers/planners, federal/state regulatory reviewers, private consulting engineers, concerned citizens, stakeholders, and academicians.

Watershed-based Placement Scenario and Tiered Analysis

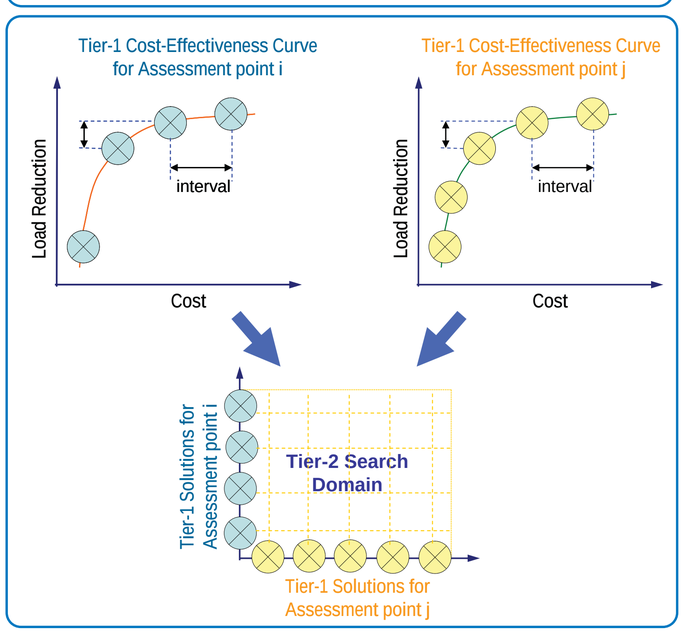
A relatively large watershed shown in the figure below can usually be subdivided into several smaller sub-watersheds. For each sub-watershed, users select an appropriate suite of feasible BMP options (types, configurations, and costs) at strategic locations. *SUSTAIN* generates time series rainfall-runoff data from BMP tributary areas and routes them through BMPs, in parallel or in series, and predicts quantity and quality at selected locations.





SUSTAIN produces output for deriving optimal cost-effectiveness curves that relate flow or pollutant load reductions with costs as in the figure below. Each point on a curve represents an optimal combination of BMPs that will collectively remove the stated amount of pollutant load at the least cost. It also shows a tiered evaluation approach for evaluation of both individual watersheds and multiple nested watersheds.

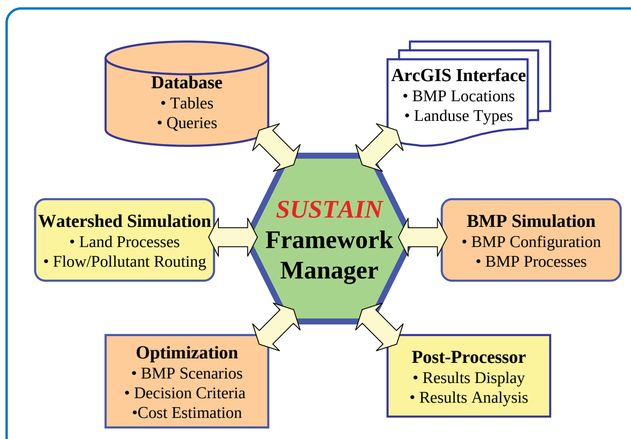
- Tier-1 optimization performs the optimization search to develop cost-effectiveness curves for each tier-1 subwatershed.
- Tier-2 optimization uses tier-1 solutions to construct a new optimization search domain and run the transport module, if needed, with solutions from all the subwatersheds to develop the combined cost-effectiveness curve for the entire watershed.



The construction of the tier-2 search domain using tier-1 optimization solutions.

Key Components and Their Functionalities

Seven key components are integrated under a common ArcGIS platform.



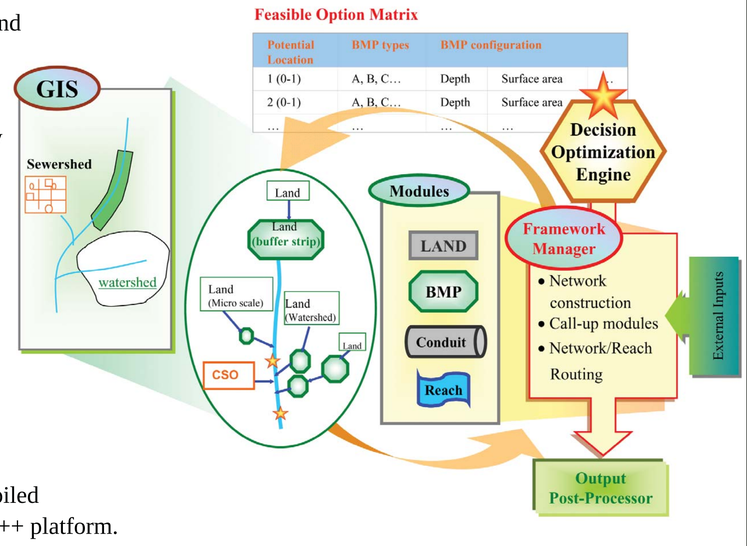
- **Framework manager (FM) –** serves as the command center of *SUSTAIN*, managing the data exchanges between system components.
- **ArcGIS Interface –** serves as the main user interface that includes the main application window with menus, buttons, and dialog boxes.

Key Components continued

Microsoft Access database – consists of tables and queries for interaction and exchange of data.

Watershed module – includes three internal stand-alone watershed models for generating flow and pollutant time series:

- ***Land*** for performing landscape runoff simulation.
- ***Conduit*** for routing of flow and pollutant through a conduit network.
- ***Reach*** for stream conveyance and pollutant routing.



The computer codes will be derived mostly from SWMM5 and some from HSPF (e.g., soil loss in pervious areas and sediment routing) and re-compiled into a dynamic link library (DLL) in the Visual C++ platform.

- **BMP module –** performs process-based simulation through ponds, constructed wetlands, infiltration trench, swales, buffer strips, and other BMPs (e.g., green roof, porous pavement) to derive their performance by simulating the major processes that affect hydrology and pollutant behavior.

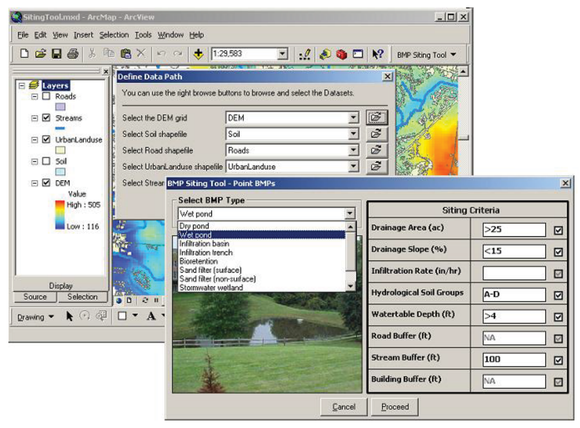
Structural BMP Types	Storage Routing	Infiltration /Filtration	Pollutant Routing/ Removal	Sheet Flow Routing/Pollutant Interception
Detention Basin	+	(o)	o	-
Bioretention Basin	o	+	o	-
Wetland	+	(o)	+	-
Buffer Strip	-	+	(o)	+
Swale	o	+	+	-

Notes: ( ) optional; + major process; o secondary process; - insignificant process.

- **Post-processor -** uses ArcGIS and Microsoft Excel to analyze and visualize model outputs.
- **Optimization module -** performs cost estimating and systematically compares performance and cost data of various BMP options and their placement scenarios. The current version includes two types of optimization search algorithms – genetic algorithm and scatter search.

Example Features of *SUSTAIN* Approach

BMP Siting Tool – The tool is designed to support users in selecting suitable locations for the most common structural BMPs based on site suitability criteria which include drainage area and slope, infiltration rate, hydrological soil group, groundwater table depth, road buffer, stream buffer, and building buffer.

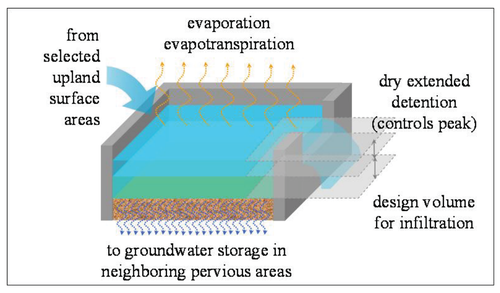


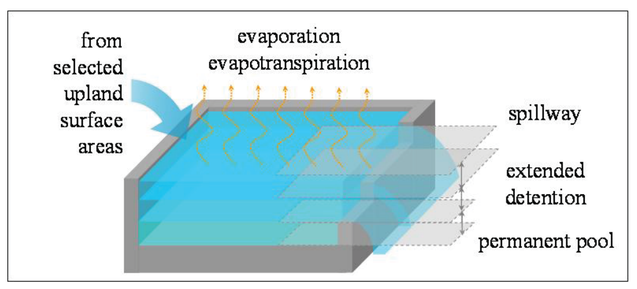
BMP Interface – BMPs are classified and conceptualized in *SUSTAIN* as scale-based and type-based. The type-based category classifies BMPs into three types based on their geometric properties:

- **Point BMPs:** Practices that capture upstream drainage at a specific location and may use a combination of detention, infiltration, evaporation, settling, and transformation to manage flow and remove pollutants.
- **Linear BMPs:** Narrow linear shapes adjacent to stream channels that provide filtration of runoff, nutrient uptake, and ancillary benefits of stream shading, wildlife habitat, and aesthetic value.
- **Area BMPs**: Land-based management practices that affect impervious area, land cover, and pollutant inputs (e.g., fertilizer, pet waste).

The scale-based category classifies various BMPs based on the size and nature of the application area, such as BMPs at lot, community, or watershed scales.

Aggregation of Distributed BMPs – For distributed BMPs located in residential parcels of a new development or an existing neighborhood, their precise locations may not be important relative to the scale of a study. Hence, their physical characteristics can be represented by the collective properties (e.g., total detention volume or total infiltration.) This "lumped" approach will reduce computational effort, especially when distributed BMPs are involved in the optimization process as decision variables. In *SUSTAIN*, distributed BMPs are aggregated as two types of generic BMPs shown below, the first representing infiltration structure and the second detention structure.





Impacts/Outcomes

- This project demonstrates a collaborative effort of USEPA with a leading watershed modeling firm for advancing the BMP/LID technologies.
- The watershed-based decision support tool would help develop restoration plans – that consider hydrologic and water quality impacts, and optimize cost and effectiveness.
- The tool will support USEPA program offices in stormwater management evaluations and cost optimizations.

Acknowledgements

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