Watershed Management Optimization Support Tool (WMOST)


Loucks and van Beek 2005

EPA Tools and Resources Webinar
February 21, 2018

Naomi Detenbeck
US EPA Office of Research and Development

United States Environmental Protection Agency

Outline

- Background on Integrated Water Resources Management
- WMOST features and availability
- Application of WMOST to Cabin John Creek, MD
- Application of WMOST to Upper Taunton River, MA
- Future directions
- Supporting materials and training

United States Environmental Protection Agency

Why Integrated Water Resource Management?

- "Cities are facing formidable and varied challenges to the **quality, accessibility, and cost efficient management of** their **water**.
- **Integrated water management** refers to **system-level approaches** that prioritize collaboration and require the "triple bottom line" consideration of **social** and **environmental** outcomes on the same level as **economic balance**.
- This holistic approach necessitates high levels of **collaboration between specialized departments** or staff.
- **"One Water" concept**… viewing wastewater, stormwater, groundwater, or any particular water source as interconnected parts of one resource.

– Mayors Innovation Project (mayorsinnovation.org)

What does WMOST do?

EPA's WMOST can be used by state and local managers to screen a wide range of options for cost-effective management of water resources.

- Accounts for water and pollutant loads at watershed scale
- Identifies water-related goals and constraints
- Evaluates integrated management practices
  - Stormwater (including green infrastructure (GI))
  - Drinking water
  - Wastewater
  - Land conservation
- Optimizes costs while finding solutions

Who and what is WMOST designed for?

Community decision makers/small watershed scale

- Utility managers
- Municipal planners
- Consultants to communities

Planning level assessments

- Supporting information for State Revolving Fund loans, grants, FEMA Community Rating System credits
- Long-range planning (Combined Sewer Overflow (CSO) consent decree response, utility 20-year plans)
- Integrated plans to meet permit requirements

Example Goals and Questions

Goal	Question
Maintain baseflows in river to support fish and reduce effluent impacts at low flows	What is our least cost solution? - Manage water demand? - Reduce leaks? - Reduce runoff/increase infiltration to groundwater? - Reduce transfers of water outside of watershed?
Maintain adequate water supply in reservoir	How can we sustain water supplies over both wet and dry years while ensuring sufficient water flows downstream as well as minimizing flooding risks/costs?
Reduce costs of floodplain insurance and take advantage of FEMA funding sources	What is the effect of implementing green infrastructure stormwater best management practices in reducing flooding risks/costs?
Reduce/eliminate sewer overflows, or meet water quality targets by reducing excess nutrient loads	What is the most cost effective balance between green and gray infrastructure?

United States Environmental Protection Agency

WMOST Availability

WMOST is a publicly available online tool

- Documentation
- User guide with case study appendices
- Pre-processor utility to format watershed model outputs as WMOST inputs
- Interactive exploration of pre-processed input data sets available via US EPA Estuary Data Mapper: www.epa.gov/edm

➢ Version 1 focuses on management of base and peak flows

➢ Version 2 adds a flooding module to assess costs associated with peak flows

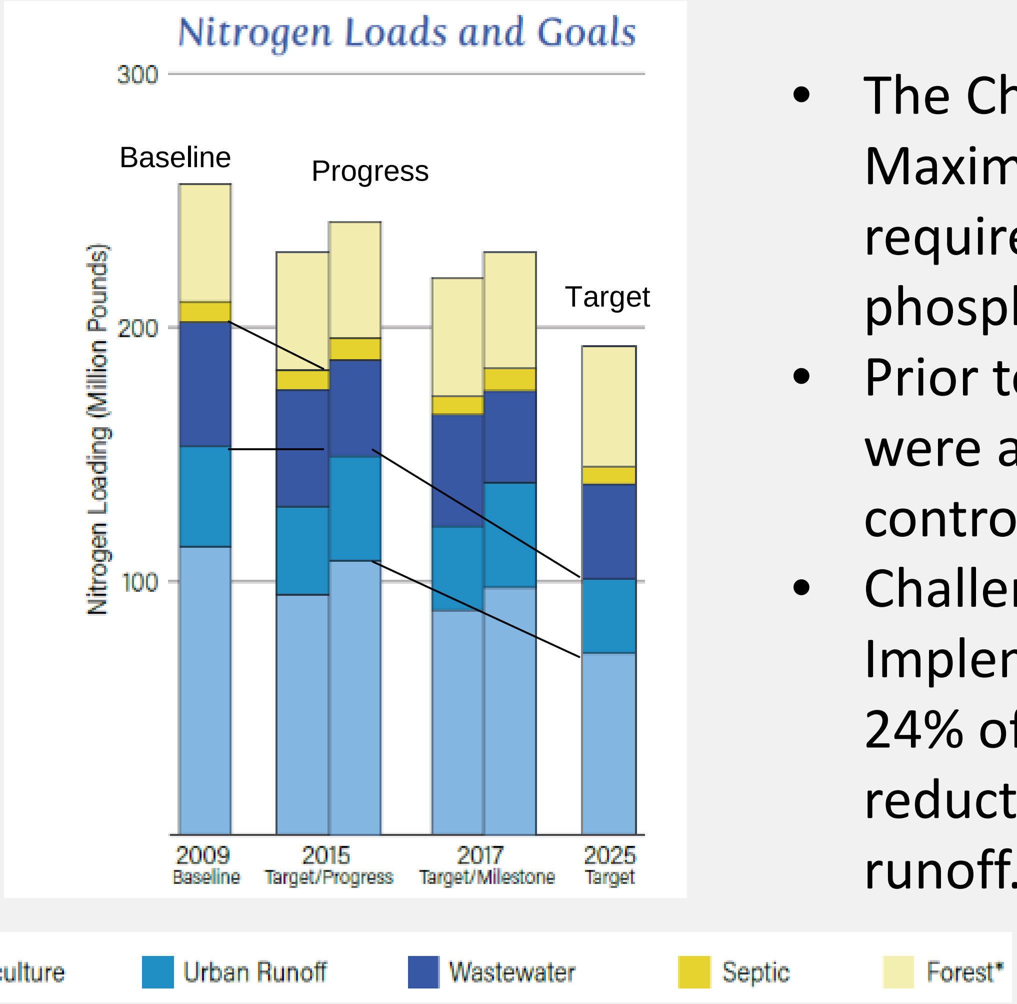
➢ Version 3 includes water quality and combined sewer overflow modules

http://www2.epa.gov/exposure-assessment-models/wmost

New Features in WMOST v3

- Pre-processor to allow users to format existing model output for WMOST
- Automatic import of preprocessed model outputs via REST request generated by WMOST
- Interactive exploration of pre-processed watershed data in Estuary Data Mapper
- Water quality module: nonpoint source, point source, septic, waste water treatment plant (WWTP)
- Expanded Best Management Practice (BMP) set: structural, nonstructural stormwater controls, agricultural BMPs
- Expanded infrastructure
- Combined Sewer Overflow (CSO) module

Applying WMOST: Pollutant load reductions to the Chesapeake Bay



- The Chesapeake Bay Total Maximum Daily Load (TMDL) requires reductions in nitrogen (N), phosphorus (P) and sediment loads.
- Prior to 2015, most load reductions were achieved via wastewater controls.
- Challenge: In Stage II Watershed Implementation Plans (post 2015), 24% of N and 36% of P planned load reductions are assigned to urban runoff.

United States Environmental Protection Agency

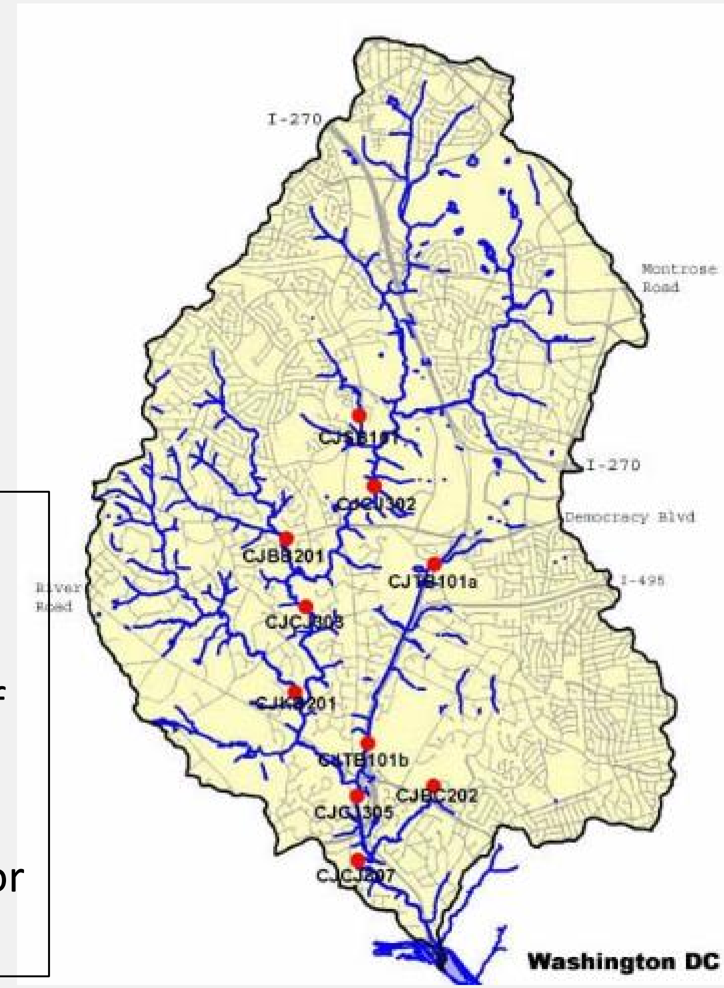
What is the Process?

1. Identify area of interest and issues
2. Determine goals, constraints and timeline
3. Consider available management options
4. Compile relevant data
    - Weather, hydrology, and loading time series <= data library
    - Infrastructure with costs
    - Water demand and withdrawals
    - Flooding cost/risk curve <= FEMA HAZUS tool
5. Populate WMOST with data and targets
6. Evaluate optimal solutions and tradeoffs

Cabin John Creek, MD Application

Partners: Maryland Department of the Environment, Montgomery County, City of Rockville

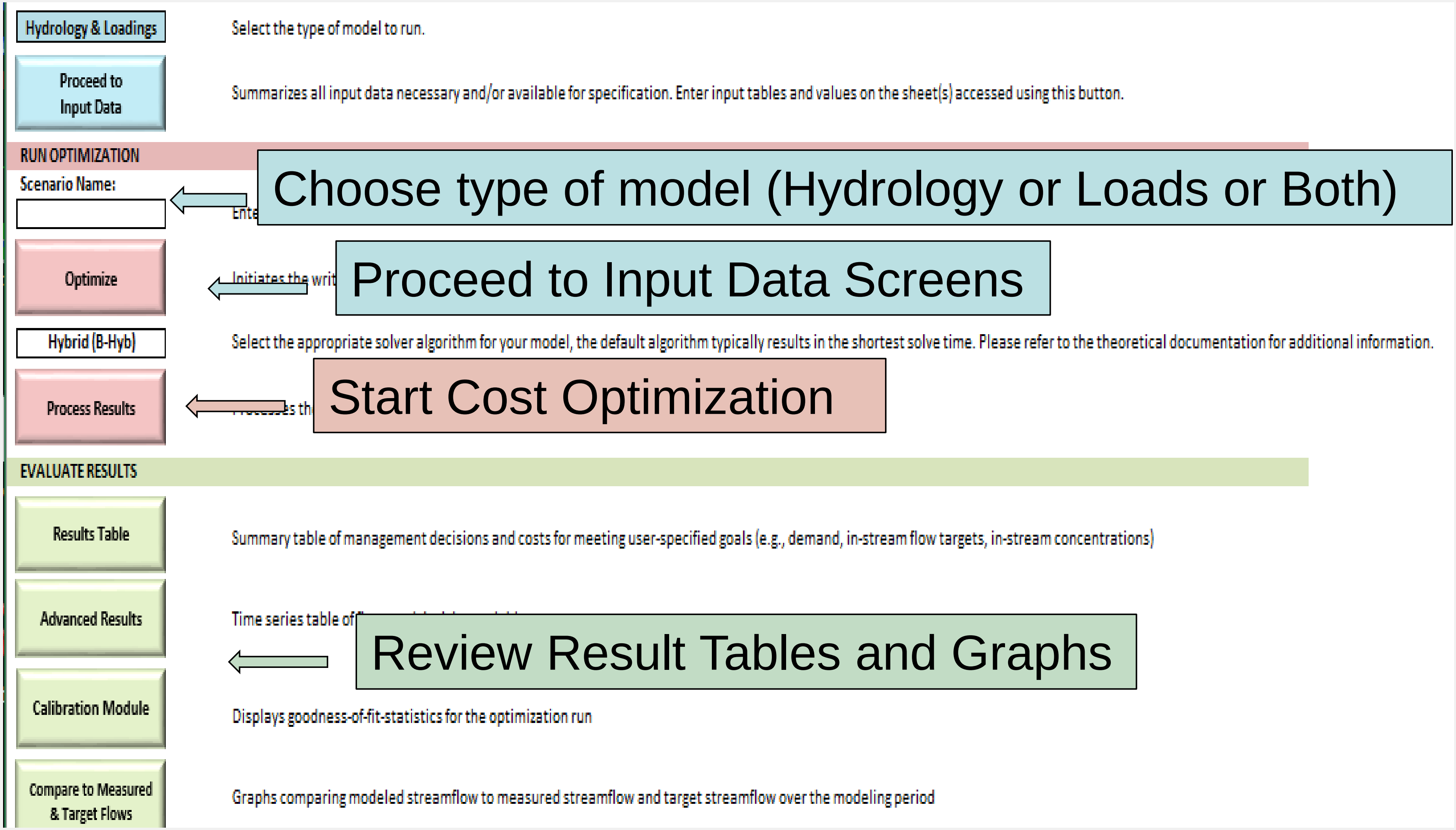
Challenge: Identifying the most cost-effective suite of stormwater BMPs in a highly urbanized watershed to meet both local sediment TMDLs and downstream nitrogen, phosphorus, suspended sediment targets for Chesapeake Bay TMDL.



WMOST Approach for Cabin John Creek

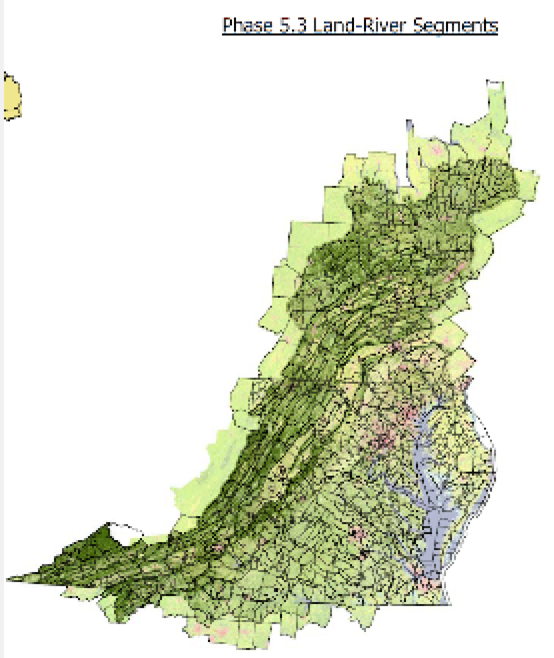
- **Goals**
  - 21% reduction in suspended sediment load to meet local TMDL for Cabin John Creek
  - Reductions in Total Nitrogen (TN) (5%) and Total Phosphorus (TP) (4%) loads to meet Chesapeake Bay TMDL
  - No water supply or wastewater constraints (sources, treatment are outside watershed)
- **Objective**
  - Minimize costs (capital + Operation & Maintenance (O&M)) for 2014 -2025
- **Management Options**
  - Stormwater BMPs, including GI
  - Forested riparian buffers
  - Nonstructural BMPs: street sweeping, tree canopy, urban nutrient management

MS-Excel interface



United States Environmental Protection Agency

Time Series



Chesapeake Bay Watershed Model

Data from the Chesapeake Bay Watershed Model were used to populate the baseline hydrology and loading time series tables in WMOST.

Montgomery County Land/Water Segment

HRU	HRU Name
1	Open Water
2	MC Developed Land, Soil Type A/B
…	

Runoff (in/acre) Recharge

Date	Ru HRU1	Ru HRU2	…	Re HRU1	Re HRU2	…
1/1/02						
1/2/02						
…						

Pollutant Loads (lb/acre)

Date	TP HRU1	TP HRU2	…	TN HRU1	TN HRU2	…	TSS
1/1/02							
1/2/02							
…							

Setting Management Options

First Set of Managed Land Uses and Their Limits					Bioretention
HRU ID	HRU Name	Minimum Area [acre]	Maximum Area [acre]	Initial Cost [$/acre]	O&M Cost [$/acre/yr]
HRU1M1	MC Developed/AB soils				
HRU2M1	MC Developed/CD soils				
HRU3M1	Rockville Developed/AB soils				

< Input name of management practice

existing

potential

SUSTAIN defaults or user-specified

3. Select the best management practices (BMPs) that you would like to model and enter the design depth for each BMP.
Indicate the decay rate of water quality constituents for each BMP. Enter 0 for no constituent decay. Use the Import Defau
See the User's Guide for descriptions of the BMPs and guidance on sizing for different water management objectives and
Agricultural BMPs are an exception and will be run for all undeveloped HRUs (EIA = 0%).

BMP Type	Design Depth For BMP [in]	TN 1st Order Decay Rate [1/hr]
Bioretention Basin	2.75	0.03
Extended Dry Detention Basin	0	0.02
Sand Filter w/UD	2.75	0.36
Biofiltration w/UD	2.75	0.03
Infiltration Basin	2.75	0.42
Porous Pavement w/UD	2.75	0.26
Extended Dry Detention Basin	2.75	0.02
Wet Pond	2.75	0.03

Import Default Decay Rates

Select via dropdown list

User-specified

BMP-Adjusted Time Series

Calculated via WMOST call to SUSTAIN model

Baseline BMP managed set 1…Managed set n

Date	Ru HRU1	Ru HRU2	…	M1Ru HRU1	M1Ru HRU2	…
1/1/02						
1/2/02						
…						

WMOST creates time series for runoff, recharge and pollutant loads for each managed set (BMP and land-use/soil combination) through interactions with EPA's SUSTAIN model.

Baseline BMP managed set 1…Managed set n

Date	TP HRU1	TP HRU2	…	M1TP HRU1	MTP HRU2	…
1/1/02						
1/2/02						
…						

The user can view the managed set time series tables for each BMP after running the stormwater module in WMOST.

Example Results Table

Most cost-effective types and amounts of BMPs required to reduce N loads by 5% from 2014 base conditions

Pre-optimization 2014 costs

Post-optimization *added* costs

Previous top 2 BMPs implemented

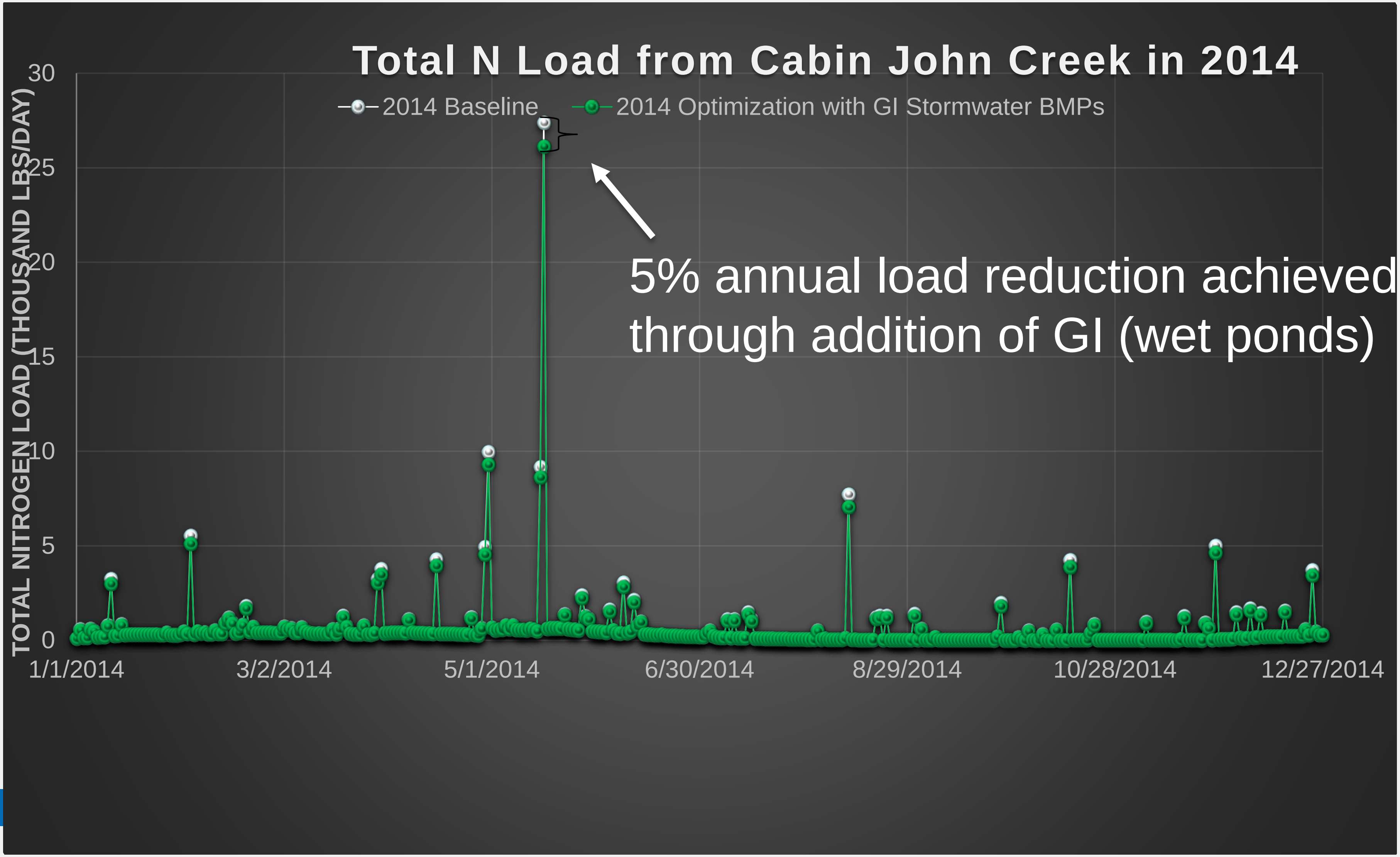
Only BMP chosen to increase

Management Option	Implementation		Cost
2.75" Bioretention Basin	0.0	Acres	
2.75" Sand Filter w/UD	0.0	Acres	
2.75" Biofiltration w/UD	0.0	Acres	
2.75" Infiltration Basin	0.0	Acres	
2.75" Porous Pavement w/UD	0.0	Acres	
2.75" Extended Dry Detention Basin	0.0	Acres	
Turfgrass A/B Montgomery County	0.0	Acres	
Turfgrass C/D Montgomery County	0.0	Acres	
Turfgrass A/B City of Rockville	0.0	Acres	
Turfgrass C/D City of Rockville	0.0	Acres	
Turfgrass A/B MD State Highway Administration	0.0	Acres	
Turfgrass C/D MD State Highway Administration	0.0	Acres	
Turfgrass A/B Other Regulated	0.0	Acres	
Turfgrass C/D Other Regulated	0.0	Acres	
Natural	0.0	Acres	
Water	0.0	Acres	
2.75" Wet Pond	3210.0	Acres	$3,394,509.28
Turfgrass A/B Montgomery County	1166.8	Acres	
Turfgrass C/D Montgomery County	390.9	Acres	Increase from 44.6
Turfgrass A/B City of Rockville	0.0	Acres	
Turfgrass C/D City of Rockville	0.0	Acres	
Turfgrass A/B MD State Highway Administration	94.5	**Acres**	
Turfgrass C/D MD State Highway Administration	0.0	Acres	
Turfgrass A/B Other Regulated	332.8	Acres	Increase from 0
Turfgrass C/D Other Regulated	121.9	Acres	Increase from 0
Natural	0.0	Acres	
Water	0.0	Acres	

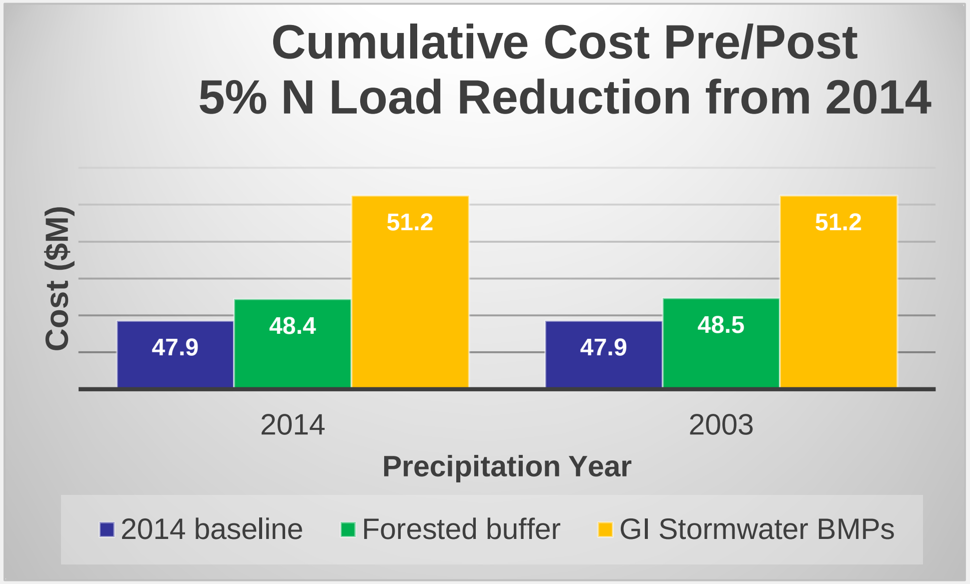
United States Environmental Protection Agency

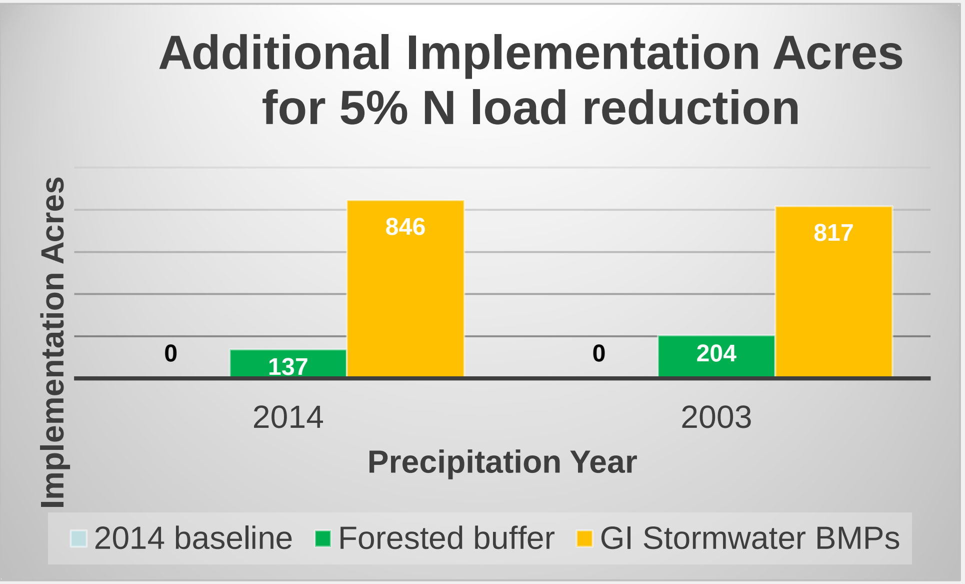
Example Output Graph

Daily time series of N loads for base conditions vs optimal solution for GI Stormwater BMPs



Comparing Optimal Solutions across Weather Regimes





- Compared solutions using inputs for wet year (2003) vs dry year with one large event (2014)
- Wet ponds chosen as lowest cost stormwater control
- Riparian buffers provide lower cost solution for 5% annual N load reduction but without runoff volume benefits

Summary: Cabin John Creek

- **Preliminary results**
  - Previous implementation favored extended dry detention ponds and wet ponds
  - Wet ponds on 3 land use/soil type classes chosen as least cost options to reduce 2014 N load by another 5%
  - Riparian buffer restoration as alternative lower cost option for total nitrogen (but without peak flow benefits)
  - For total suspended solids, riparian buffers alone can't meet 21%↓ target for wet year but combination of wet ponds and forested buffers provides lowest cost option
  - Required levels of implementation vary across wet and dry years

- **Iterative process: next steps**
  - Comparing effectiveness/cost of nonstructural and other BMPs
  - Adding base flow and peak flow targets to water quality goals
  - Evaluating dry detention pond conversions

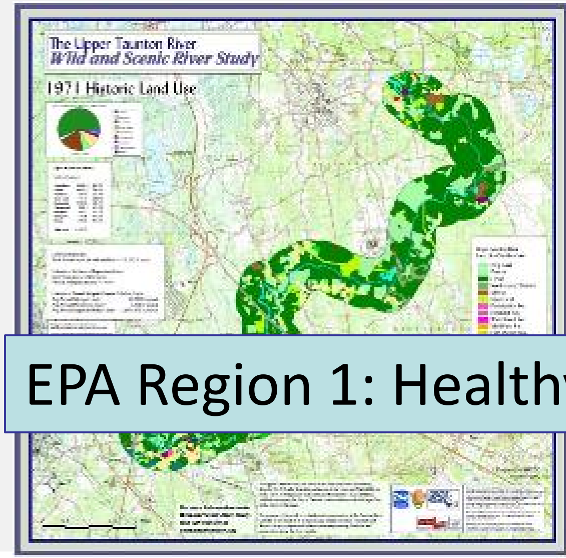
Impact

Maryland will use the results of this (and future) case studies to provide guidance to be applied to similar communities/watersheds dealing with similar targets.

"One of Maryland's greatest challenges, and opportunities, is to ensure its Phase I MS4's meet permit and TMDL restoration requirements in ways that are affordable and sustainable. This study, in a small urban watershed, is a cooperative effort among state, county and city governments and EPA to develop a balanced implementation strategy. EPA ORD's modeling tools used in this study have unique features such as stormwater BMP runoff reduction estimates and cost optimization modules to help us achieve environmental results, while maximizing savings for ratepayers." – Maryland Department of the Environment Secretary Ben Grumbles

EPA United States Environmental Protection Agency

Applying WMOST: Inform community planning decisions in watersheds with outstanding natural resources but rapid growth



EPA Region 1: Healthy Communities Grant Program

Mass Audubon

SRPEDD

Southeastern Regional Planning and Economic Development District

MAPC

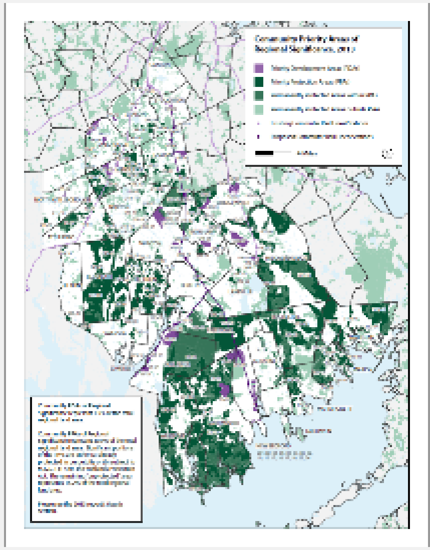
METROPOLITAN AREA PLANNING COUNCIL

manomet

Soaring Solutions. Grounded Science.

The Nature Conservancy

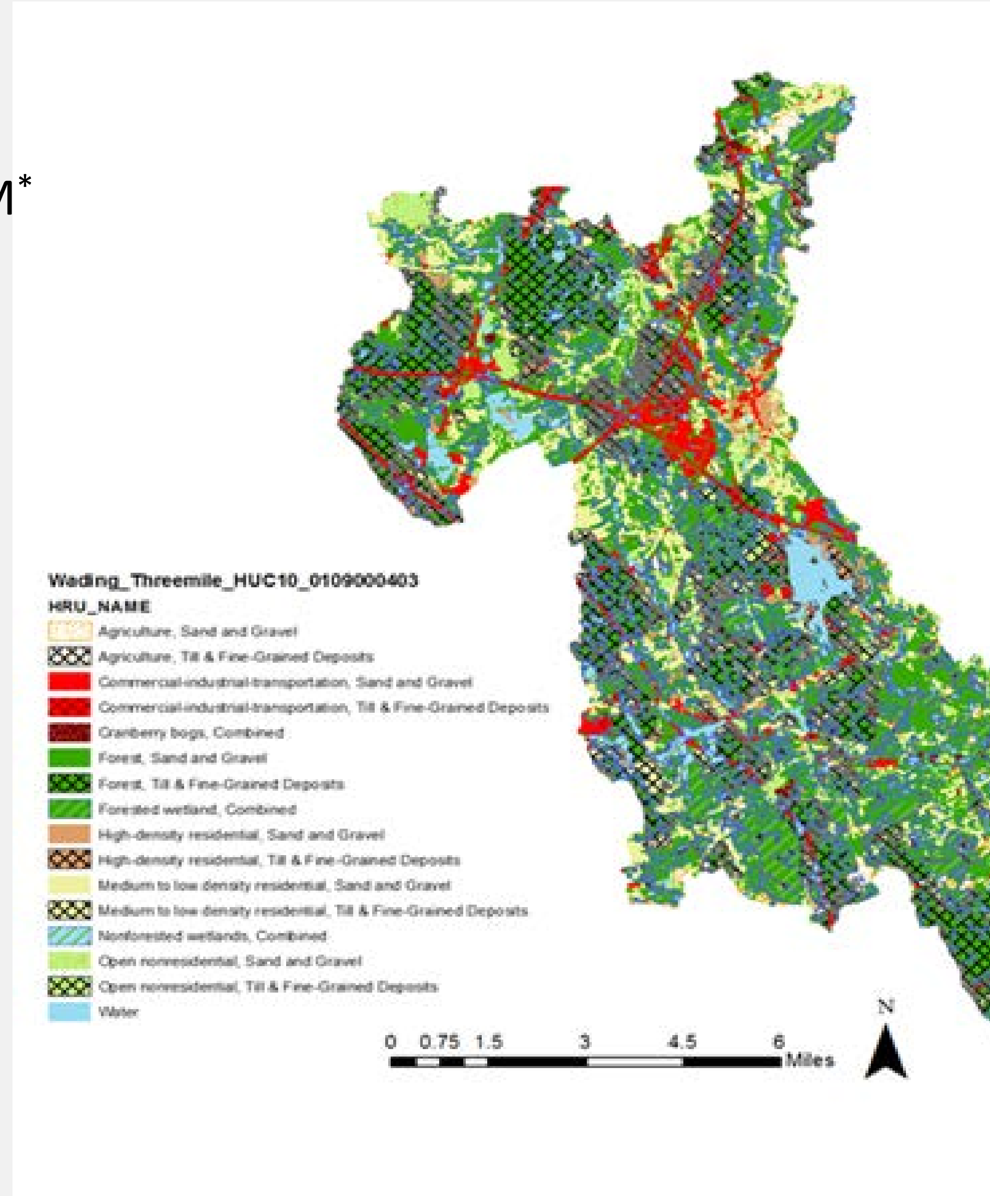
WMOST Approach for Upper Taunton River, MA



- **Goals and Constraints**
  - Ecoregional targets for total P concentration
  - Total N load reduction for protection of downstream Mt. Hope Bay/Narragansett Bay estuary
  - Sustainable water supply, minimum low flows for fish
  - Land conservation
- **Objective**
  - Part 1: Minimize costs (capital + O&M) for near-term planning horizon
  - Part 2: Minimize future costs under projected growth and climate
- **Management Options Considered**
  - Land conservation, Stormwater BMPs, Forested riparian buffers (restoration, conservation), Repair infrastructure leaks, Upgrade wastewater treatment, Water conservation, Aquifer storage and recharge

Data Sources

- **Input Data (2002 - 2006)**
  - Runoff, Recharge, Nitrogen and Phosphorus loadings from SWMM* model
  - Hydrologic Response Units: combination of Land use and Surficial Geology
  - Water demand and withdrawals
  - Septic systems
  - Point source discharges
  - Infrastructure (town, utility data)

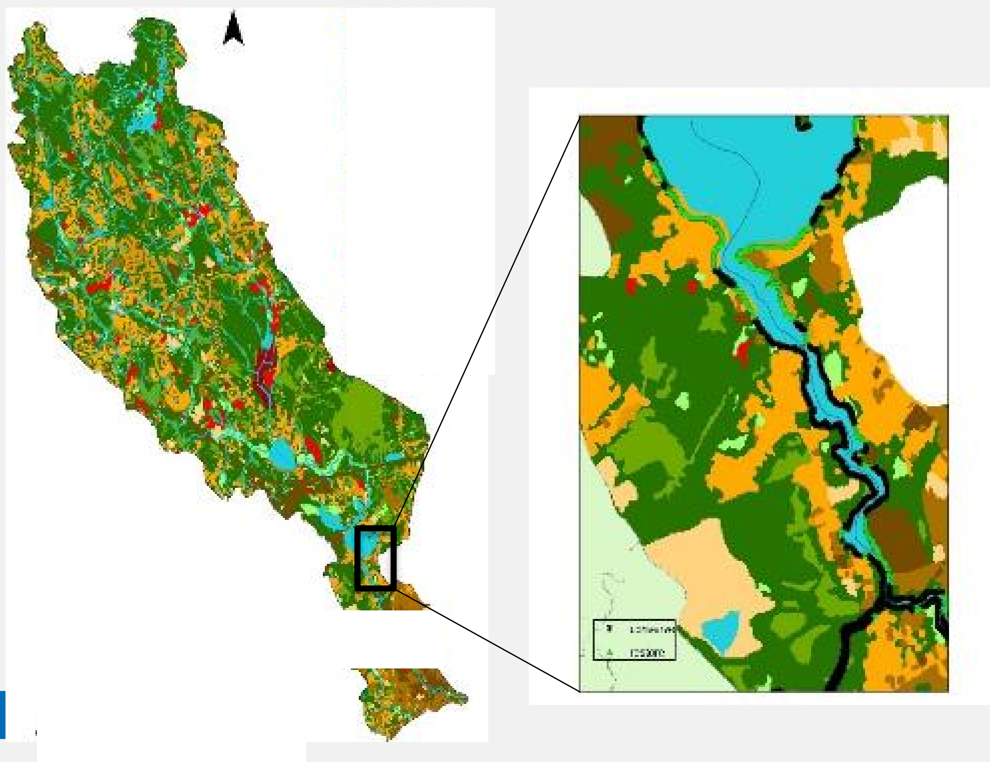


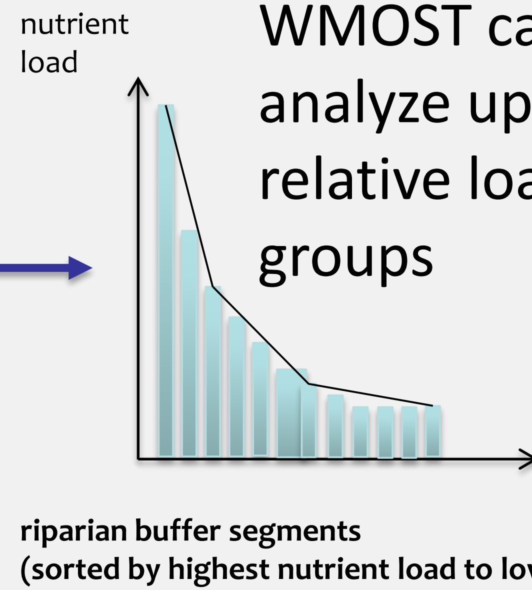
*Storm Water Management Model (SWMM)

United States Environmental Protection Agency

Factoring in varying efficiencies for forested buffers

- WMOST can analyze up to three relative loads groups for riparian buffers
- For this case study, to enhance WMOST we used the **Riparian Analysis Toolbox** from Chesapeake Bay Program (Baker et al 2006) which ranks riparian segments by upgradient load received to determine the relative loads groups





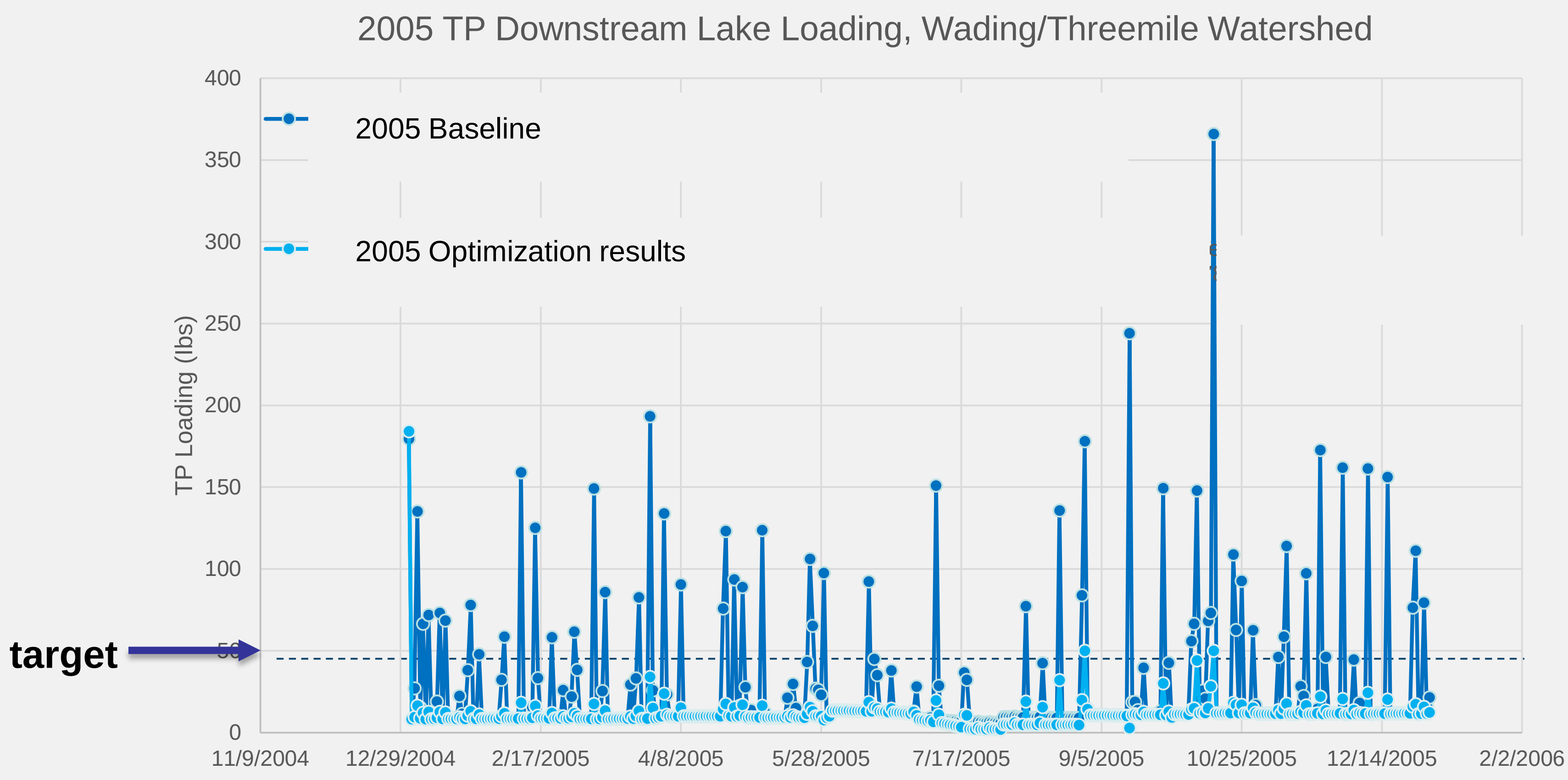
WMOST can analyze up to 3 relative loads groups

Which Stormwater BMPs are most cost-effective for reducing total N and total P loads?

- **Comparison of 9 stormwater BMPs with 2" design depths**
  - Bioretention basin, Enhanced biofiltration with ISR, Grassed swales, Infiltration basins, Extended dry detention ponds, Gravel wetland, Infiltration chamber, Infiltration trench, Wet pond
  - ➢ **Infiltration basin consistently chosen as only most cost-effective option**

- **Comparison of infiltration basins with 2", 1" and 0.6" design depths**
  - ➢ **0.6" design depth consistently chosen as most cost-effective option**

WMOST Graph Results Tab
Total P Load to Lake for 2005



Combined maximum riparian buffer restoration + some infiltration basins can meet **growing season loading target** at much reduced cost for wet year as compared to infiltration basins alone.

United States Environmental Protection Agency

Impact

Results from the Upper Taunton case study are being used:

- Grant applications for improved watershed management using WMOST results as supporting information
- Future scenario runs: Consultations/support by Southeastern Regional Planning and Economic Development District to communities on their development of Master Plans, open space plans, etc.

Future Directions

- Robust decision making tools
  - Hydrologic Scenario Comparison Assessment Module (HCAM): Comparison of WMOST output across multiple climate (or other) scenarios
  - Application of WMOST to multiple climate change scenarios => find most robust solutions in face of uncertainty
- Co-benefits module
- Multiple objective optimization version
  - Simultaneous optimization of multiple targets (rather than just cost)
  - Generation of trade-off curves

Training and Outreach Materials

- WMOST website
  - Fact sheet and User guides with case studies
  - Recorded workshop videos for v2

  http://www2.epa.gov/exposure-assessment-models/wmost

- Green Infrastructure Modeling Toolkit (quick overview): https://www.epa.gov/water-research/green-infrastructure-modeling-toolkit

- Upcoming technical training webinar (to be recorded)
  - March 8, 2018 from 1-3 pm Eastern

  https://www.epa.gov/waterdata/surface-water-quality-modeling

- In person workshop at International Environmental Modeling & Software Conference, Fort Collins, CO, June 24-28, 2018 www.iemss2018.engr.colostate.edu

Opportunities for States

- Additional case studies needed, including for upcoming modules
  - Co-benefits module
  - Robust decision making
  - Multi-objective optimization

- If there is interest, EPA ORD is planning to set up an online WMOST course for stakeholders interested in applying WMOST to their own case study
  - Coverage of WMOST one module at a time
  - "Homework exercises" for participants: populating WMOST case studies
  - Opportunity to compare results and approaches

Contacts

Naomi Detenbeck

US EPA Office of Research and Development

401-782-3162

detenbeck.naomi@epa.gov

For future modules:

Robust decision making: **Chris Weaver** (weaver.chris@epa.gov)

Multi-objective optimization: **Amy Piscopo** (piscopo.amy@epa.gov)

Acknowledgments

EPA: Tim Stagnitta (ORISE), Amy Piscopo, Marilyn ten Brink, Chris Weaver, Region 1 (Trish Garrigan, Jackie LeClair, Ralph Abele) ***Abt***: Alyssa Le, Annie Brown, Justin Stein, Isabelle Morin, Viktoria Zoltay ***Collaborators***: Maryland Department of the Environment (Jeff White, Shannon McKenrick); Montgomery Co; City of Rockville, MD; Manomet (Eric Walberg, Jennifer Hushaw); SRPEDD (Bill Napolitano et al.); TNC; MA Audubon; Monponsett Ponds Watershed Workgroup