Watershed Management Optimization Support Tool (WMOST): Benefits Module

Naomi Detenbeck
U.S. EPA Office of Research and Development
Atlantic Coastal and Environmental Sciences Division

Chesapeake Bay Program Modeling Workgroup Quarterly Review
July 8, 2020

Loucks and van Beek 2005
Watershed Management Optimization Support Tool

- User-friendly decision support tool that identifies most cost-effective integrated water management actions for meeting specific goals for water quantity and quality
- Developed explicitly to inform management decisions at small watershed scale (≤ HUC12 – HUC10)
- Uniqueness – scale, IWRM scope/coordinated approach, cost, broad audience, level of technical expertise required
- Value added to existing tools and models
  - Uses output from existing TMDL models (e.g., HSPF, SWAT, SWMM)
  - Integrated with SUSTAIN/SWMM to simulate BMP processes
  - Uses output from FEMA’s HAZUS tool to incorporate flooding costs/risks
- Promotes efficiency in finding best solutions through optimization rather than doing repeated model simulations
WMOST mass balances of water & pollutants
Benefits monetized in WMOSTv3 prior to benefits module

• WMOST provides optimal (least-cost) integrated management solution to meet water quantity and quality targets
  - Wastewater, stormwater, drinking water, land conservation
  - Capital and O&M infrastructure costs included

• Reduced costs associated with meeting loading targets through integrated management practices can be derived through scenario comparisons, e.g.,
  - Reductions in flood-related risk and costs (flood module)
  - Reductions in potential CSO storage/treatment (e.g., underground storage) associated with repair of I/I problems, green infrastructure BMPs
  - Reductions in interbasin transfer costs for drinking water imports if infiltration by GI stormwater BMPs increases groundwater availability
Additional benefits and cobenefits monetized in new Benefits Module

• Benefits (related to water quality endpoints)
  – Changes in recreational and non-use values
  – Reduced drinking water treatment costs (TSS)
• Co-benefits (related to non water-quality endpoints)
  – Property values (green space)
  – Social cost of carbon
  – Heating/cooling costs
  – Human health
    • Reduced exposure to atmospheric emissions
## Summary of Benefits and Cobenefits

<table>
<thead>
<tr>
<th>Effect of Management Options</th>
<th>Environmental Outcome</th>
<th>Benefit Category</th>
<th>Valuation Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water Quality Benefits</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meet water quality targets</td>
<td>Changes to surface water quality (TN,</td>
<td>Changes in recreational and non-use values</td>
<td>Willingness-to-pay for water quality improvements</td>
</tr>
<tr>
<td>based on chosen management</td>
<td>TP, and TSS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>options</td>
<td>Changes to TSS concentrations</td>
<td>Changes in drinking water treatment costs</td>
<td>Avoided water treatment costs</td>
</tr>
<tr>
<td><strong>Non-Water Quality Co-benefits</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implementation of land</td>
<td>Increased green space</td>
<td>Improved aesthetic quality of the landscape</td>
<td>Change in property values</td>
</tr>
<tr>
<td>conservation, bioretention</td>
<td>Reduced criteria air pollutant levels</td>
<td>Reduction in adverse health outcomes</td>
<td>Benefits per hectare of tree cover</td>
</tr>
<tr>
<td>basin, grass swale, gravel</td>
<td>from increased tree canopy</td>
<td></td>
<td>Social cost of carbon</td>
</tr>
<tr>
<td>or constructed wetland,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>riparian buffers, or increases in urban tree canopy</td>
<td></td>
<td>Carbon sequestration from increased tree canopy</td>
<td>Tons of carbon sequestered</td>
</tr>
<tr>
<td>Green roof implementation</td>
<td></td>
<td>Reduction in power plant emissions</td>
<td>Benefits per ton of pollutant removed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduction in heating/cooling needs</td>
<td>Electricity savings</td>
</tr>
</tbody>
</table>
WQ Benefits
Recreational and non-use values

• Water Quality Index approach – used in multiple EPA rule-makings
  – total nonmarket benefits of water quality changes based on the changes in ecosystem services provided by surface water that are valued by humans, including water-based recreation, aquatic biodiversity, wildlife support, aesthetic, and non-use
  – WQI aggregates multiple parameters into a single index value (0-100 scale)
    • TN, TP, TSS changes due to management derived from WMOST runs
    • Other WQ parameters (DO, BOD, fecal coliform) baseline derived from nationwide database or local user input
WQ Benefits
Drinking water treatment costs

- $\Delta$TSS $\Rightarrow$ $\Delta$ turbidity (US EPA 2009)
- Aluminum sulfate is the primary coagulant used to treat turbidity
- $Al = 33 \log(T) - 28$ (US EPA 2009)
  - $Al =$ aluminum dose (mg/L)
  - $T =$ turbidity (NTU)

$$TC_{Al} = \sum_{t=1}^{\text{ndays}} (Q_{SwWtp,t} + Q_{ResWtp,t}) \times \left(\frac{Al \times (3.79 \times 10^6)}{9.07 \times 10^8}\right) \times C_{Al}$$

- $TC_{Al} =$ total alum cost
- $Q_{SwWtp,t} =$ daily flow from surface water system to water treatment plant (MG/day)
- $Q_{ResWtp,t} =$ daily flow from reservoir to treatment plant (MG/day)
Non-WQ Cobenefits

Property values

• $\Delta$ housing prices resulting from increased green space (both natural and constructed green infrastructure) per HUC12 or HUC10 using coefficients from meta-regression of results in existing hedonic literature (Mazzotta et al. 2014)

• % change in annual rental value of property depends on
  – % percentage change in green space
  – distance of green space from residences
  – characteristics of the changed green space
  – population density

• Supported by nationwide database of residential buildings within 250 and 500 meters of riparian zone at HUC12 scale
# Non-WQ Cobenefits Related to canopy cover

<table>
<thead>
<tr>
<th>Environmental Outcome</th>
<th>Benefit</th>
<th>Source(s)</th>
<th>Region Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avoided human health damages resulting from tree removal of air pollutants (NO₂, SO₂, O₃, PM₂.₅)</td>
<td>Nowak et al. (2014)</td>
<td>National (regressions); county-level (population density)</td>
</tr>
<tr>
<td>Increased acres of urban/community trees</td>
<td>Electricity savings</td>
<td>Nowak et al. (2017); personal communication with authors</td>
<td>State-level</td>
</tr>
</tbody>
</table>
## Non-WQ Cobenefits Related to green roofs

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Source(s)</th>
<th>Region Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity savings</td>
<td>State-level: U.S. EIA (2018)</td>
<td>State-level (you can provide local values)</td>
</tr>
<tr>
<td>Avoided human health damages from avoided NO\textsubscript{x}, SO\textsubscript{2}, and PM\textsubscript{2.5} emissions from power plants</td>
<td>Quantification: U.S. EPA (2019b) Monetization: U.S. EPA (2018)</td>
<td>Quantification: Regional (AVERT regions) Monetization: National</td>
</tr>
</tbody>
</table>
Benefits Module Interface

- Embedded in WMOST Scenario Comparison Tool
- Allows import of multiple WMOST run result files (TN, TP, TSS)
- Incorporates required look-up tables
# Benefits Module Interface

## Benefit Calculations

ScenCompare will calculate benefits related to outcomes targeted by a management practice (direct benefits) and benefits that arise from other outcomes of implementing the management practice selected to meet the target (co-benefits).

### 1. Study Characteristics

**Specify the year in which you'd like to evaluate benefits.**

| Year | 2019 |

### 1A. Calculate Social Cost of Carbon

If calculating management option co-benefits (see Section 3), choose if you would like to calculate co-benefits using the global or domestic social cost of carbon.

| Social Cost of Carbon | $46.56/metric ton | $56.76/metric ton |

### 1B. Benefits Module Interface

The Benefits Module uses several databases to calculate management option direct benefits and co-benefits. The databases are based on USGS' fourth level of hydrologic unit classification (HUC12).

- The Module requires land use-specific information about the land uses found within your watershed.
- Select a model below that represents your watershed using the drop-down list.
- Press the button below to populate the table with the HRIU names from your watershed.

<table>
<thead>
<tr>
<th>Model Run</th>
<th>Scenario TSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS</td>
<td>TSS</td>
</tr>
</tbody>
</table>

### 2. Calculation of Direct Benefits

Once input values have been entered below, use this button to calculate the value of direct benefits.

**Calculate Direct Benefits**

### 2A. Choose the appropriate baseline and managed model runs below.

<table>
<thead>
<tr>
<th>Model Run</th>
<th>Model Run Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>Initial conditions with the default settings</td>
</tr>
<tr>
<td>TSS/WT</td>
<td>Treatment of TSS/WT</td>
</tr>
<tr>
<td>Managed</td>
<td>Managed model run with specific interventions</td>
</tr>
</tbody>
</table>

**Change in water treatment costs**

| Estimated ratio of turbidity to TSS | 1.5 by default |
| Cost of alum | $300.00/tank/yard |

**Total nonmarket benefits of water quality changes**

Indicate below if your case study falls into any of the three defined U.S. regions. If your case study does not fall into any of the three, leave all values as zero.

<table>
<thead>
<tr>
<th>Region</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast</td>
<td>0</td>
</tr>
<tr>
<td>Central</td>
<td>0</td>
</tr>
<tr>
<td>South</td>
<td>0</td>
</tr>
</tbody>
</table>

**Annual willingness-to-pay for water quality changes**

$1,024,288.74
Key references

More info

- Naomi Detenbeck (detenbeck.naomi@epa.gov)
- WMOST (www.epa.gov/ceam/wmost)
- Benefits module (in review)
  - Will be added to WMOST web site
  - Tool
  - Tool with example data set
  - User guide
  - Theoretical documentation (includes stand-alone spreadsheet illustrating underlying calculations)