



Optimization Tool Development

February 26, 2018

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Description: The project goal is to facilitate cost-effective reductions of nutrient loads entering the Chesapeake Bay from the watershed by developing an optimization module for the Chesapeake Assessment Scenario Tool (CAST).

Status (Phase 1): developing an optimization plan

Overview

Motivation:

Of all possible types and combinations of feasible Best Management Practices (BMPs), which mix(es) of BMPs will allow us to meet the target loads at the lowest total cost?

Tools:

- Chesapeake Assessment Scenario Tool (CAST)
- Scenario Optimization Module

Outline



- **CAST and optimization**
- **The vision: a “scenario optimization module”**
- **What is the current phase of development?**
- **How will a prototype tool utilize info from CAST?**
- **Next steps and moving forward**

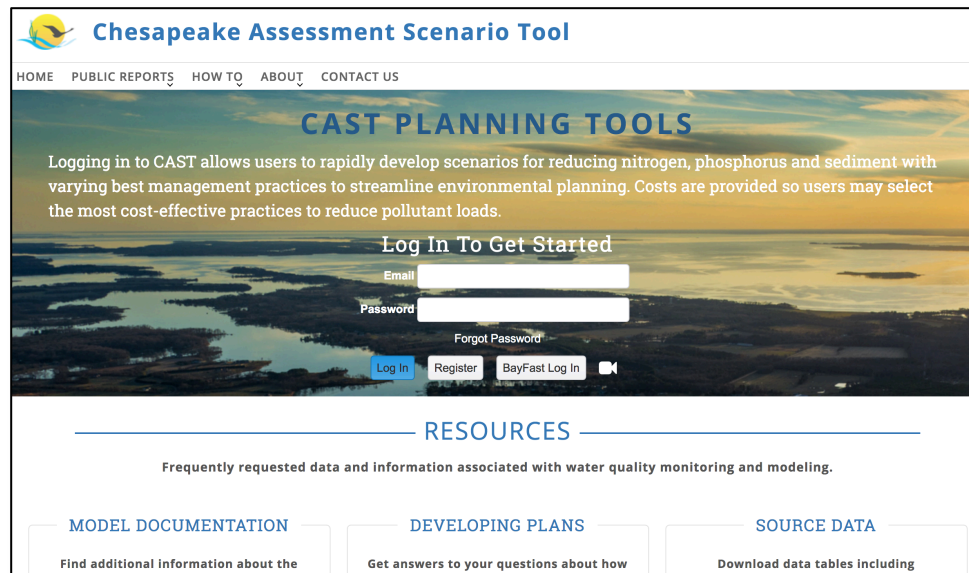
Chesapeake Assessment Scenario Tool (CAST)

A “web-based nitrogen, phosphorus and sediment load estimator”

Originally developed in 2011, but has undergone substantial changes over the years

Users specify:

- **A geographical area (e.g. a county)**
(& other restrictions, such as “agencies”)
- **Best Management Practices (BMPs) to apply on that area**



The screenshot shows the homepage of the Chesapeake Assessment Scenario Tool (CAST). At the top, there is a navigation bar with links: HOME, PUBLIC REPORTS, HOW TO, ABOUT, and CONTACT US. Below this is a large banner image of a coastal landscape with water and trees. The banner contains the text "CAST PLANNING TOOLS" and a description: "Logging in to CAST allows users to rapidly develop scenarios for reducing nitrogen, phosphorus and sediment with varying best management practices to streamline environmental planning. Costs are provided so users may select the most cost-effective practices to reduce pollutant loads." Below the banner is a login section titled "Log In To Get Started" with fields for "Email" and "Password", a "Forgot Password" link, and buttons for "Log In", "Register", and "BayFast Log In". At the bottom, there is a "RESOURCES" section with the text "Frequently requested data and information associated with water quality monitoring and modeling." and three links: "MODEL DOCUMENTATION" (Find additional information about the), "DEVELOPING PLANS" (Get answers to your questions about how), and "SOURCE DATA" (Download data tables including).

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CAST provides:

- **Estimates of nitrogen, phosphorus, and sediment load reductions (e.g. by sector, load source, delivery edge)**
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Load Sources
Cost profiles

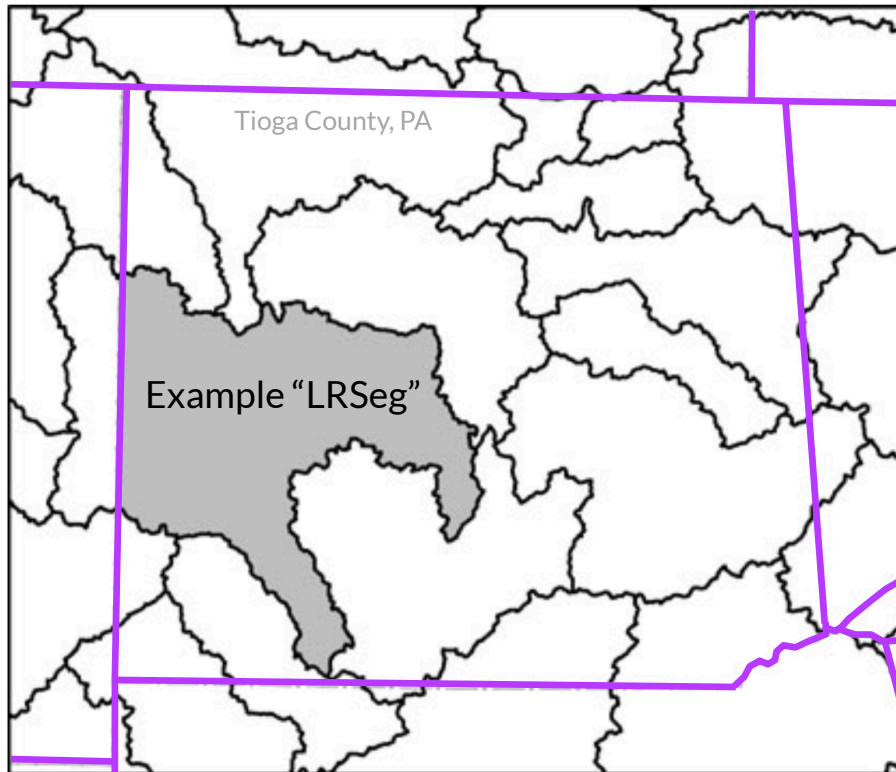
BMP effects on
• loads • other BMPs

CAST provides:

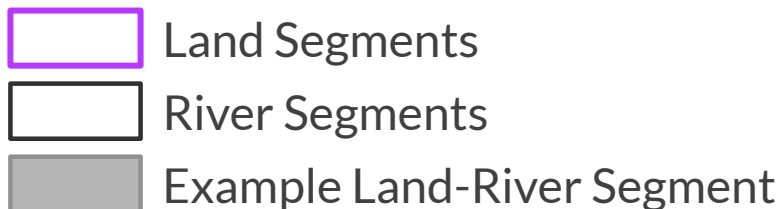
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Best Management Practices (BMPs) in CAST

BMPs are applied at the scale of a land-river segment

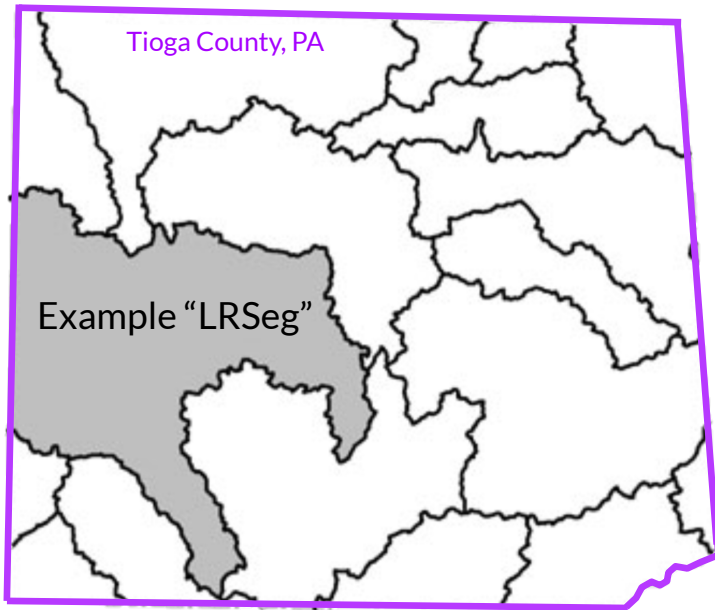


Land-River segments are the intersection of River segments with Land segments (and are contained within counties)



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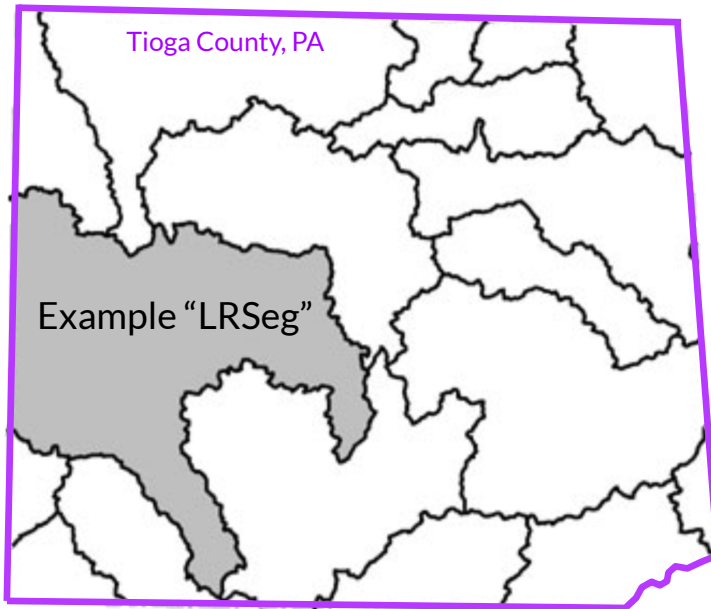


 Example Land-River Segment

- Land-River segments are the intersection of River segments with Land segments (and are contained within counties)
- Acres of a county-applied BMP are distributed among the Land-River segments
- 2,057 total modeled land-river segments
 - 1,933 are inside the Bay watershed
 - 124 are outside (can still affect credited BMPs when distributed throughout a county)

Best Management Practices (BMPs) in CAST

There are different BMP candidate spaces within a county



 Example Land-River Segment

Within the entire county:

- Number of animals for each animal type
- Tons of manure produced by each animal type

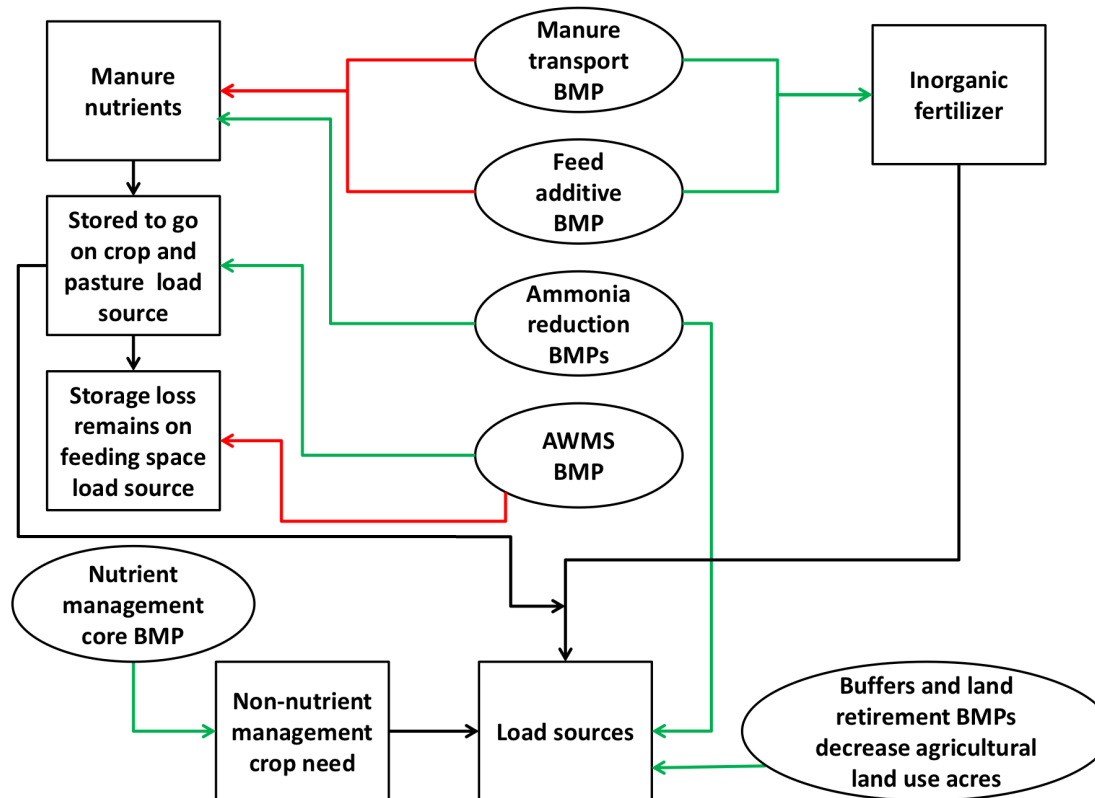
Within each LRseg:

- Acres of land (partitioned among 12 agencies)
- Miles of roads
- Miles of stream/shoreline
- Number of septic systems

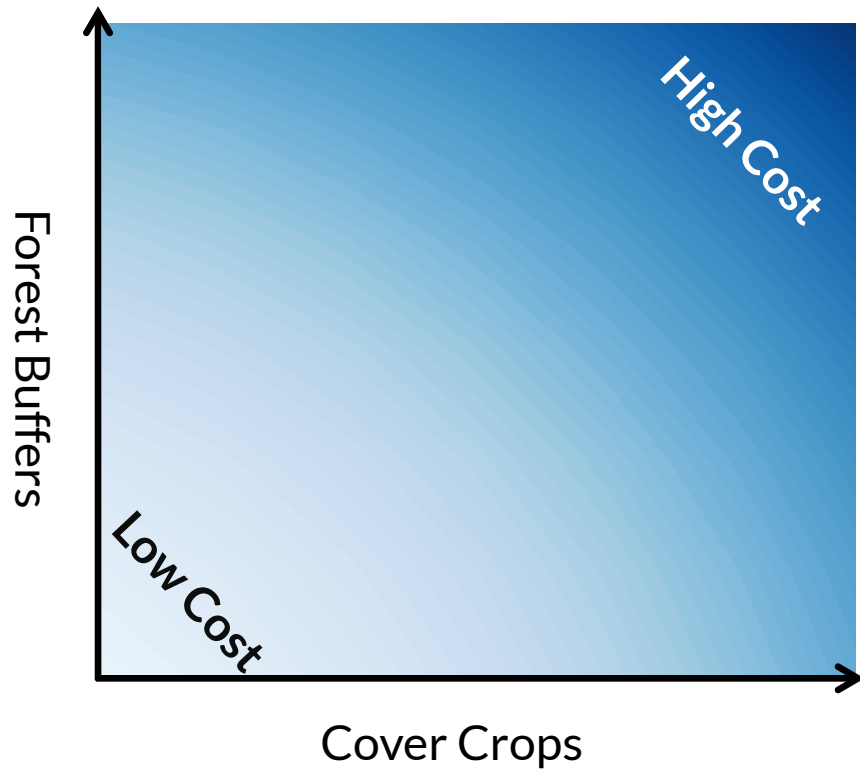
Best Management Practices (BMPs) in CAST

There are a variety of BMP constraints and interactions

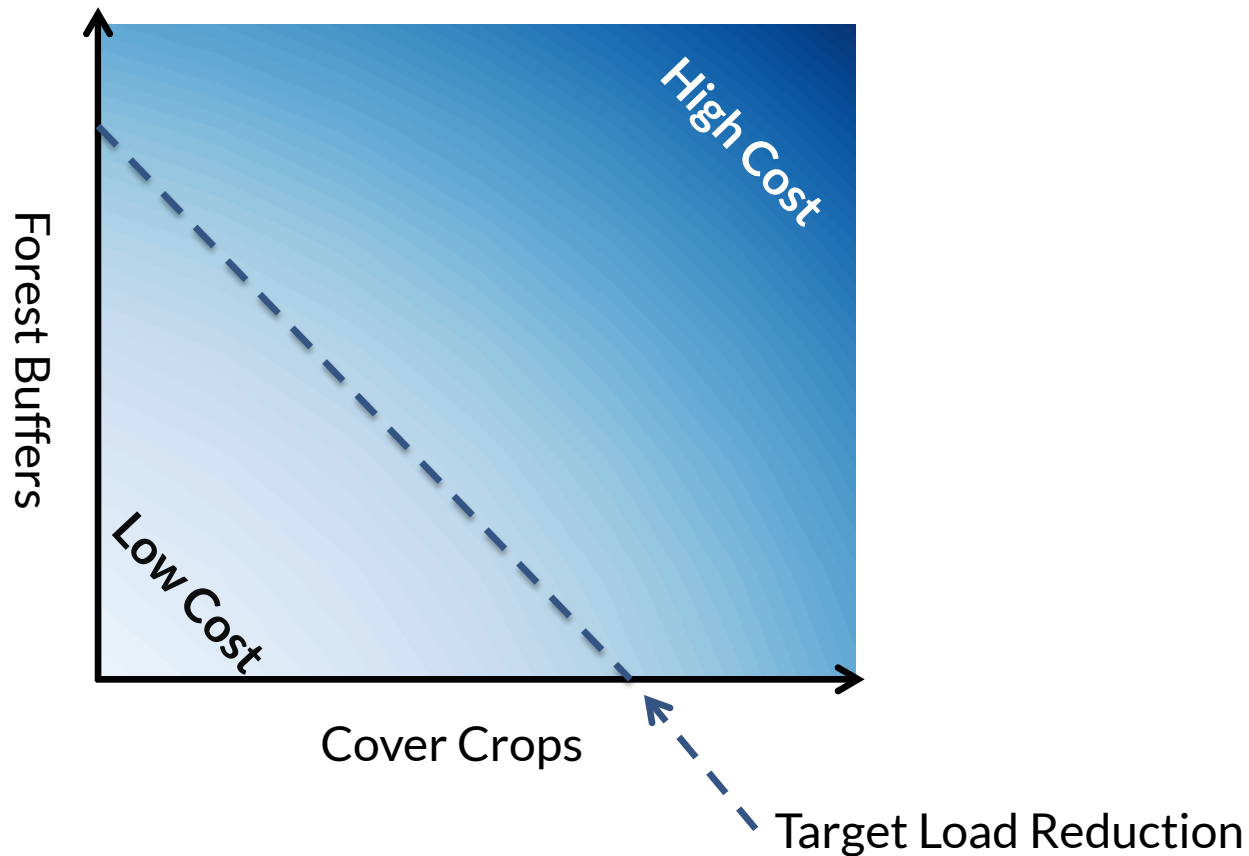
- Load source changes
- Mutually exclusive BMP spaces
- Transfer of manure tons between counties



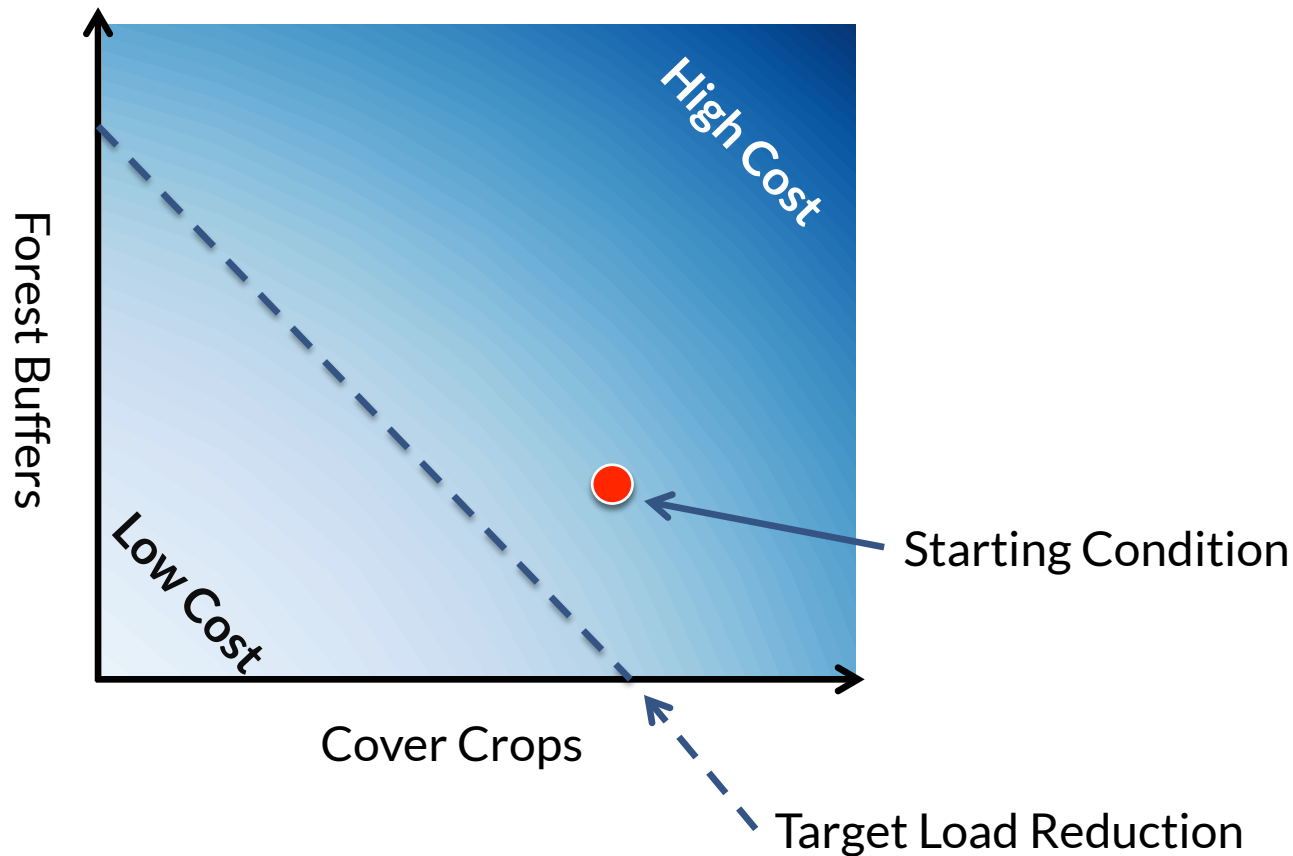
What is meant by optimization?



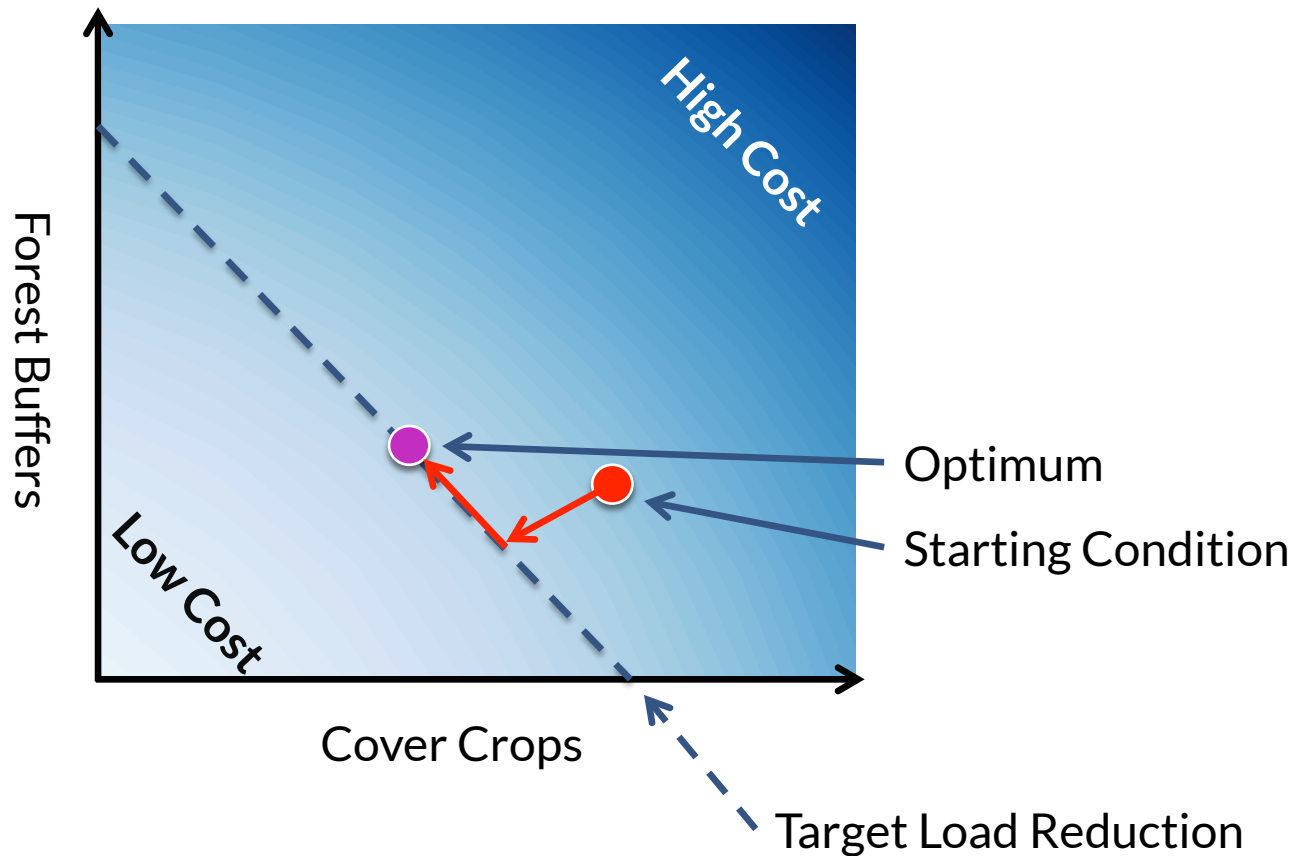
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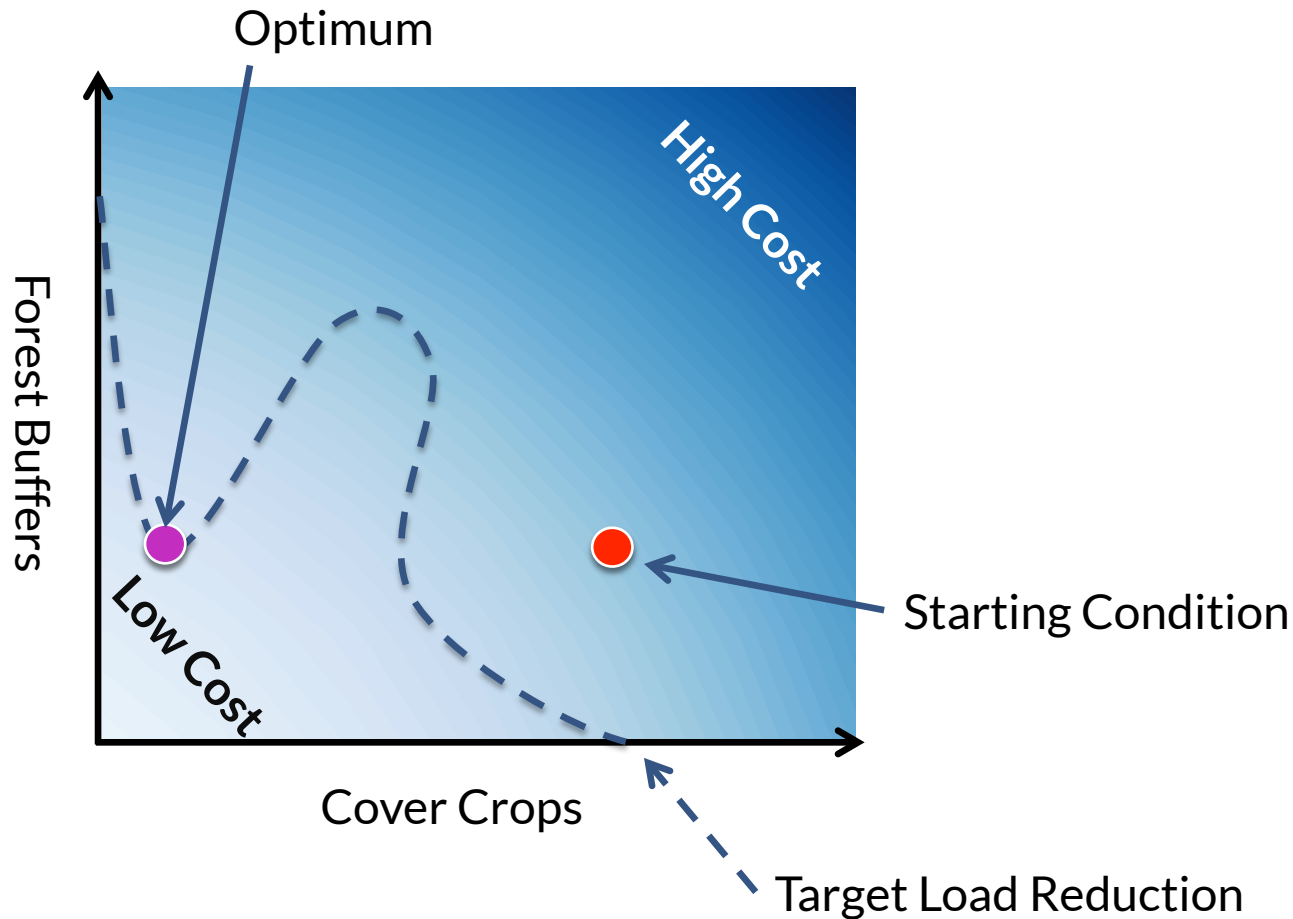
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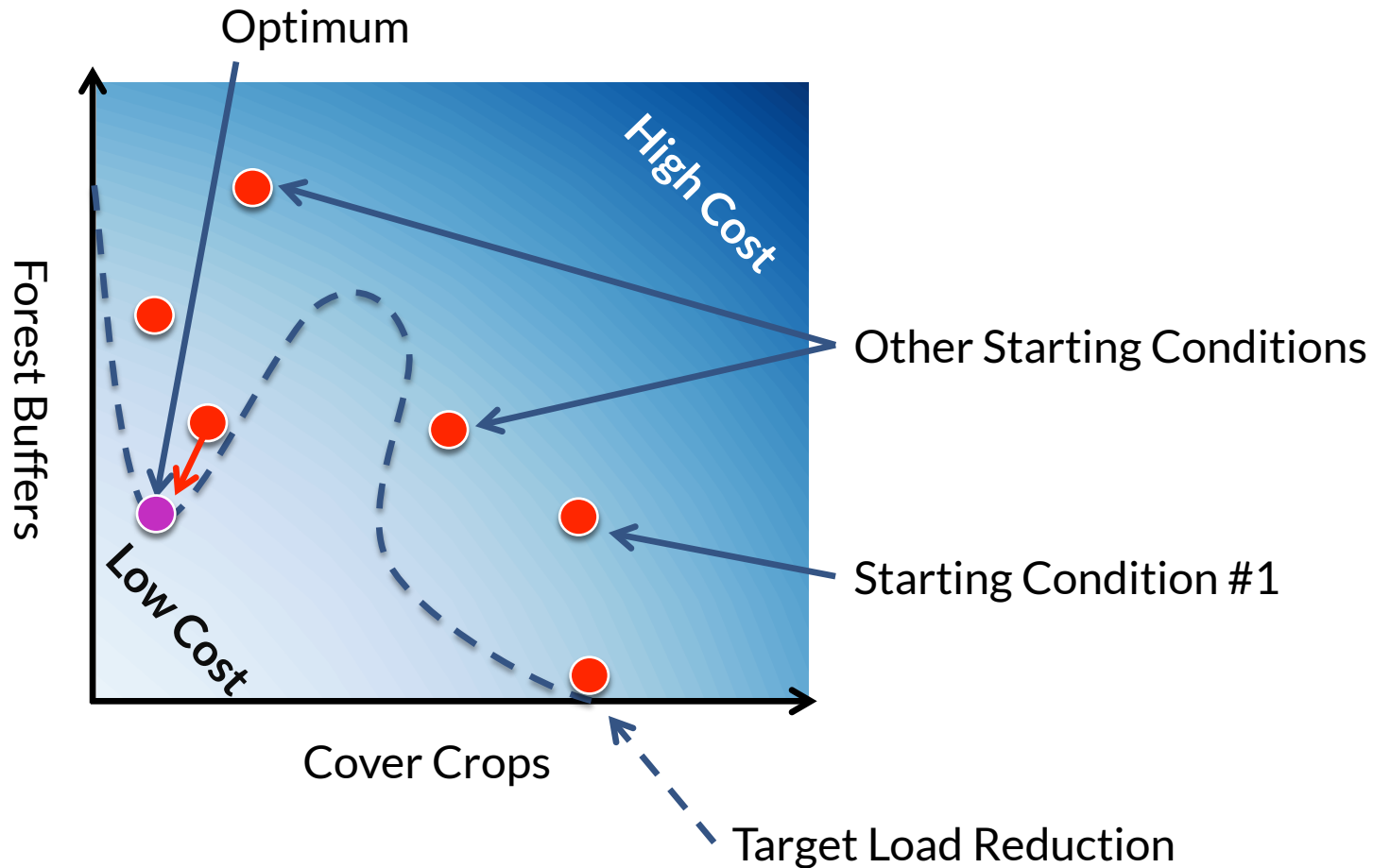
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“all possible types and combinations of feasible BMPs” – Provided by CAST tables

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“mix(es) of BMPs” – Generated by optimization algorithm and user constraints

How does Scenario Optimization fit with CAST?



Of **all possible types and combinations of feasible BMPs**, which **mix(es) of BMPs** will allow us to meet the **target loads** at the lowest total cost?



“**target loads**” – Specified by user/ CBP partnership decisions

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“mix(es) of BMPs” – Generated by optimization algorithm and user constraints

“target loads” – Specified by user/ CBP partnership decisions

“total cost” – Costs are calculated by CAST

Current Phase

Investigate and Develop an Optimization Plan

Learn about CAST (uses, algorithms, and data/input/output structures)

Consider:

- objectives and designs for a Phase 2 prototype
- suitable algorithms (or combinations)

Identify model simplifications (reduced parameter sets)

Design an efficient interface between CAST and the proposed optimization software

Optimization Description



Objective:

(Primary) Minimize the total annual costs of BMP implementation (includes capital, installation, opportunity, maintenance)

(Secondary) Maximize co-benefits

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- Number of acres (or other unit) of each BMP in each land-use category and land river segment (continuous)
- Treatment technology upgrades at each significant point source facility (discrete)

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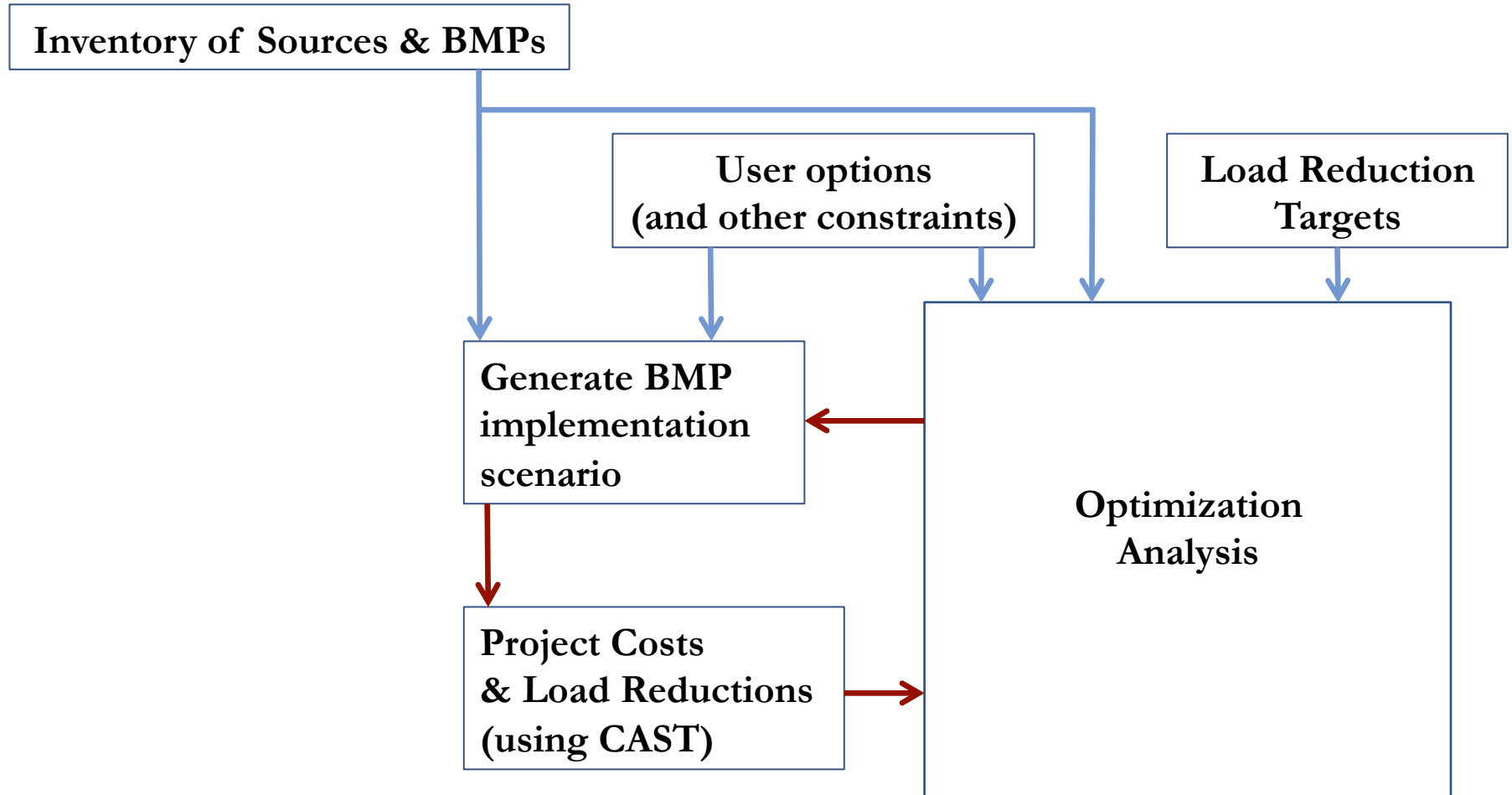
Basic Constraints:

- Scale/region of scenario (and/or agencies)
- Nitrogen and Phosphorous delivered load reductions \geq load targets
- BMP'd acres \leq available acres (by segment and land-use)
 - BMP'd roads \leq available miles
 - BMP'd shorelines \leq available miles
 - BMP'd animals \leq available animal counts

Other Constraints:

- BMP constraints, for example:
 - agricultural land retirement \leq X acres
 - cover crop oats \geq X % of agricultural acres
- Land use restrictions for certain BMPs
- Capital limitations for certain sectors?

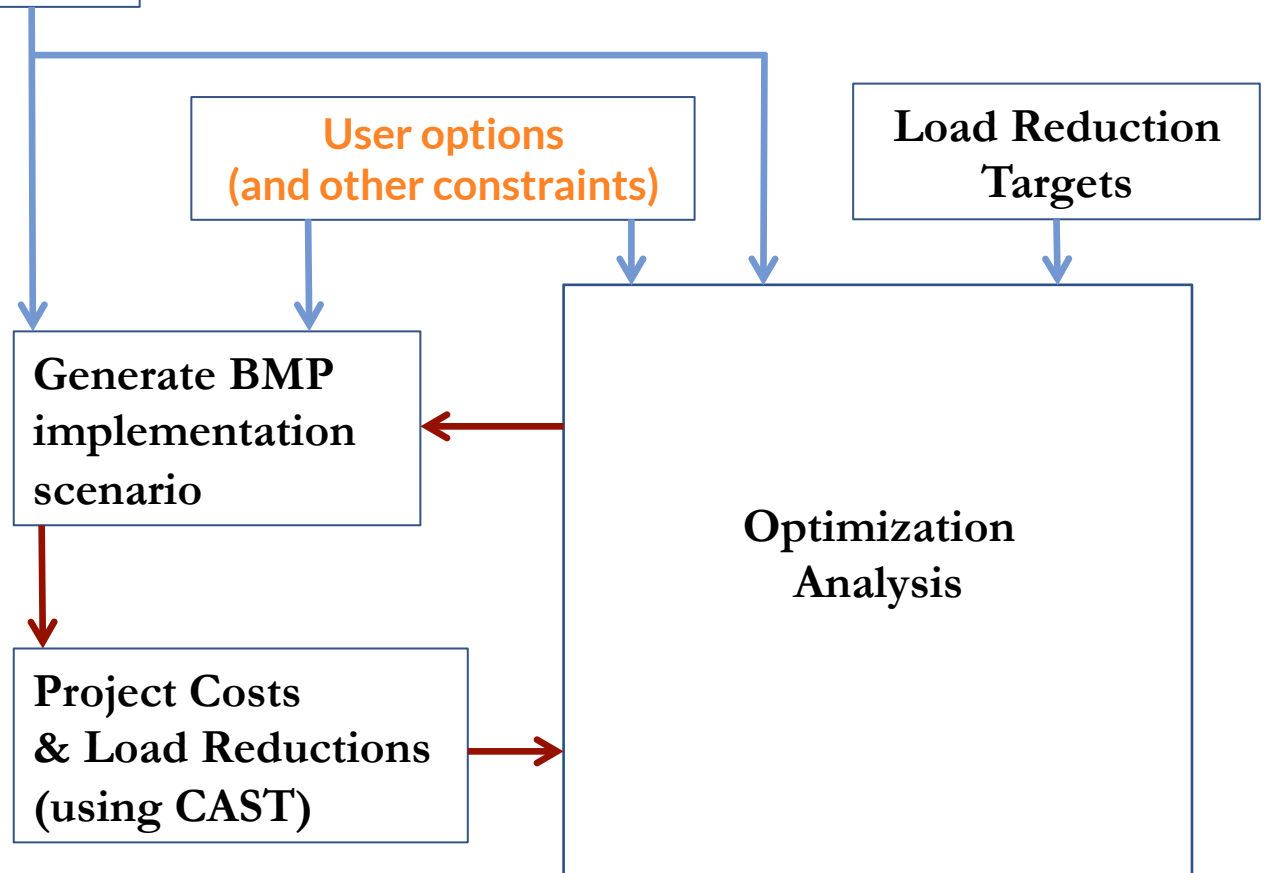
Optimization Tool Sandbox



Optimization Tool Sandbox

Inventory of Sources & BMPs

- Land-river segments and load sources included in the scenario
- Pre-BMP acres eligible for BMP application on each segment-source
- BMPs feasible for each segment-source



A complete set of possibilities is generated

Inventory of Sources & BMPs

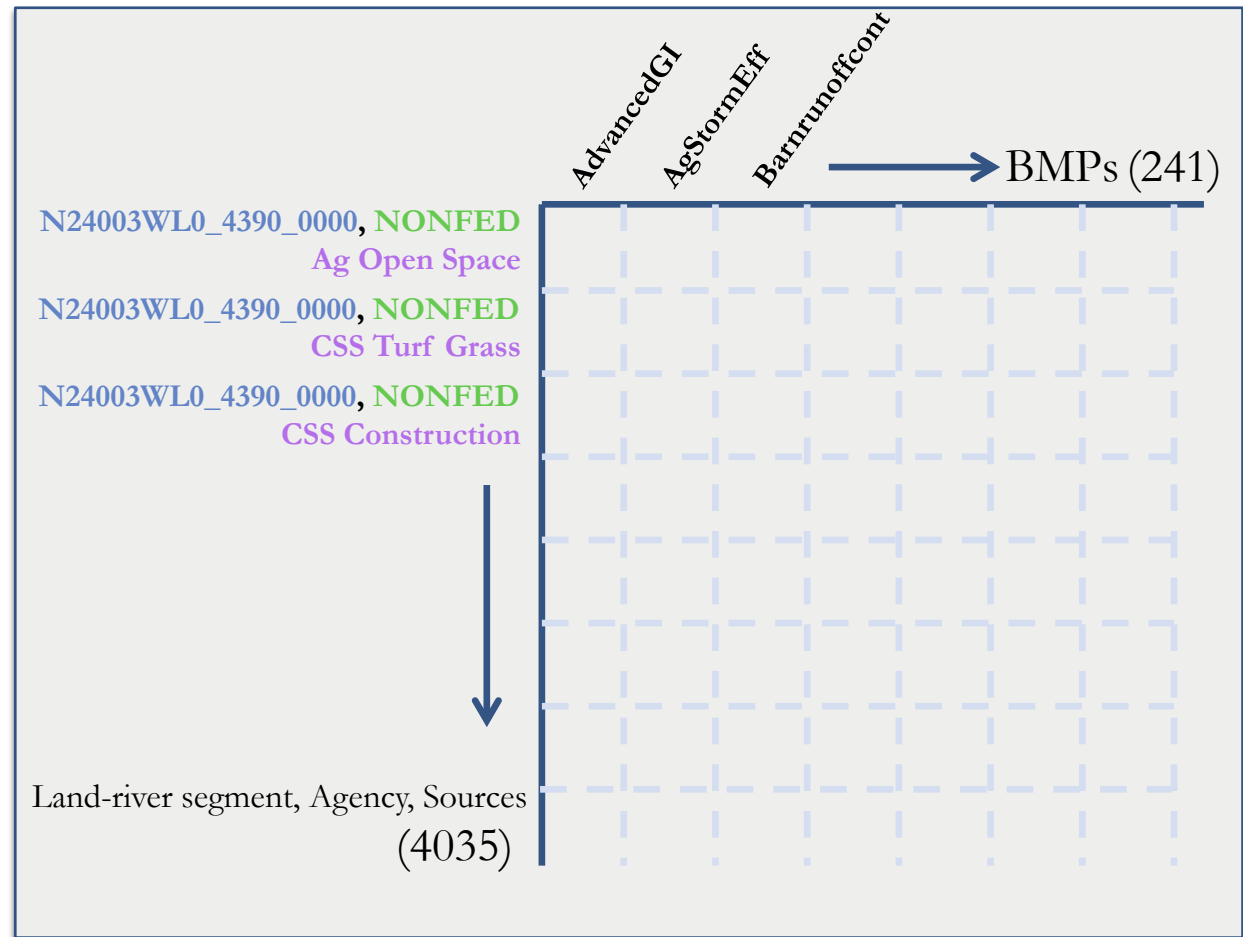
User options
(and other
constraints)

Generate BMP
implementation
scenario

- Land-river segments and load sources included in the scenario
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- BMPs feasible for each segment-source

Include:

- All land river segments, sources for geography
- All BMPs



Allowable Source-BMP pairs are identified

Inventory of Sources & BMPs

User options
(and other
constraints)

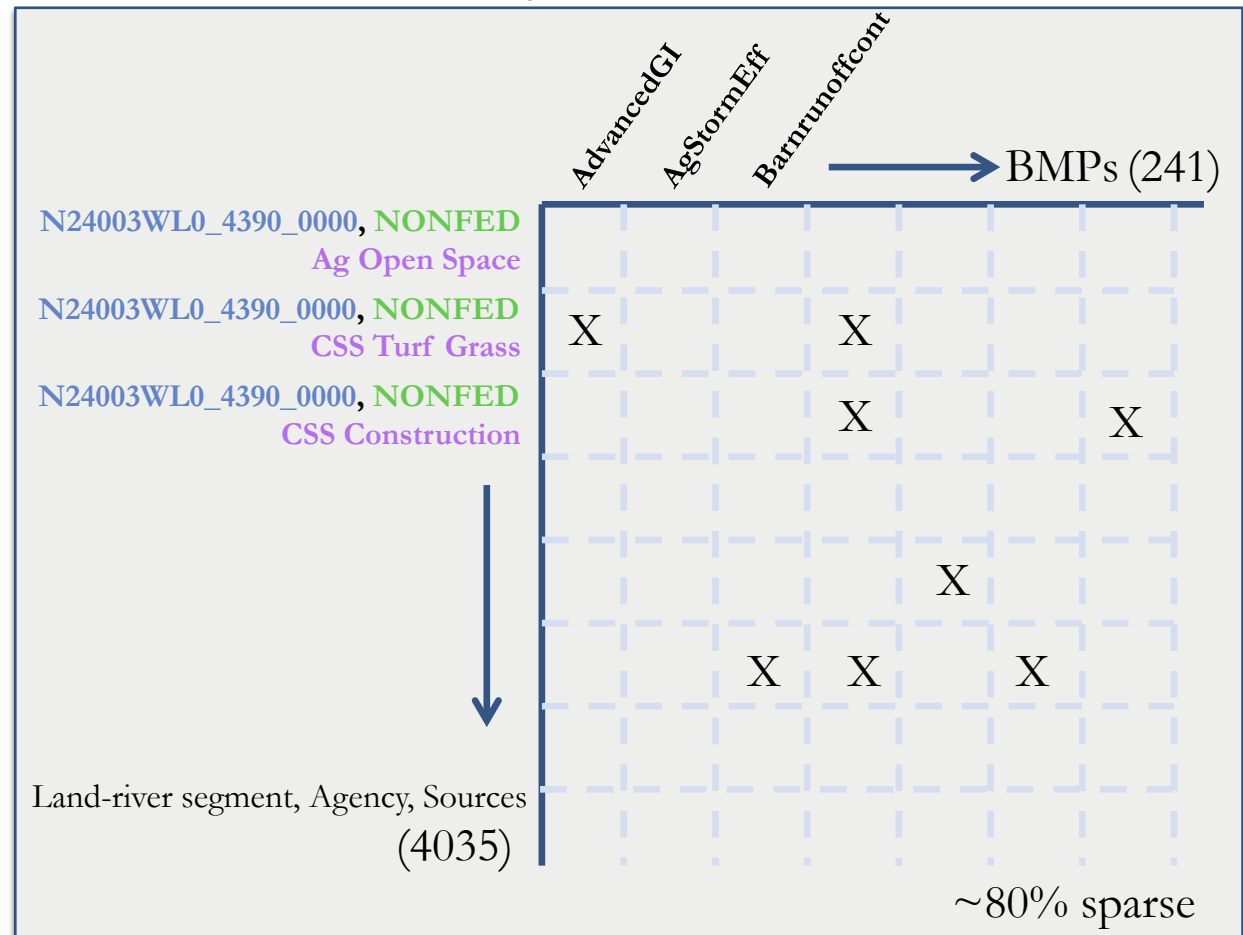
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Maximum number of knobs to turn:

~ 200,000 - Anne Arundel County

~ 2 million - Maryland



Values for each allowable Source-BMP pair

Inventory of Sources & BMPs

User options
(and other
constraints)

Generate BMP
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Basic constraints determine value bounds, e.g.

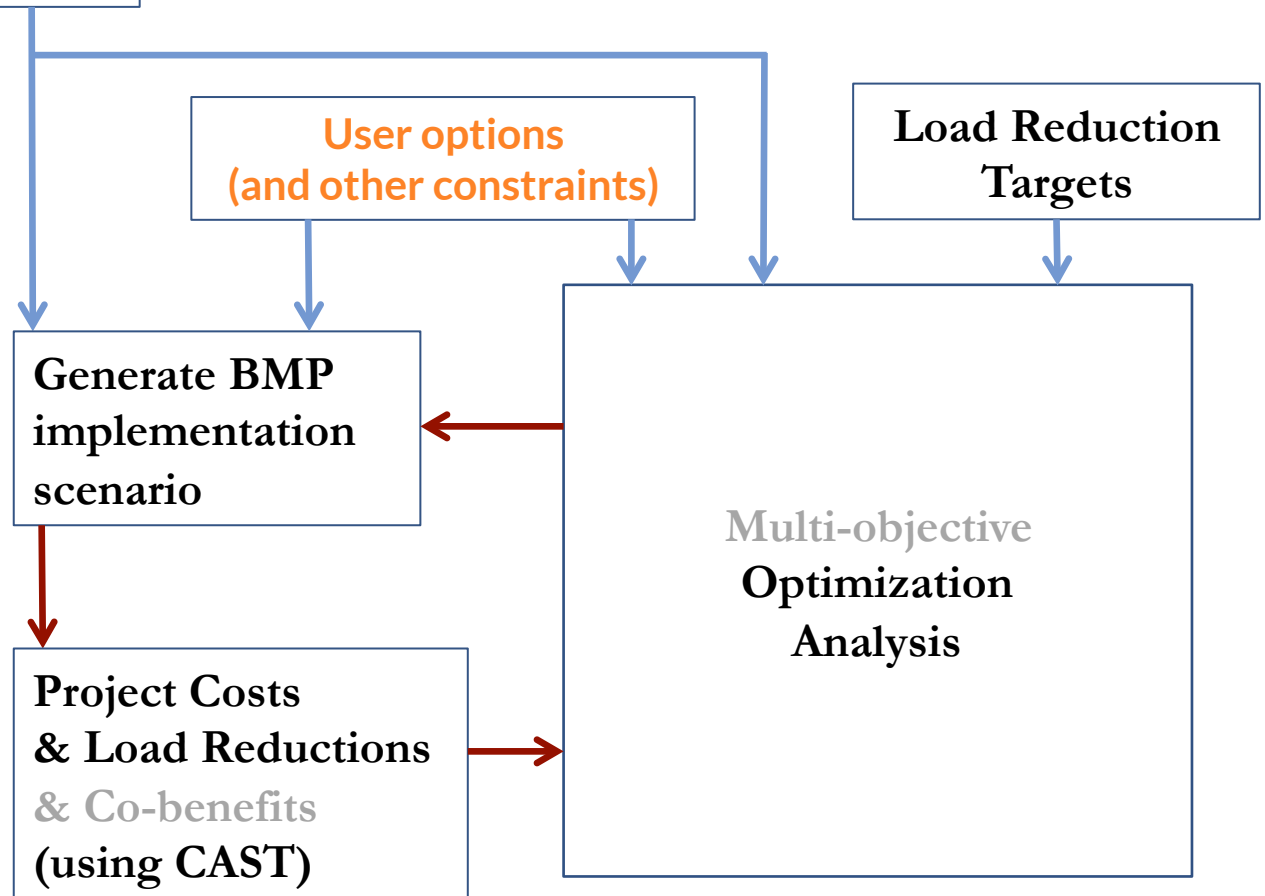
- Pre-BMP acres
- Miles of available roads

	AdvancedGI	AgStormEff	Barrunoffcont	BMPs (241)
N24003WL0_4390_0000, NONFED Ag Open Space				
N24003WL0_4390_0000, NONFED CSS Turf Grass	9		87	
N24003WL0_4390_0000, NONFED CSS Construction			0	2.3
			31	
		20	57	44
Land-river segment, Agency, Sources (4035)				

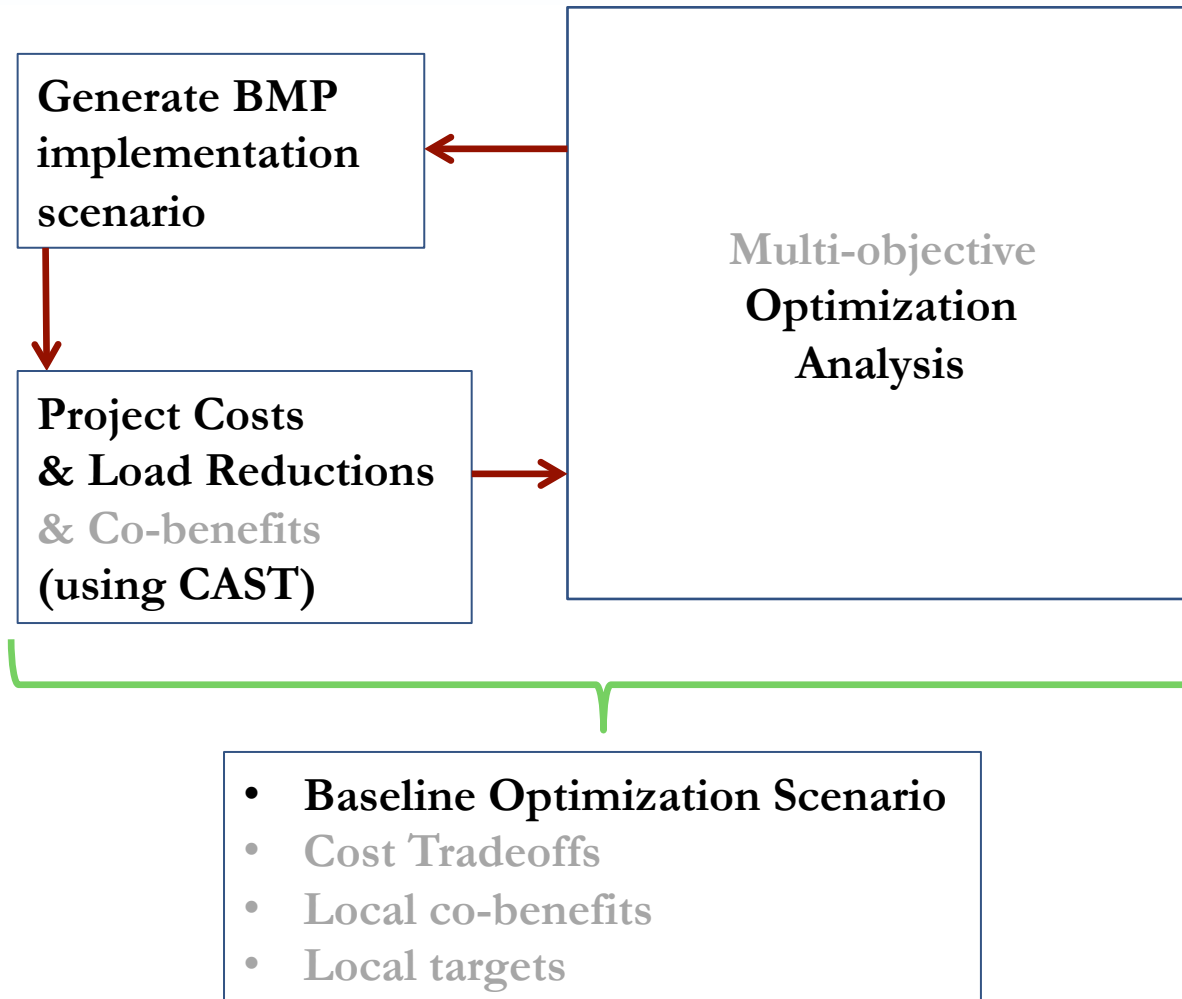
Optimization Tool Sandbox

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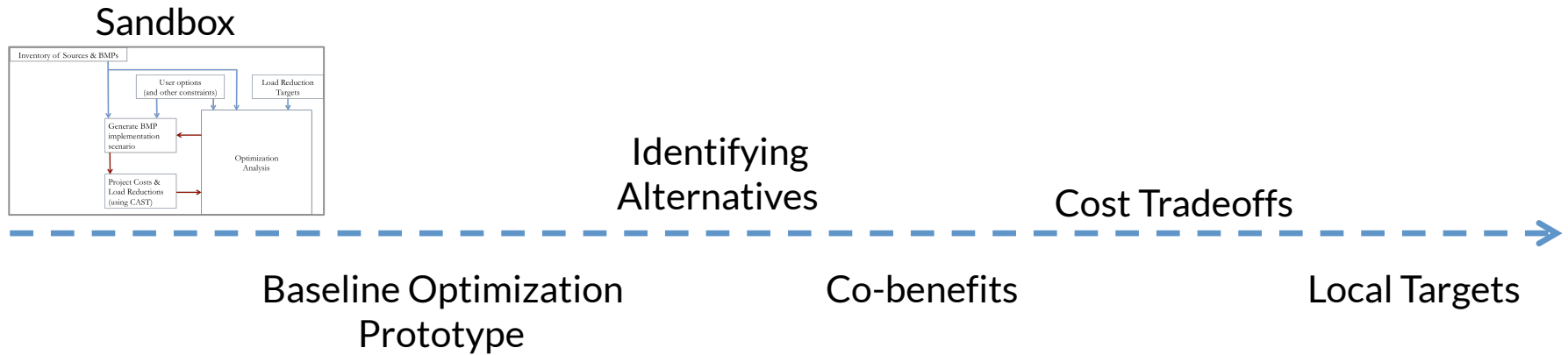
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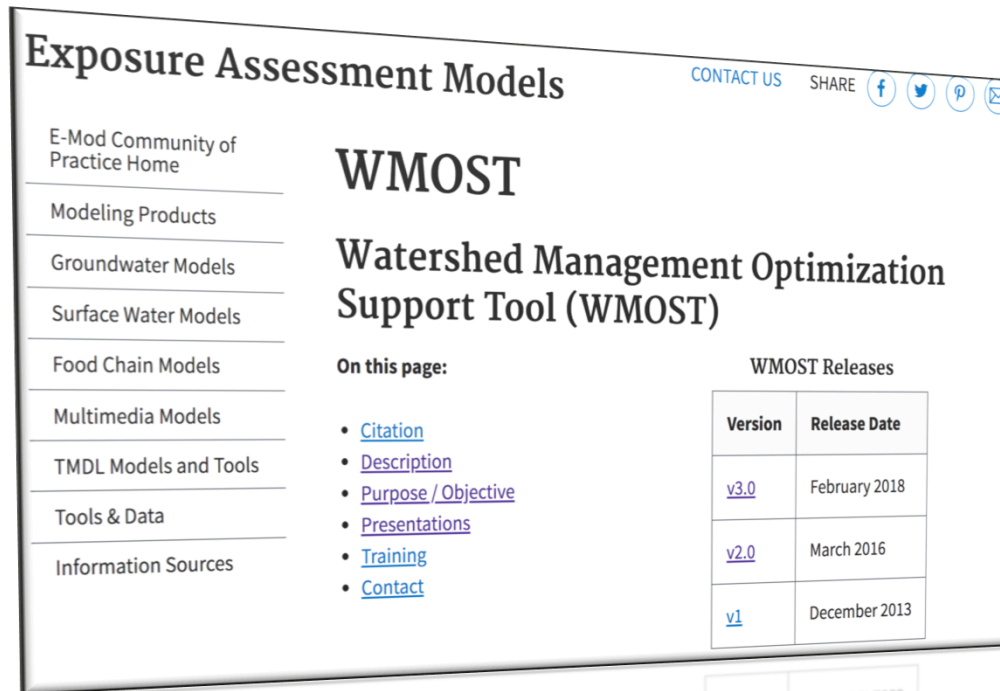


Looking Forward



Exploring potential synergies

Watershed Management Optimization Support Tool (WMOST)



The screenshot shows a web page titled "Exposure Assessment Models" with a navigation menu on the left. The main content area features the title "WMOST" and "Watershed Management Optimization Support Tool (WMOST)". Below this, there is a list of links under "On this page:" and a table of "WMOST Releases".

Exposure Assessment Models

E-Mod Community of Practice Home

Modeling Products

Groundwater Models

Surface Water Models

Food Chain Models

Multimedia Models

TMDL Models and Tools

Tools & Data

Information Sources

WMOST

Watershed Management Optimization Support Tool (WMOST)

On this page:

- [Citation](#)
- [Description](#)
- [Purpose / Objective](#)
- [Presentations](#)
- [Training](#)
- [Contact](#)

WMOST Releases

Version	Release Date
v3.0	February 2018
v2.0	March 2016
v1	December 2013

Developed and maintained by team at the EPA Office of Research and Development

Collaborating with:

- Naomi Detenbeck
- Amy Piscopo

Next Steps



Phase 1: Investigate and Develop an Optimization Plan

Continue developing a prototype in python

Continue learning about CAST (uses, algorithms, and data/input/output structures)

Refine optimization objectives, constraints, user needs

Continue considering suitable algorithms and tool designs for Phase 2 prototype

User Interface

What does a user want to be able to do/see?

Select geographic region of interest and land use types

- Geographic region by State, County, In/Out of CBWS, Land-river segment
- Land Use types by agency, sector, and base conditions

Select BMP constraints

- ideas: exclude certain BMPs, max/min acreage of certain BMPs,

See and compare objective attributes of nondominated solutions

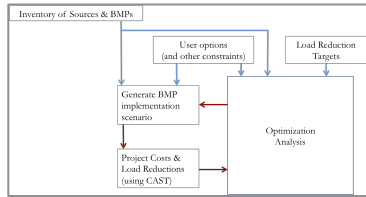
- load reductions
- cost
- co-benefits

See the set of BMP assignments for each solution

- by land use, segment, state, sector
- in categories or individually, and in acreage or percent

Looking Forward

Sandbox



Identifying
Alternatives

Cost Tradeoffs

Baseline Optimization
Prototype

Co-benefits

Local Targets

What does a user want to be able to do/see...

- Select** geographic region of interest and land use types
- Select** BMP constraints
- See** and compare objective attributes of nondominated solutions
- See** the set of BMP assignments for each solution

Questions

- Other constraints?
- Other objectives?
- Departures from existing scenarios, with given costs
- Computational resources/speed