Optimization Tool Development

February 1, 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

Outline

- **The vision: a “scenario optimization tool” for the Chesapeake Assessment Scenario Tool (CAST)**
- **What is the current phase of development?**
- **How will a prototype tool utilize information from CAST?**
- **Next steps and moving forward**

CBP Optimization Overview

Motivation:

How can we facilitate the development of cost-effective plans for achieving target nutrient loads, which enter the Chesapeake Bay from the watershed?

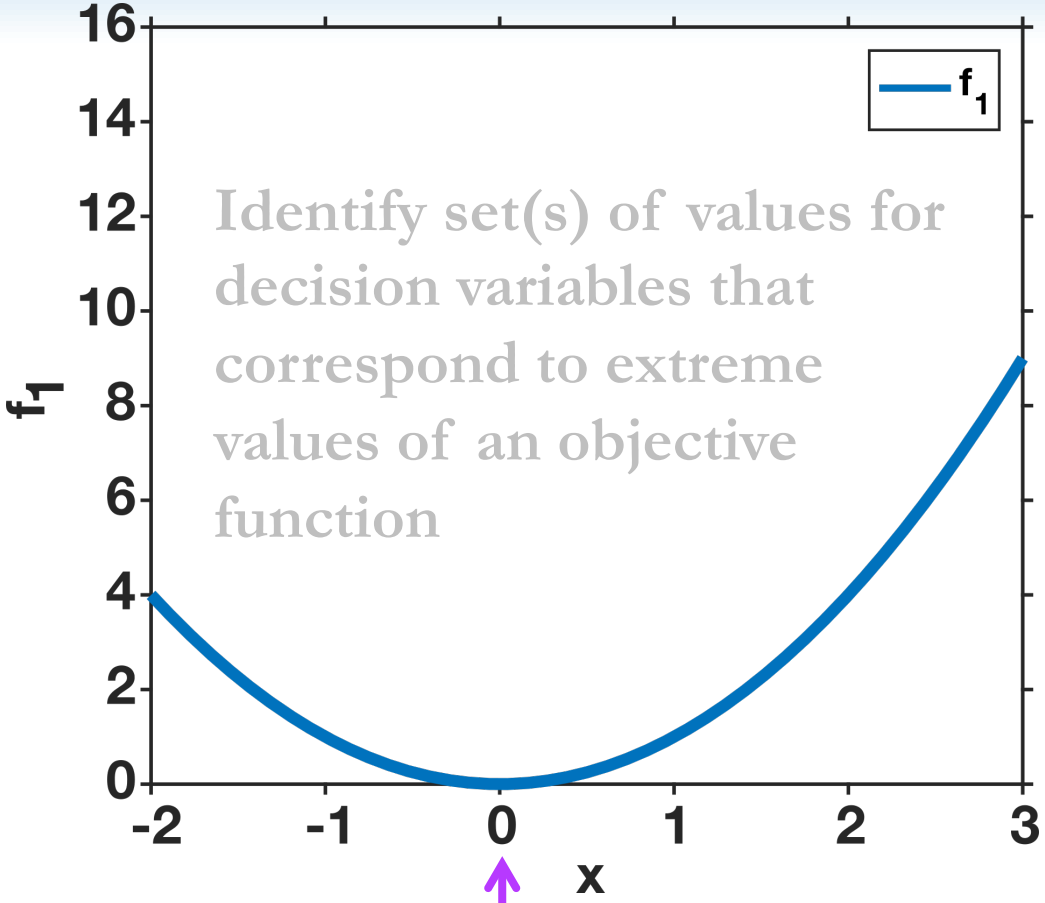
Tools:

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

Optimization Goal

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

What is meant by "Optimization"?



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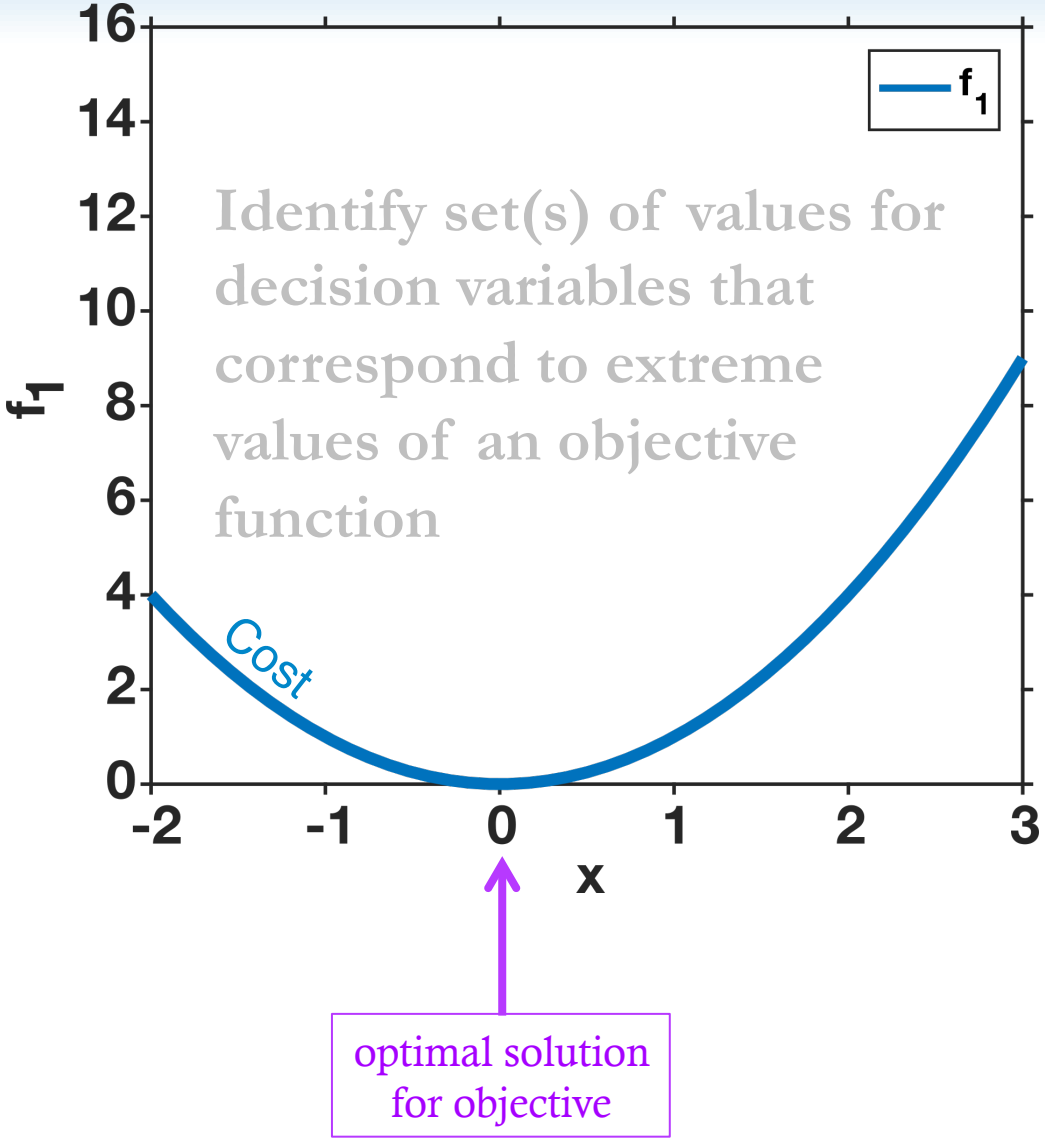

- "Extreme value" that is desired for CAST scenarios is a minimum cost

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?

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

"target loads" – Specified by user/ CBP partnership decisions

"lowest total cost" – Costs are calculated by CAST

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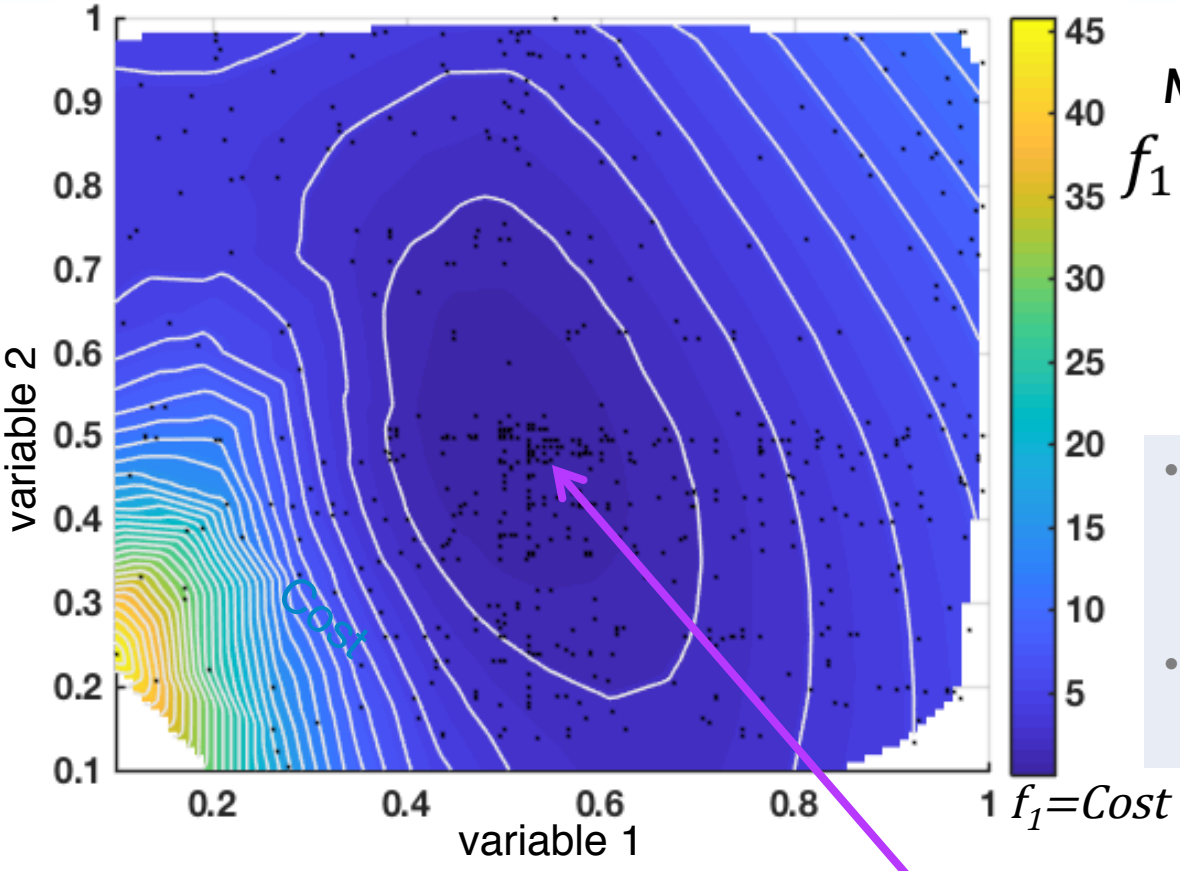


Objective:

Minimize

$$f_1 = CAST_{cost}(x_1, x_2 \ldots x_n)$$

- Each variable represents the amount for a (Geo, Agency, Load Source, BMP) coordinate
- Various algorithms can be used to identify optimal solutions

Current Phase

Investigate and Develop an Optimization Plan

- Learn about the CBWSM/CAST, their uses, algorithms, and data structure of inputs and outputs;
- Consider appropriate programming objectives and designs for a Phase 2 prototype
- Look for model simplifications (reduced parameter sets) and design an efficient interface between CAST and the proposed optimization software;
- Considering potentially suitable optimization algorithms or combinations of algorithms

Optimization Description

Objective:

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

(Secondary) Maximize co-benefits

Decision Variables

- 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)

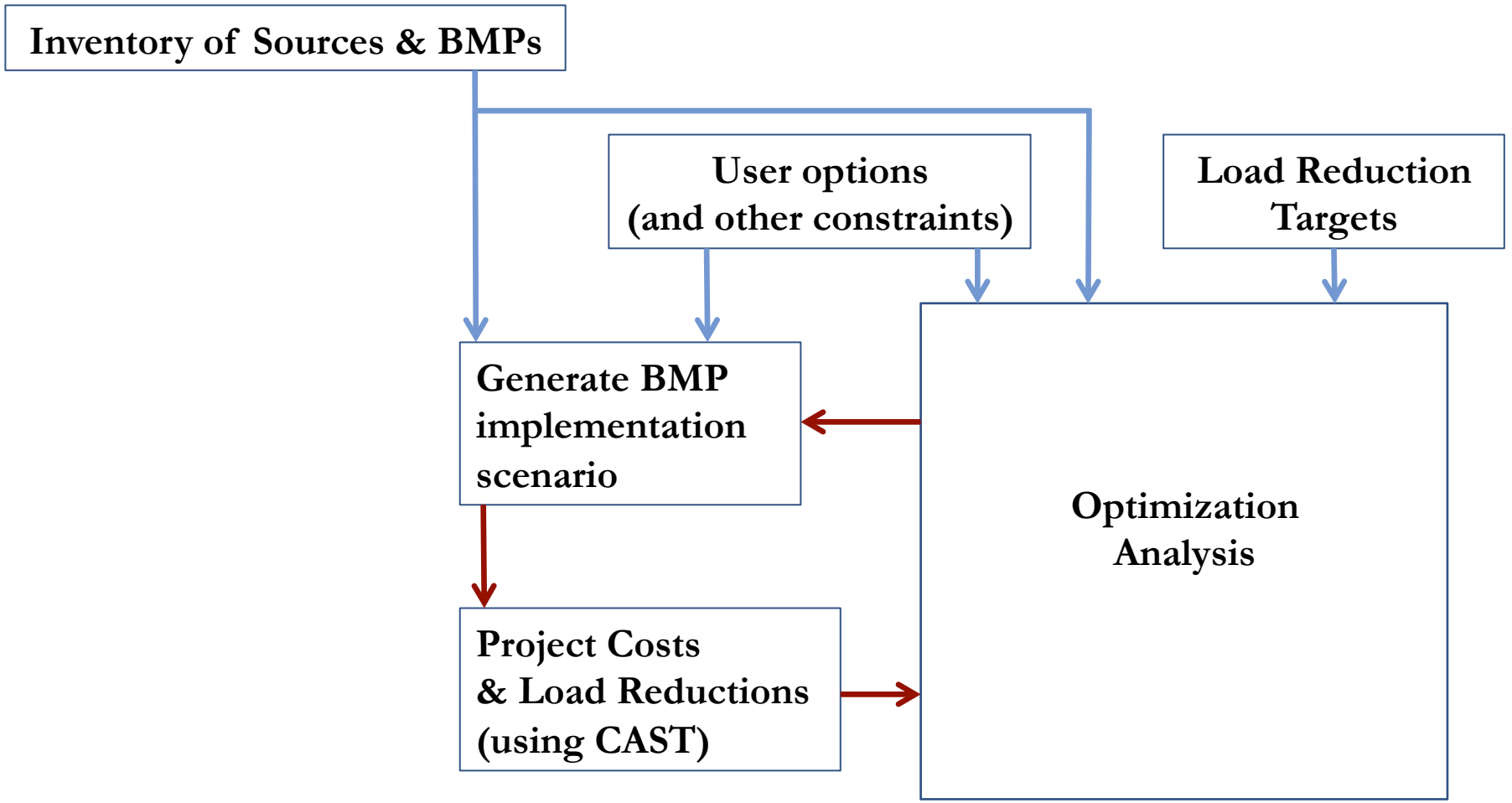
Basic Constraints:

- Scale/region of scenario (and/or agencies)
- N and P delivered load reductions ≥ TMDL targets
- BMP'd acres ≤ available acres (by lrseg and land-use [Pre-BMP and Post-BMP])
  - BMP'd roads ≤ available miles
  - BMP'd shorelines ≤ available miles
  - BMP'd animals ≤ available animal counts

Other Constraints:

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

Optimization Tool Sandbox

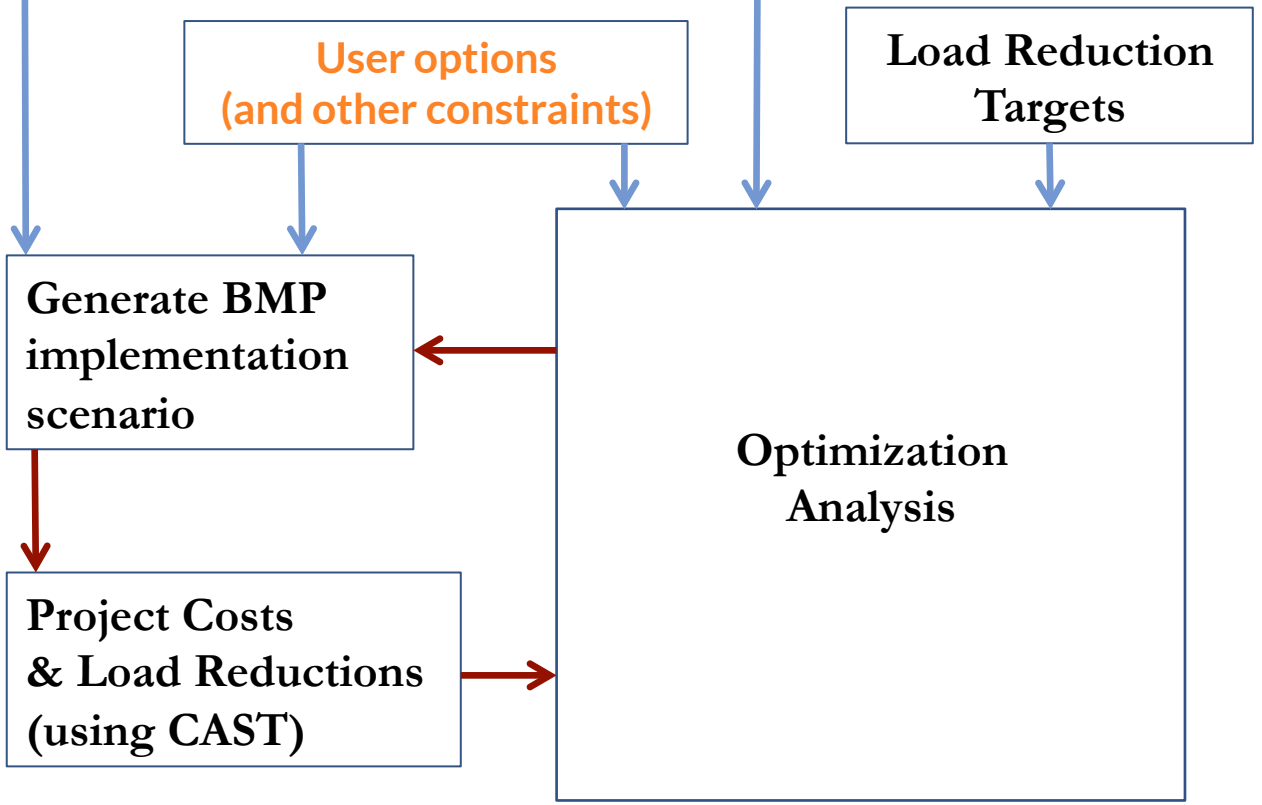


Optimization Tool Sandbox

I Land-river segments, load sources included in the scenario

A Pre-BMP acres eligible for BMP application on each segment-source

J 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

I segment-sources included in the scenario

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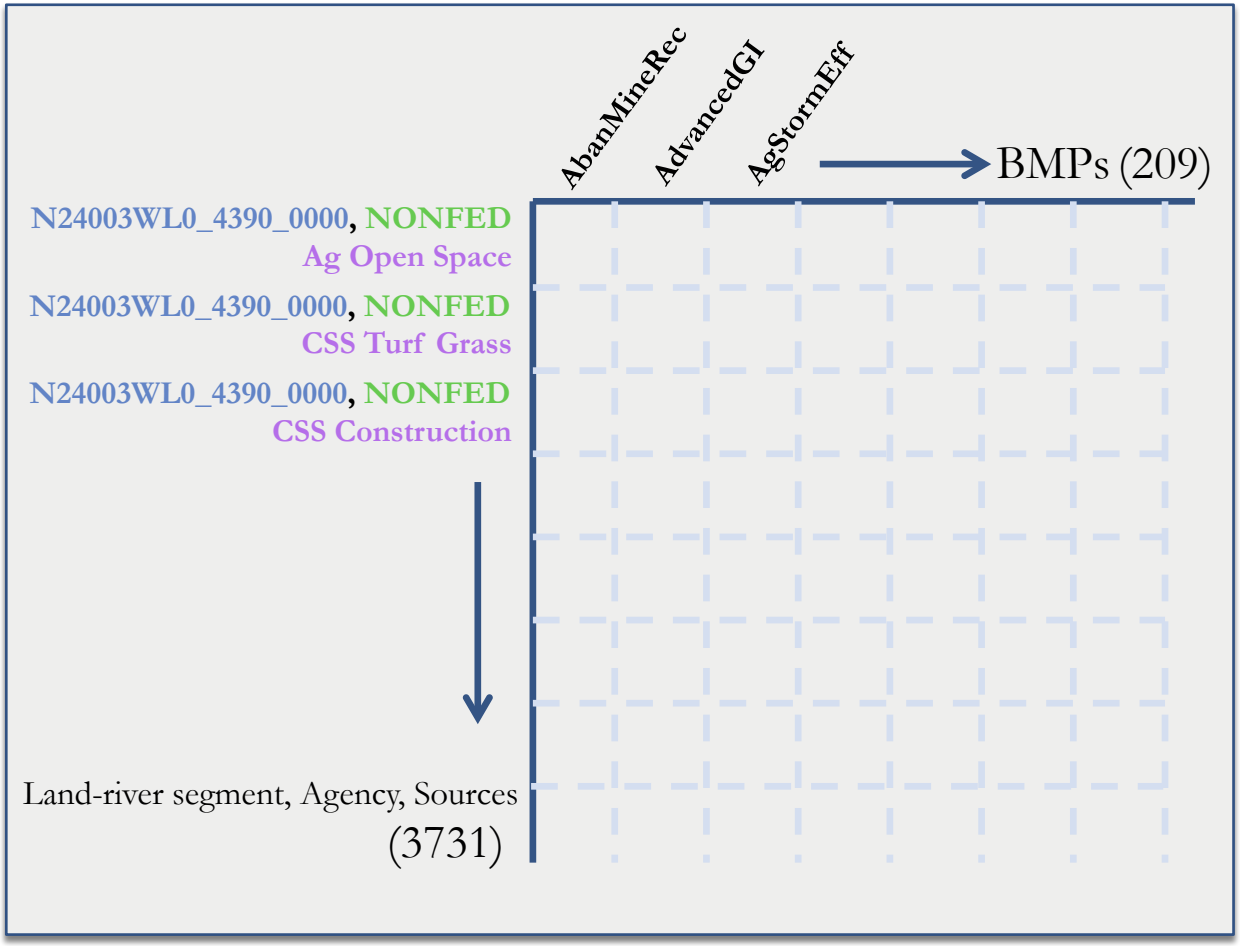
Include:

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



Allowable SegSource-BMP pairs are identified

Inventory of Sources & BMPs

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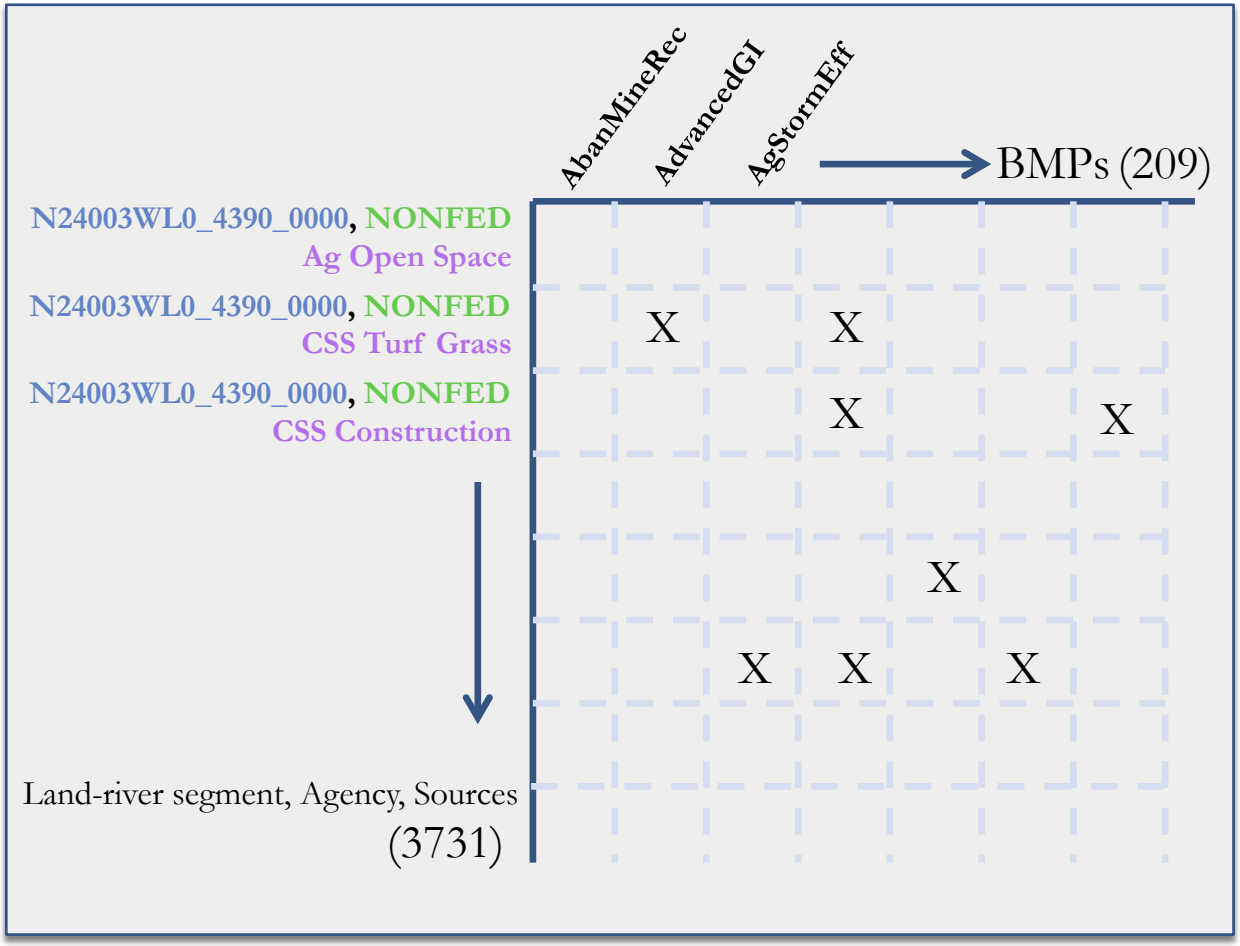

Values for each allowable SegSource-BMP pair

Inventory of Sources & BMPs

User options (and other constraints)

Generate BMP implementation scenario

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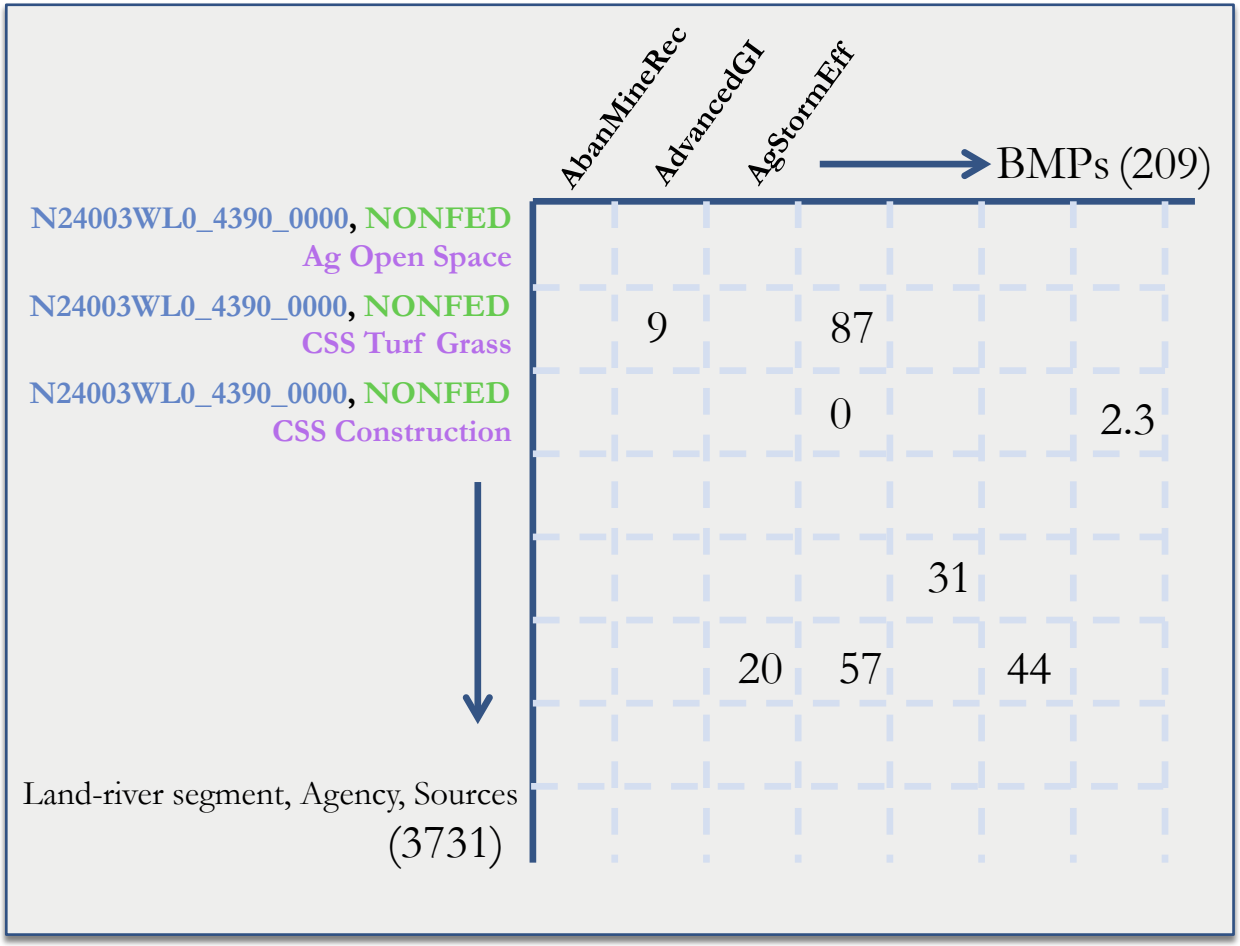
Basic constraints determine value bounds, e.g.

- **Pre-BMP acres**
- **Miles of available roads**



“possibility matrix”

LandRiverSegment	AgencyCode	LoadSource	AbanMineRec	AdvancedGI	AgStormEff	BarnRunoffCont	BioRetNoUDAB
N24003WL0_4390_0000	NONFED	Ag Open Space					
N24003WL0_4390_0000	NONFED	CSS Buildings and Other					384
N24003WL0_4390_0000	NONFED	CSS Construction					
N24003WL0_4390_0000	NONFED	CSS Forest					
N24003WL0_4390_0000	NONFED	CSS Mixed Open					
N24003WL0_4390_0000	NONFED	CSS Roads					825
N24003WL0_4390_0000	NONFED	CSS Tree Canopy over Impervious					671
N24003WL0_4390_0000	NONFED	CSS Tree Canopy over Turfgrass		469			256
N24003WL0_4390_0000	NONFED	CSS Turf Grass		31			68
N24003WL0_4390_0000	NONFED	Double Cropped Land					
N24003WL0_4390_0000	NONFED	Full Season Soybeans					

“stacked CAST input matrix”

N24003WL0_4390_0000	NONFED	Ag Open Space	ConPlan	670
N24003WL0_4390_0000	NONFED	Ag Open Space	DitchFilter	965
N24003WL0_4390_0000	NONFED	Ag Open Space	TreePlant	740
N24003WL0_4390_0000	NONFED	Ag Open Space	WaterContStruc	388
N24003WL0_4390_0000	NONFED	Ag Open Space	WetlandCreateFloodplain	670
N24003WL0_4390_0000	NONFED	Ag Open Space	WetlandCreateHeadwater	918
N24003WL0_4390_0000	NONFED	Ag Open Space	WetlandRestoreFloodplain	270
N24003WL0_4390_0000	NONFED	Ag Open Space	WetlandRestoreHeadwater	834
N24003WL0_4390_0000	NONFED	CSS Buildings and Other	BioRetNoUDAB	384
N24003WL0_4390_0000	NONFED	CSS Buildings and Other	BioRetUDAB	589
N24003WL0_4390_0000	NONFED	CSS Buildings and Other	BioRetUDCD	817

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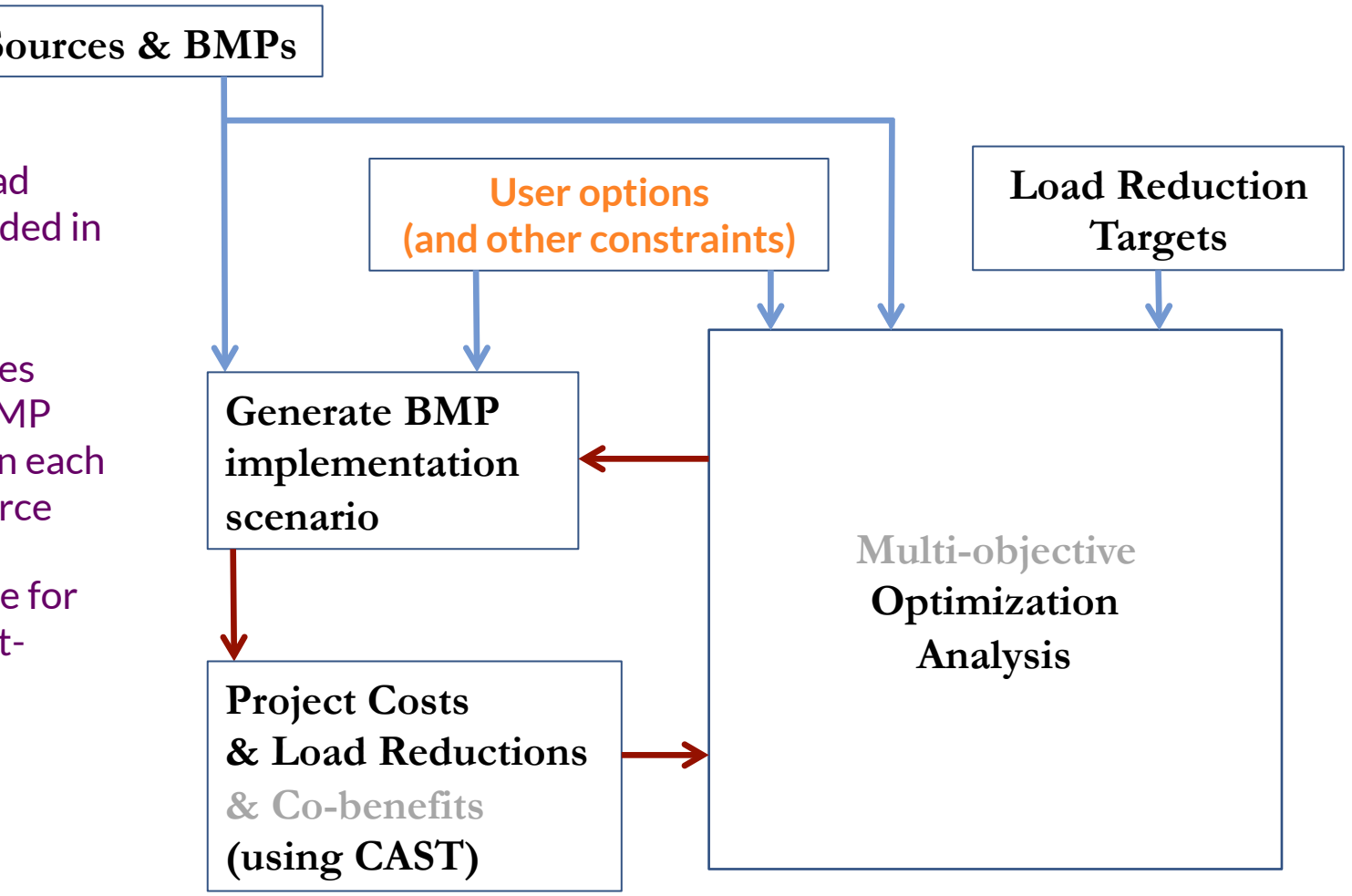

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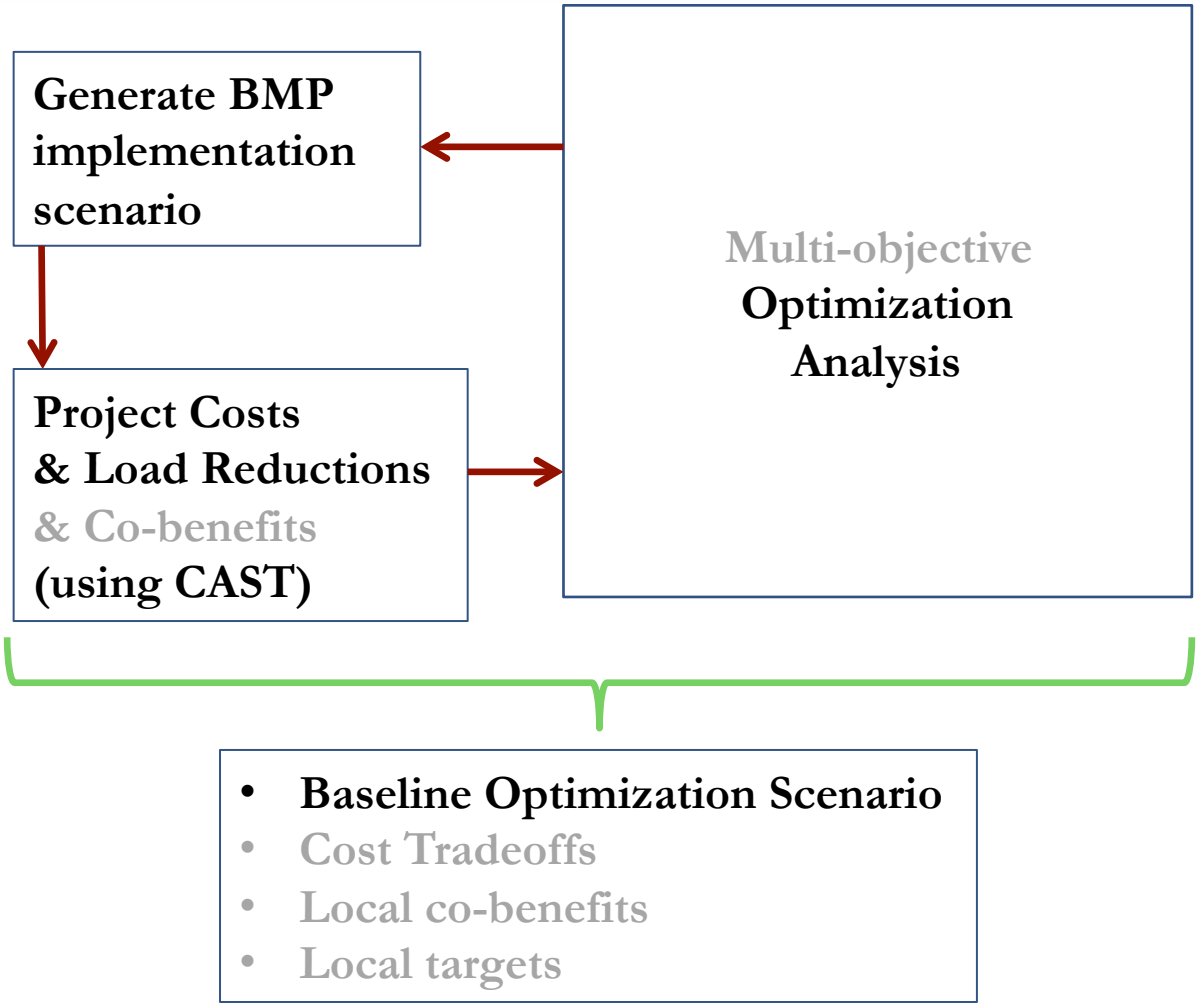
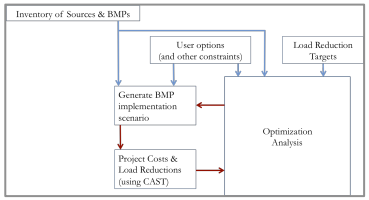


Looking Forward

Sandbox



Identifying Alternatives

Cost Tradeoffs

Baseline Optimization Prototype

Co-benefits

Local Targets

Next Steps

Phase 1: Investigate and Develop an Optimization Plan

- Continue developing a prototype in python
- Continue learning about the CBWSM/CAST, their uses, algorithms, and data structure of inputs and outputs;
- Refine optimization objectives, constraints, user needs
- Consider suitable optimization algorithms and tool designs for a Phase 2 prototype
- Look for model simplifications (reduced parameter sets) and design an efficient interface between CAST and the proposed optimization software;

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

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Questions

Other constraints?

Other objectives?

- E.g. Do we want to include the ability to include incentive costs (minimize BMP implementer cost and/or local/state jurisdiction) as an object?

Computational resources

- API for CAST
- What speeds are necessary for a useable tool?

Looking Forward

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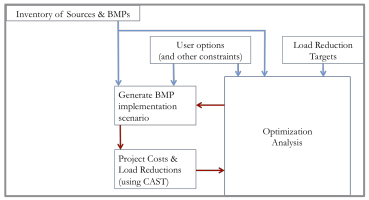

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