

Development of Efficient Multi- Objective Optimization Procedures

Kalyanmoy Deb, Pouyan
Nejadhashemi, Gregorio
Toscano, Ritam Guha and Hoda
Razavi



Agenda

- New Member Onboarding
- Our current status
- Migration to a dedicated Server system
- Dashboard improvement
 - Current
 - Future
- Live Demonstration of the dashboard
- Update on Proposed Webinar
- Future Plans

Gregorio's Update





- Dr. Gregorio Toscano has been working on the project from 2020 as a postdoctoral researcher.
- Recently Dr. Toscano has joined Catholic University of America (CUA) as an Assistant Professor in the department of Electrical Engineering and Computer Science.
- He will continue supporting the project on a part-time basis.

About the New Member

Research Experience

Northrop Grumman [2023 - Present] 
(War strategy optimization)

Hemlock Semiconductor [2022] 
(Timeseries Analysis and Forecasting)

Google (Soft Collaboration) 
[2022]
(AutoML and Control Policy Learning)

Ford Motor Company [2021] 
(Interpretable AI)



Name & Pronouns

Ritam Guha
He/Him

Education

Ph.D., CSE,
Michigan State
University 
(2021-Present,
supervisor: Kalyanmoy
Deb)



Contact Information

guharita@msu.edu
+1 (843) 364 2641

Timeline of the Project

Calendar Year	2020			2021			2022			2023			2024			2025			2026					
Calendar Quarter	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
Project Year	Year 1			Year 2			Year 3			Year 4			Year 5			Year 6								
Task 1: Development of an efficient single-objective optimization procedure for cost-effective BMP allocation	█	█	█	█	█	█																		
1.1: Understanding CAST modules and effect of BMPs on objectives and constraints	█	█																						
1.2: Development of a simplified point-based structured single-objective optimization procedure		█	█	█																				
1.3: Development of a hybrid customized single-objective optimization procedure				█	█	█																		
1.4: Verification and validation with CBP users and decision-makers and update of optimization procedure					█	█																		
Task 2: Development of an efficient multi-objective (MO) optimization procedure for cost-loading trade-off BMP allocation							█	█	█	█	█	█	█											
2.1: Develop generative MO optimization using hybrid optimization procedure developed at Task 1							█	█	█															
2.2: Develop simultaneous MO customized optimization using population-based evolutionary algorithms							█	█	█	█	█	█												
2.3: Comparison of generative & simultaneous procedures and validation with CBP users & decision-makers										█	█	█	█											
2.4: Develop an interactive multi-criterion decision-making aid for choosing a single preferred solution											█	█	█											
Task 3: Multi-state implementation using machine learning and parallel computing platforms														█	█	█	█	█						
3.1: Comparative study to choose a few best performing methods														█	█	█	█	█						
3.2: Scalability to State and Watershed level Scenarios															█	█	█	█						
3.3: "Innovation" approach for improving scalability																█	█	█						
3.4: Distributed computing approach for improving scalability																	█	█						
Task 4: Interactive optimization and decision-making using user-friendly dashboard																			█	█	█	█	█	
4.1: User-friendly optimization through a dashboard																			█	█	█	█	█	
4.2: Surrogate-assisted optimization procedures																			█	█	█	█	█	
4.3: Robust optimization method for handling uncertainties in variables and parameters																				█	█			
4.4: Sustainable watershed management practices																						█	█	

We are here

Task 4: Interactive optimization and decision-making using user-friendly dashboard

4.1 User-friendly optimization through a dashboard

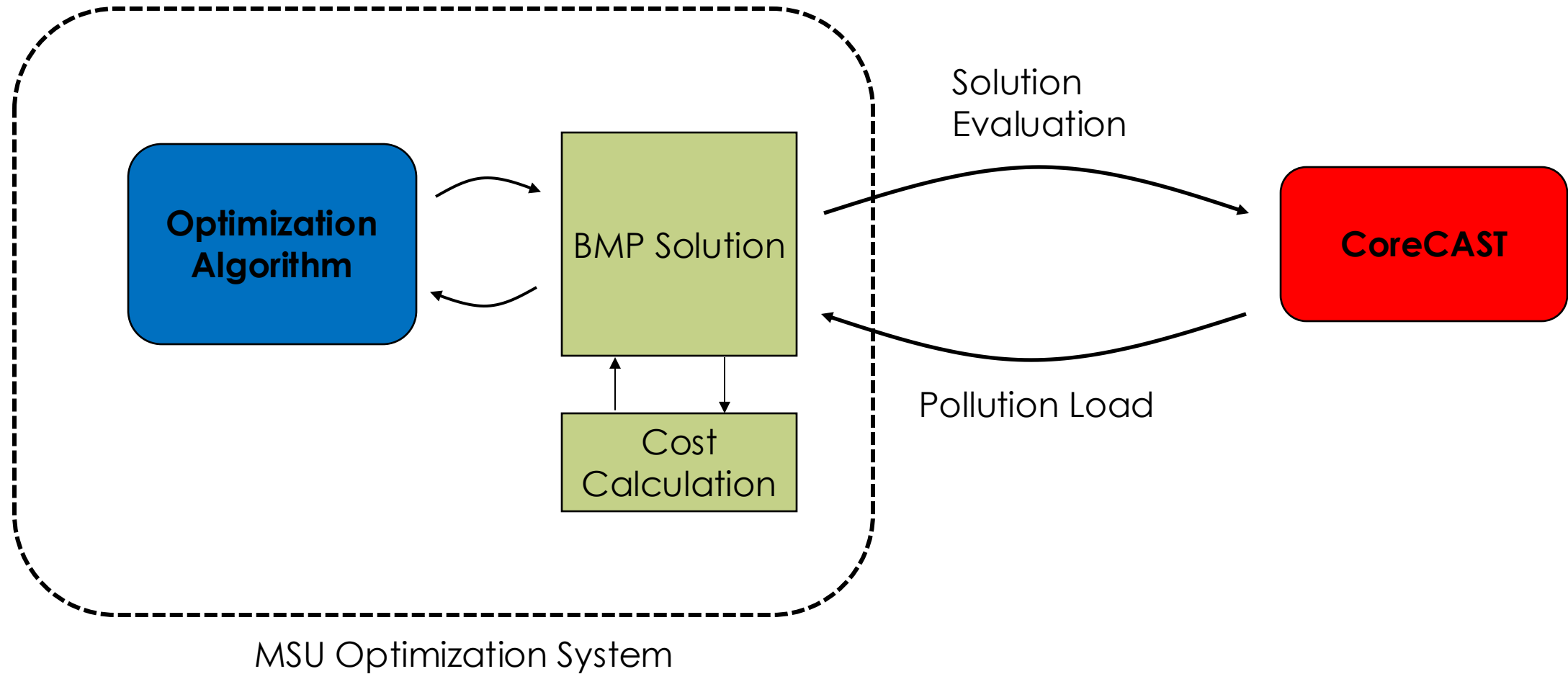
4.2. Surrogate-assisted optimization procedure

4.3 Robust optimization methods for handling uncertainty in variables and parameters

4.4 Sustainable watershed management practices

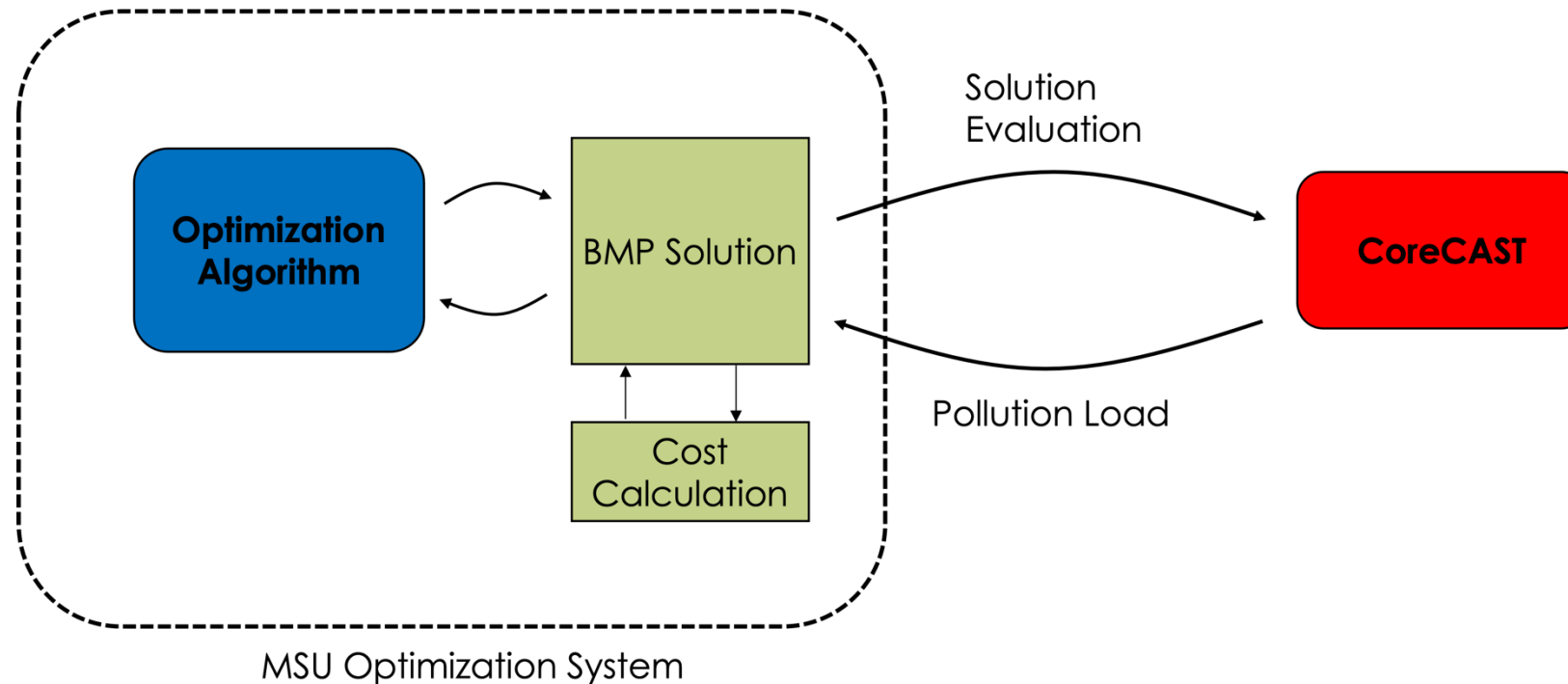
Timeline of the Project

Optimization Process Overview



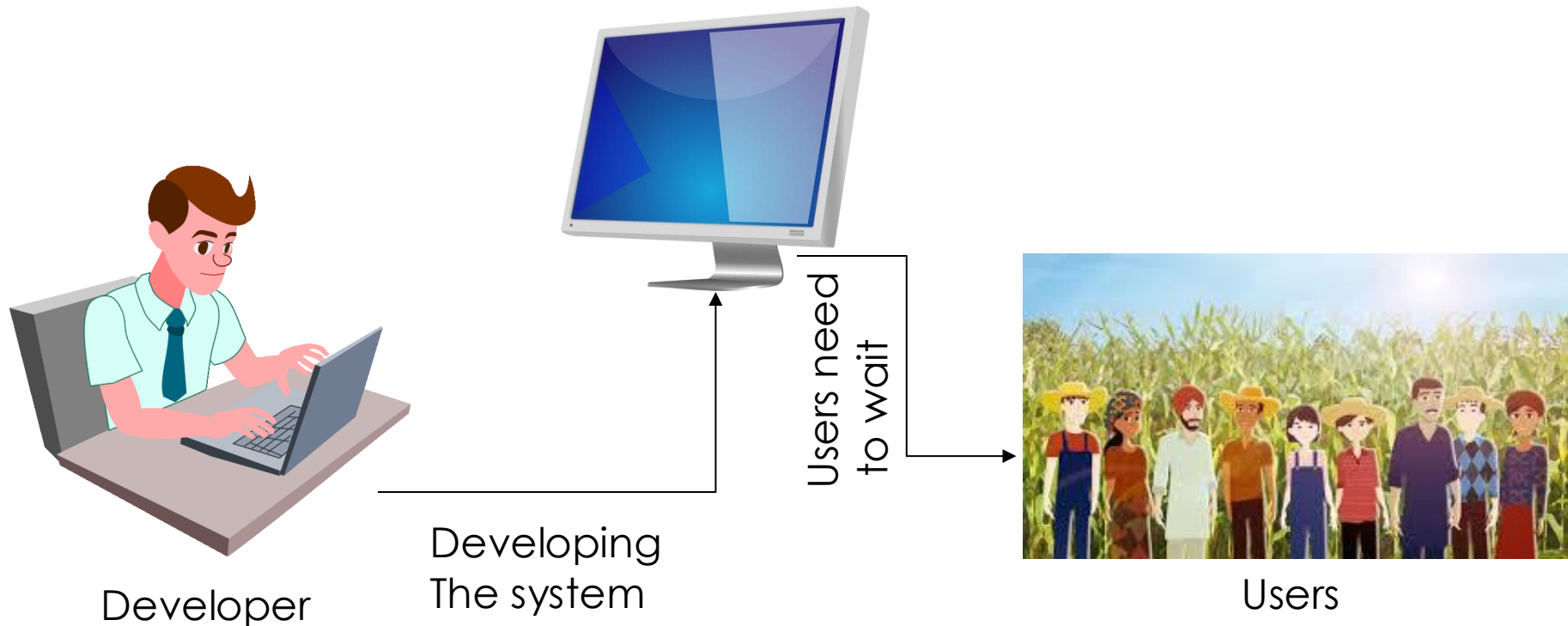
Current State of the Optimization Software Platform

- The current implementation uses the CoreCAST system for the external evaluation of BMPs. The implementation code resides outside the EPA AWS system.



Current State of the Optimization Software Platform

- Any request for the optimization process routes to the external system which is fully developmental – a downside of this is that when development is taking place, no optimization can happen.



Moving to a Robust and Scalable Platform

- Decided to move the implementation code to a robust, maintainable and scalable system.
- Robust, Scalable and Secure Platform: Housed in MSU's COIN Lab
 - Established at MSU in 2012.
 - Mainly focused on optimization projects.
 - Has 13 PCs, 2 MSU-maintained servers, 2 NVIDIA 1080 GPU stacks and 24-hr facility support.
- We are shifting the responsibilities to COIN Lab where we are developing one user version and one developmental version to ensure uninterrupted user support.

Migration to COLN Lab Servers

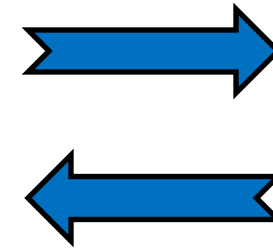
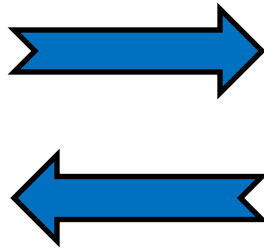
User



External Developmental System



CoreCAST Server



Cons:

- Downtime Risks
- Limited Resources
- Maintenance

Migration to COIN Lab Servers

External Developmental
System



COIN Lab Server



Migration to COIN Lab Servers

External Developmental
System



COIN Lab Server



Migration to COIN Lab Servers

COIN Lab Server



User Program



Migration to COIN Lab Servers

COIN Lab Server



User Program



Copy



Developer Program



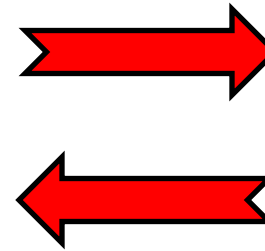
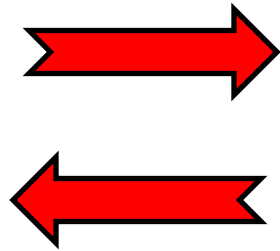
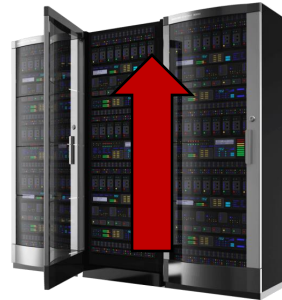
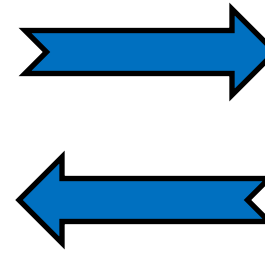
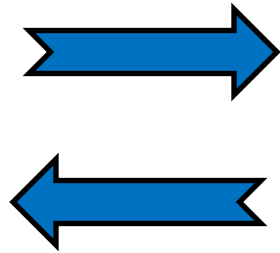
Migration to COIN Lab Servers

COIN Lab Server

(<https://coinlab.chesapeakebay.app/>)

EPA Server

User



Developer

(<https://dev-coinlab.chesapeakebay.app/>)

Current Dashboard Improvements

ID	Issue	Date	Status	Comment	Priority (1-5)	Contributor
1	Wastewater data set needs to be checked in the web interface. (bulk?)	10/16/2024	Done	It is imported as it is from CAST – with the new update	5	Ritam, Gregorio
2	Database update to consider the 2023 Progress data.	11/5/2024	Done	Gregorio is working on that on his part. Need to pull the data to COINLab.	5	Ritam
3	Improve the time of optimization run for run multiple scenarios at the same time.	10/16/2024	Done	Should be able to handle 10-15 executions through the cores	5	Ritam
11	Create two websites: one for development and one stable version	11/8/2024	Done		5	Ritam
26	Incorporate the load reduction on all three pollutants: Nitrogen, Phosphorus, Sediments	9/10/2024	Done		5	Gregorio
15	Provide the dataset and county information to the user while editing a case study	11/11/2024	Done		3	Ritam
16	we need to prepare the system for all year (especially 2023 dataset), Access to data for 2024 year and other years	10/16/2024	Done		2	Ritam, Gregorio
21	Missing decimal point in expected load in the past executed scenario		Done		2	Ritam, Gregorio
22	Replace the word "scenario" with "case study"	11/8/2024	Done		2	Ritam
31	Change the "Case Studies" -> "Optimization Scenario"		Done		5	Ritam, Gregorio
33	Remove "My"		Done		5	Ritam
34	Remove decimal points from the load and make them comma separated		Done		5	Ritam

Current Dashboard Improvements: New Data

New Wastewater Data Import

WASTEWATER DATA SET*

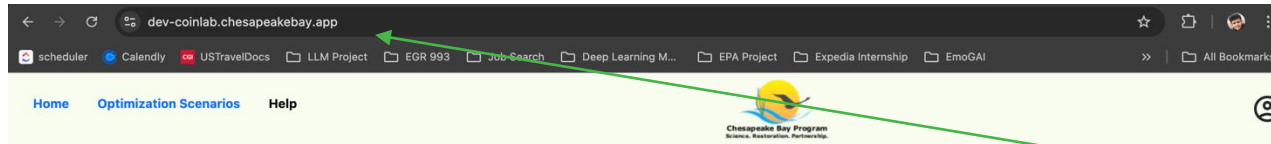
-
- 2023
- WIP 3 CAST-2023 version
- WIP 3 Climate Change CAST-2023 version
- 2023 Progress
- New Castle
- Sussex

Navigation buttons: < > >>

The image shows a screenshot of a web application interface. At the top, there is a light green header with the text 'WASTEWATER DATA SET*'. Below this is a dropdown menu. The menu is currently open, showing a list of options. The first option is '2023', which is highlighted in blue. Below it are 'WIP 3 CAST-2023 version', 'WIP 3 Climate Change CAST-2023 version', and '2023 Progress'. At the bottom of the dropdown, there are three red text items: 'New Castle' and 'Sussex'. A green arrow points from the text 'New Wastewater Data Import' to the '2023 Progress' option in the dropdown menu. Below the dropdown menu, there are three navigation buttons: a left arrow, a right arrow, and a double right arrow.

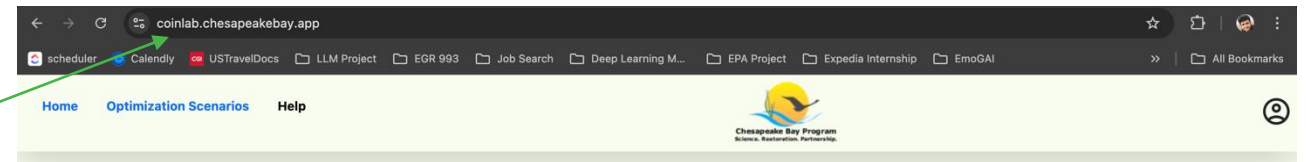
Current Dashboard Improvements: Two Websites

<https://dev-coinlab.chesapeakebay.app/>



One developmental server

<https://coinlab.chesapeakebay.app/>



Another user server

Developmental process should never stop an user from using the system

Current Dashboard Improvements: Load Reduction Target on all three Pollutants

Wastewater Dataset

2023 Progress

Selected Counties

Carroll

Pollution Load and Implementation Cost Specification

POLLUTION REDUCTION TARGET:

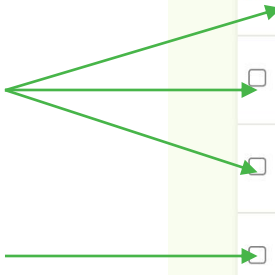
Edge of Stream

Pollutant	Initial Load (lbs/year)	Removal Percentage (%)	Expected Load (lbs/year)
<input checked="" type="checkbox"/> Nitrogen	5,395,607	30	3,776,925
<input type="checkbox"/> Phosphorus	168,888	30	118,222
<input type="checkbox"/> Sediments	551,088,198	30	385,761,739
<input type="checkbox"/> Oxygen Units (ug/l)	94,585,989	30	66,210,192

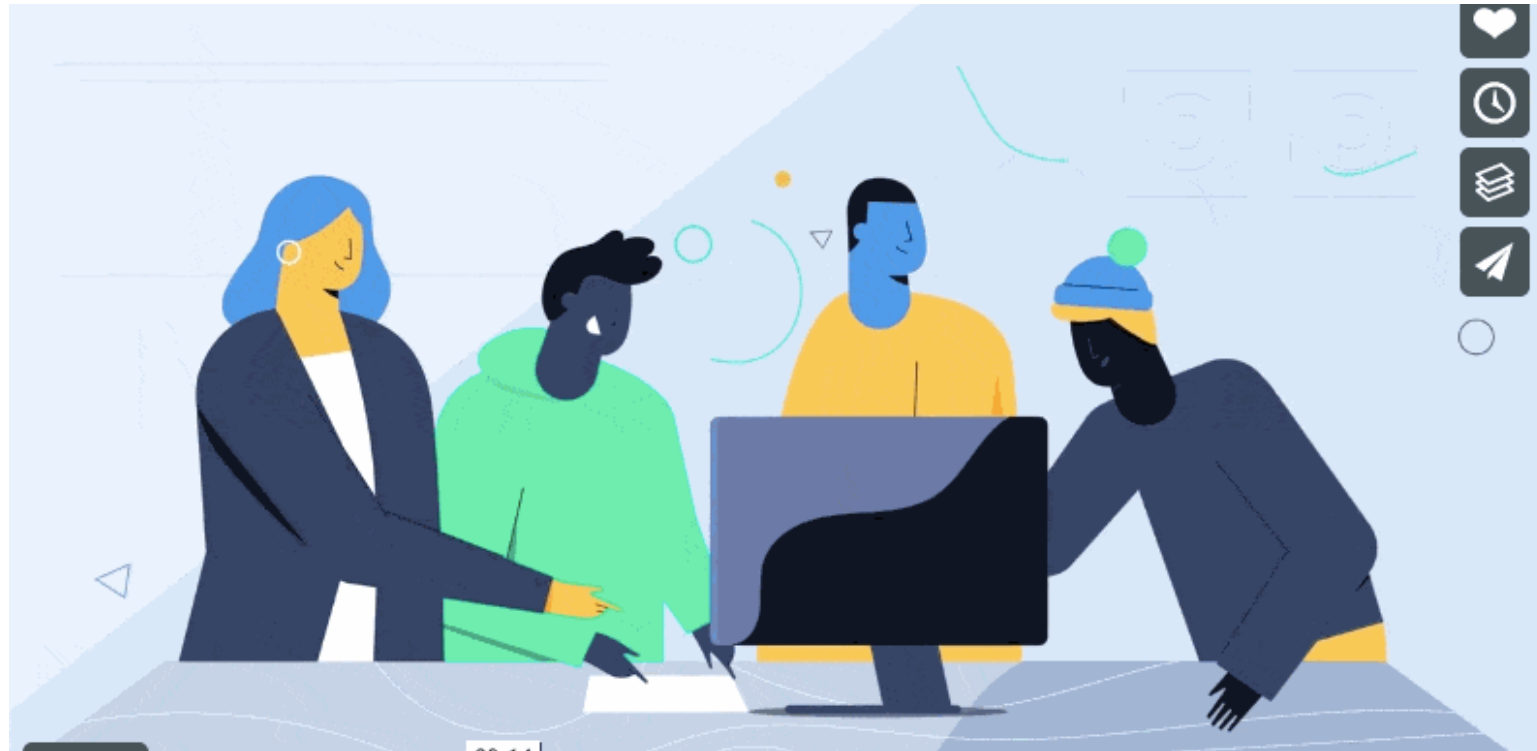
All three pollutants

OR

oxygen



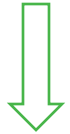
Live Demonstration



Link: <https://dev-coinlab.chesapeakebay.app/>

Future Dashboard Improvements: Status Updates

Insert a status column



ID	Optimization Scenario Name	Wastewater Data Set	Counties	Date modified (EST)	Actions
3	Carroll	2023 Progress	MD: [Carroll]	12/02/2024 6:22 p.m.	
4	Kent	2023 Progress	DE: [Kent]	12/02/2024 7:08 p.m.	
5	Richmond	2023 Progress	VA: [Richmond]	12/02/2024 9:03 p.m.	
6	Lancaster	2023 Progress	VA: [Lancaster]	12/02/2024 9:03 p.m.	
7	Washington DC	2023 Progress	DC: [Washington]	12/02/2024 9:05 p.m.	
16	Richmond 20 Iter	2023 Progress	VA: [Richmond]	12/11/2024 4 p.m.	

Status
Completed
Initializing
Optimizing
Completed
Completed
Optimizing

Will help the users keep track of what is going with each scenario: Optimizing/Fetching Base Scenario/Complete

Future Dashboard Improvements: Email Updates

- Will notify the users with two emails:
 - When Optimization starts
 - When Optimization completes
- When the optimization completes, the email might have a link to access the optimization results.



Future Dashboard Improvements: Cost Updates (Advanced Settings)

Update Costs

BMP*

STATE*

COST



UNIT

NEW COST*

Submit

- Some of the cost information in the system might be old.
- If the user has updated cost information, the costs can be updated based on latest information

Future Improvements: Enable result sharing

Id	# Optimization Run	# Solutions	Actions
3	1	12	  



Should help the user
Share the results of the
Optimization with other users
in the system

Future Improvements: Deleting Scenarios/Results

- Right now, only the admins can delete scenarios

ID	Optimization Scenario Name	Wastewater Data Set	Counties	Date modified (EST)	Actions
3	Carroll	2023 Progress	MD: [Carroll]	12/02/2024 6:22 p.m.	
4	Kent	2023 Progress	DE: [Kent]	12/02/2024 7:08 p.m.	
5	Richmond	2023 Progress	VA: [Richmond]	12/02/2024 9:03 p.m.	
6	Lancaster	2023 Progress	VA: [Lancaster]	12/02/2024 9:03 p.m.	
7	Washington DC	2023 Progress	DC: [Washington]	12/02/2024 9:05 p.m.	
16	Richmond 20 Iter	2023 Progress	VA: [Richmond]	12/11/2024 4 p.m.	
17	Washington DC 20 Iter	2023 Progress	DC: [Washington]	12/11/2024 4:01 p.m.	
18	Lancaster 20 Iter	2023 Progress	VA: [Lancaster]	12/11/2024 4:01 p.m.	
19	Kent Iter 20	2023 Progress	DE: [Kent]	12/12/2024 10:35 a.m.	

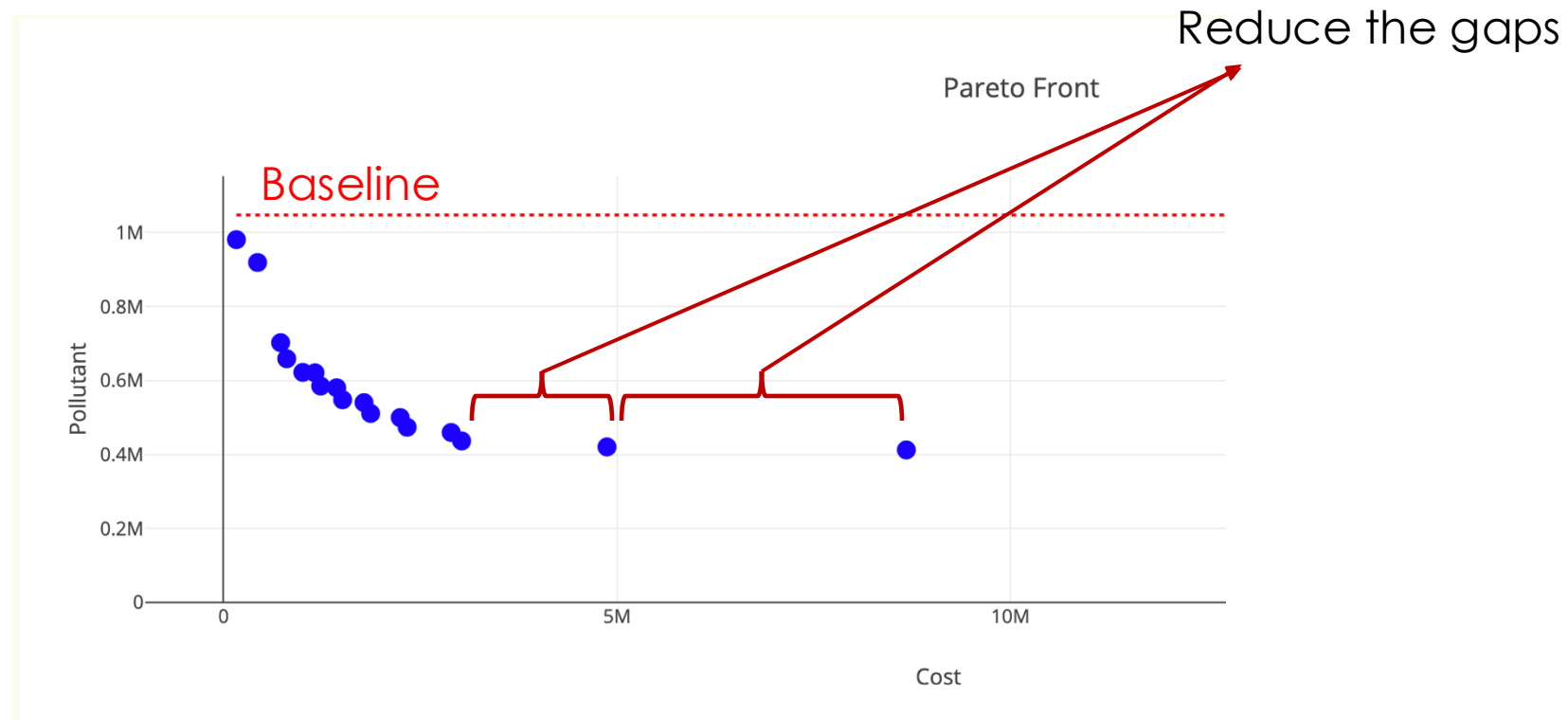
Not needed anymore.
The user should have the ability to delete it.

Delete optimization results at will

Id	# Optimization Run	# Solutions	Actions
3	1	12	

Future Improvements: Improvement in Optimization Algorithm

- Spread is not uniform, we are improving the algorithm to make the solution distribution more uniform.



Update on Proposed Webinar

- Getting delayed due to change of personnel and change in host computer
- Gregorio was not able to provide any time for the project
- However, almost back in track now, a couple of matters remain to be solved
- We shall have a more firmed date during next Quarterly Meeting
- Will schedule a separate call with Lewis to discuss our plan
- Based on above, we requested a no-cost extension by an year (March 2027) to complete the project

Future Plans

- Get the Optimization Code ready for demonstration during the webinar – First priority
- Scale-up study from one county to multiple counties to multiple states
 - Using "Innovization" (rule discovery) concept
 - Parallel CoreCAST evaluations of multiple solutions to speed up the optimization process
 - Surrogate-assisted optimization
 - Robust optimization

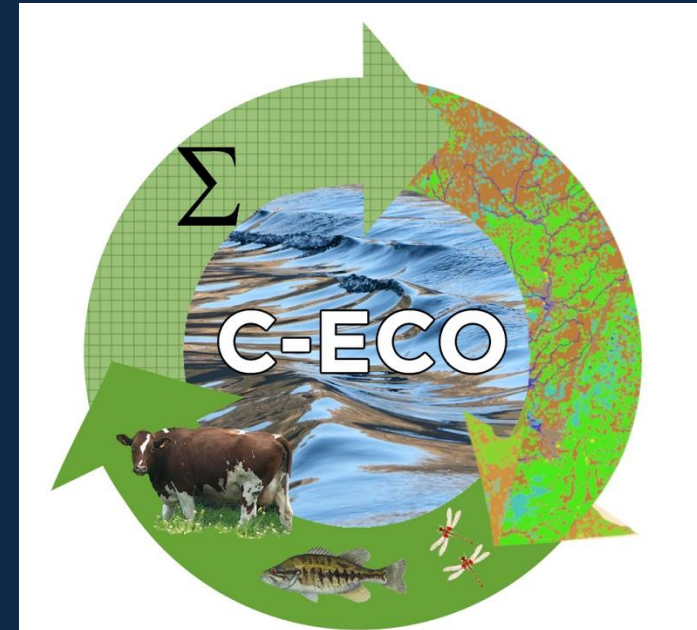


MICHIGAN STATE
UNIVERSITY



Computational Optimization and Innovation

Thankyou



Computational Ecohydrology



Thank you!