Development of Efficient Multi-Objective Optimization Procedures

Kalyanmoy Deb, Pouyan Nejadhashemi, Ritam Guha and Hoda Razavi



Agenda

- New Member Onboarding: Auden Garrard
- Revised Work Plan
- Assistance from CoreCAST team
- Conflict Resolution between Optimization WebApp and CAST
- Dashboard Updates
 - Replicating CAST UI Interface
- Live Demonstration of the dashboard
- Future Plans

About the New Member

Project Experience

- Front End Developer
- Auto-Owners Insurance

Technologies:

Node.js, Python, Java, COBOL, Django

 Recovery of Lost and Stolen IT Assets
 General Motors

Technologies: PowerShell, JavaScript, C++,



Auden Garrard
He/Him

Education

Master in Computer Science Michigan State University

Contact Information garrardw@msu.edu

Personal Hobbies

- Rock climbing
- Kayaking
- Pottery

Revised Timeline of the Project

Original End Date: March 31, 2026

Proposed Extended End Date: March 31, 2027

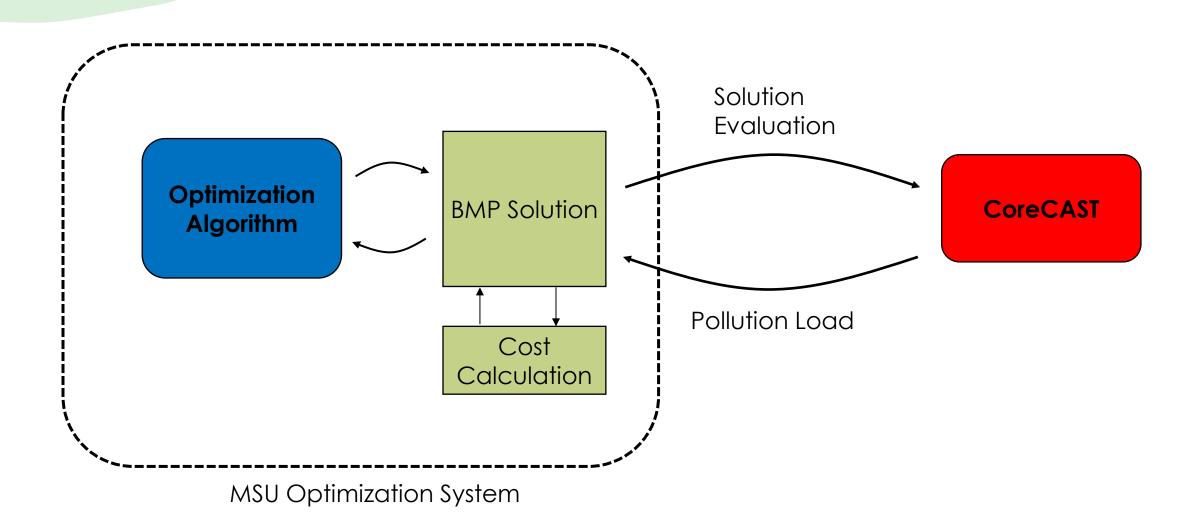
Calendar Year	Q2	2020						2022						23			20			2025								2027
Calendar Quarter		Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
Project Year		Yea	ar 1			Ye	ar 2			Yea	ar 3			Yea	ar 4			Yea	ır 5			Yea	ar 6		Yea	ar 7 (e:	xtend	ed)
Task 1: Development of an efficient single-objective optimization procedure for cost-effective BMP allocation																												
1.1: Understanding CAST modules and effect of BMPs on objectives and constraints																												
 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 procedre 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						-	-																			\vdash	<u> </u>	
3.2: Scalability to State and Watershed level Scenarios 3.3: "Innovization" approach for improving scalability						-	-															 				$\overline{}$	<u> </u>	
3.4: Distributed computing approach for improving scalability						\vdash	\vdash							_												\longrightarrow		\vdash
3.4. Discribated computing approach for improving scalability						_	_																					-
Task 4: Interactive optimization and decision-making using user- friendly dashboard																												
4.0: Completion of remaining studies of Task 3																												
4.1: User-friendly optimization through a dashboard																										$\overline{}$		
4.2: Surrogate-assisted optimization procedure																												
4.3: Robust optimization method for handling uncertainties in variables and parameters																												
4.4: Sustainable watershed management practices																												

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

- 4.0 Completion of remaining studies of Task 3
- 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 (Recap)



Assistance from the CoreCAST Team

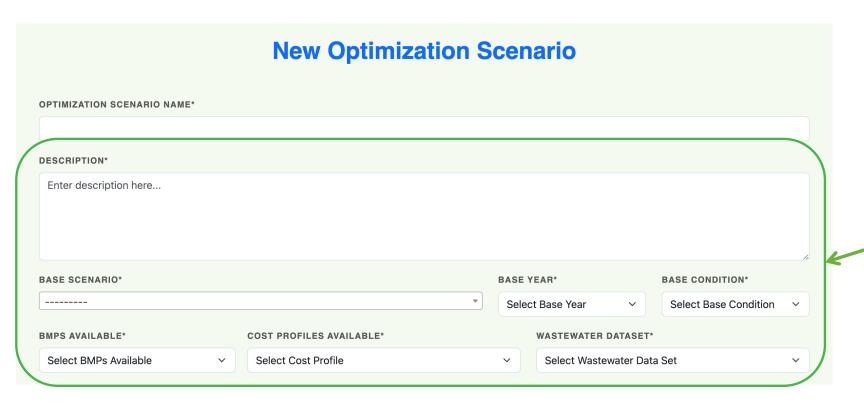


- Due to the transfer of project leadership from Gregorio to Ritam, we encountered substantial challenges in comprehending the system and its integration with CoreCAST.
- Thanks to the CoreCAST team, we have now received the following essential documents:
 - 1. **Documentation** on CoreCAST.
 - 2. A copy of the **database** used in CoreCAST.
 - 3. A detailed **validation** of our results.
- With this invaluable support, we have successfully
 addressed several issues in our web interface, which were
 previously caused by a lack of understanding of the
 CoreCAST system.

Previous Dashboard Inputs

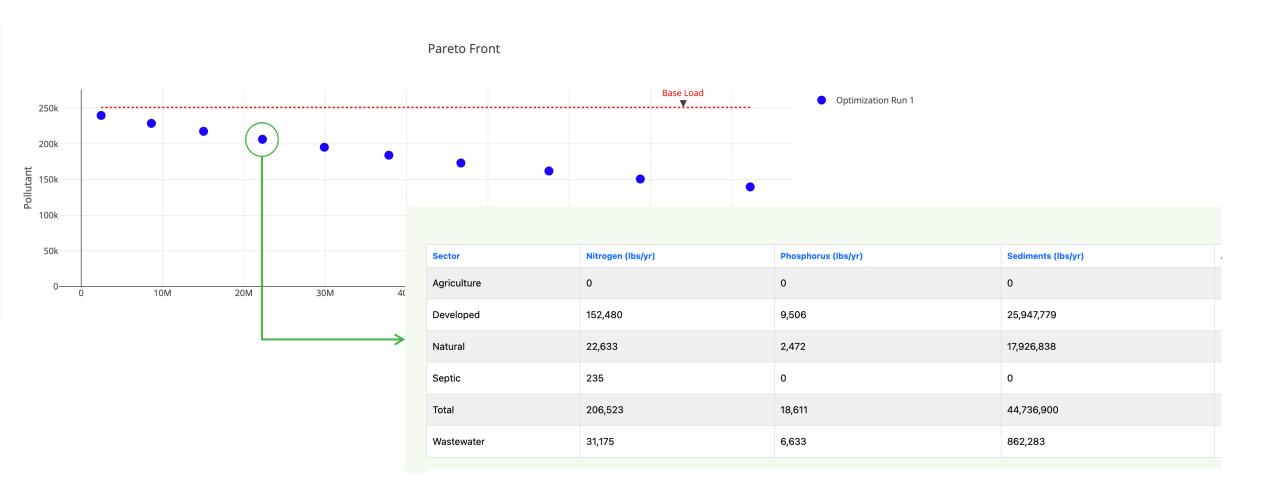
Web App UI **New Optimization Scenario OPTIMIZATION SCENARIO NAME*** Carroll 2023 Ritam **WASTEWATER DATA SET*** 2023 Progress **CAST UI** Not matching **ADD SCENARIO** with CAST Copy Existing Scenario Without BMPs View Documentation Version: CAST-2023 (?) * Required field Scenario Name * (?) Base Year * (?) Base Condition * (?) Select Base Year Select Base Condition Scenario Description * Wastewater Data Set * (?) Select Wastewater Data Set BMPs Available * (?) Select BMPs Available Cost Profile * ? Select Cost Profile (Max. characters 500) Check to view geographies located only in the Chesapeake Bay Watershed Area V

Current Dashboard Improvements



Added new options for the user inputs to remove any ambiguity with the CAST system

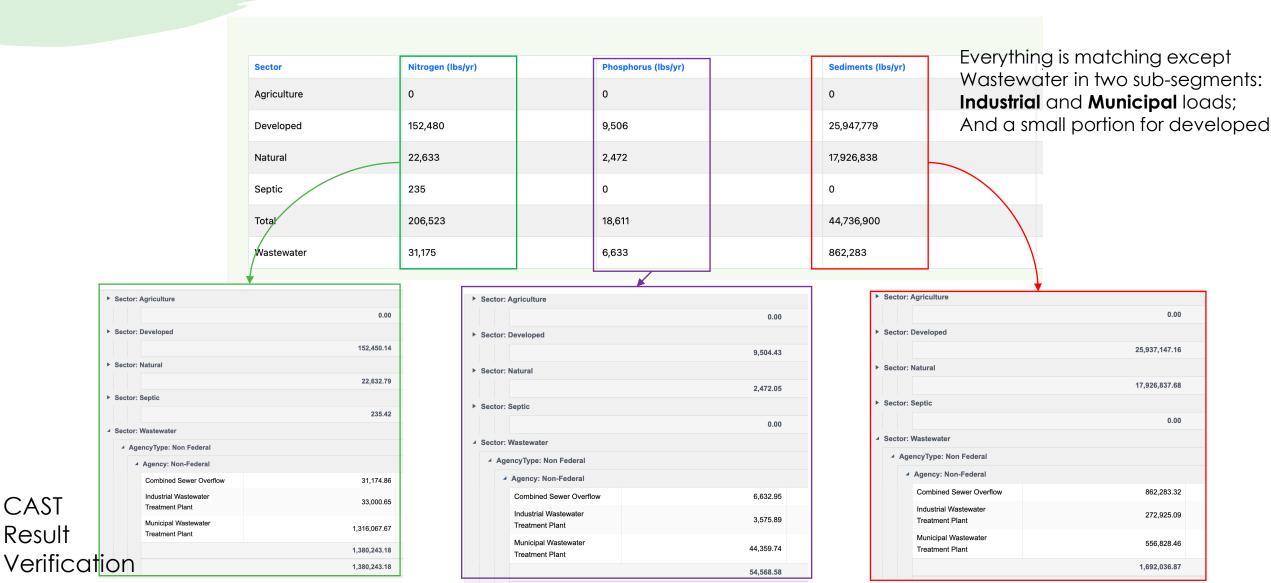
Optimization Run with Washington DC



Optimization Run with Washington DC

CAST

Result



Wastewater Mismatch Correction

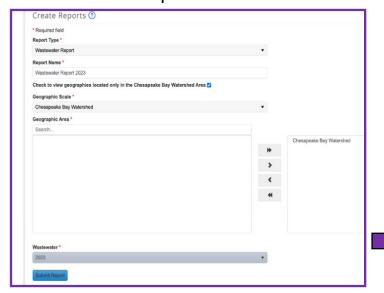
- We have identified that the two sub-segments of wastewater namely Industrial and Municipal Treatment Plant loads can be retrieved from Wastewater Reports:
 - 1. **Nitrogen Loads EOS**: No3LbsPerYearEos, Nh3LbsPerYearEos, OrgnLbsPerYearEos
 - 2. **Phosphorus Loads EOS**: Po4LbsPerYearEos, OrgpLbsPerYearEos
 - 3. Sediments Loads EOS: TssLbsPerYearEos
- We are in the process of obtaining the reports and integrating it to our web interface.



Wastewater is polluting more than what our system thinks!

Wastewater Mismatch Correction

CAST Reports Section



Match!

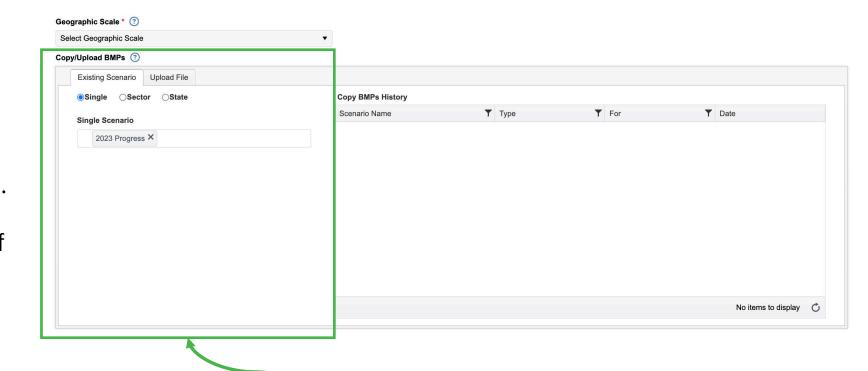
EOS Nitrogen	EOS Phosphorus	EOS Sediments	EOT Nitrogen	EOT Phosphorus	EOT Sediments
119071.8860	4747.7632	76731.9283	74980.9756	2992.3246	27398.6016
22543.8977	171.8241	42983.9054	263.7143	55.0644	23710.3483



Npdes	Facility	Outf	LandRiverSegment	Geography		Agency	LoadSource	Sign FloAv	/gMillior B	BodLbsPer\ D	olbsPerYe N	lo3LbsPerY∈NI	h3LbsPerYe Or	gnLbsPerY∉l	Po4LbsP(0	OrgpLbsl 1	SSLbsPerYe	NO3LbsPe(N	H3LbsPer (JRGNLbsP(P)	O4LbsPerY(C	ORGPLbs T	SSLbsPerYearl
									0.3222	11674.7340	0.0000	13851.2592	0.0000	0.0000	0.0000	0.0000	15001.7976	1738.8931	0.0000	0.0000	0.0000	0.0000	48.6034
MDG766057	CARROLL COUNTY FAMILY YN	001	MD-N24013WM0_3881_3880(CBWS	Carroll, MD (CBWS Portion Only	Non-Federal	Industrial Wastewater Treatment Plant	N	0.0002	18.1820	3.0303	1.0303	0.0848	0.0970	0.0861	0.0352	9.0910	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
									0.0019	35.2993	47.8545	0.0000	27.2440	0.0000	0.0000	0.0000	27.1505	0.0000	19.7136	0.0000	0.0000	0.0000	17.9857
MDG766144									0.0002	18.1820	3.0303	1.0303	0.0848	0.0970	0.0861	0.0352	9.0910	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
									0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MD0001881	BTR HAMPSTEAD, INCBLACK	001 I	MD-N24013WM0_3881_3880(CBWS	Carroll, MD (CBWS Portion Only	Non-Federal	Industrial Wastewater Treatment Plant	N	0.2170	19826.5950	3304.4325	17820.2490	1467.5499	1677.2000	19.1700	7.8300	4503.9999	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
									0.0354	487.8486	812.0506	2711.9621	153.2796	83.0781	470.2674	113.4804	599.8585	1427.5690	80.6860	43.7321	214.2935	51.7112	165.1853
									0.0010	0.0000	24.3401	4.4421	0.7302	0.9128	0.0204	0.0100	91.2754	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
									0.0010	0.0000	24.3401	4.4421	0.7302	0.9128	0.0204	0.0100	91.2754	3.5275	0.5799	0.7248	0.0144	0.0071	62.2918
									2.0243	7091.6907	47097.9902	9388.4351	518.0356	6516.9934	0.0000	608.1958	24514.8642	5128.9491	283.0054	3560.2661	0.0000	277.1453	6750.7497
MDG344224	WALSH FUEL & SUPPLY CO,IN	001	MD-N24013PM2_2860_3040(CBWS)	Carroll, MD (CBWS Portion Only	Non-Federal	Industrial Wastewater Treatment Plant	N	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MD0024589									0.0054	25.9532	135.4949	325.6338	300.0502	9.2326	0.0000	2.6092	148.6450	90.3270	83.2304	2.5610	0.0000	0.2028	3.0747
MDG912397	SHEETZ STORE # 132	001	MD-N24013PM3_3040_3340(CBWS)	Carroll, MD (CBWS Portion Only	Non-Federal	Industrial Wastewater Treatment Plant	N	0.0025	228.2607	38.0434	32.3369	2.6630	3.0435	1.0804	0.4413	114.1303	21.8978	1.8033	2.0610	0.8055	0.3290	64.4877
MD0000779	LEHIGH CEMENT COMPANY L	001	MD-N24013PM1_3450_3400(CBWS)	Carroll, MD (CBWS Portion Only	Non-Federal	Industrial Wastewater Treatment Plant	N	0.1400	12791.3519	2131.8919	28.9798	2.3866	2.7275	0.0000	0.0000	33727.7961	23.0135	1.8952	2.1660	0.0000	0.0000	23017.8547
MDG499852									0.0010	0.0000	24.3401	4.4421	0.7302	0.9128	0.0204	0.0100	91.2754	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MD0022527	MOUNT AIRY WWTP	001	MD-N24013WM1_3882_3880(CBWS	Carroll, MD (CBWS Portion Only	Non-Federal	Municipal Wastewater Treatment Plant	Υ	0.6536	5382.5892	14577.4628	1058.7626	550.9026	1069.8109	29.9366	169.0661	1990.0273	578.4073	300.9608	584.4431	13.6416	77.0408	548.0012
MD0001384	CONGOLEUM CORPORATION	001	MD-N24013WM0_3881_3880(CBWS	Carroll, MD (CBWS Portion Only	Non-Federal	Industrial Wastewater Treatment Plant	Υ	0.1195	807.0417	2279.7744	413.8601	76.8661	654.8738	29.6006	20.5699	3281.3356	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MDG498000	MEDFORD QUARRY (REICHLII	001	MD-N24013PM1_3450_3400(CBWS)	Carroll, MD (CBWS Portion Only	Non-Federal	Industrial Wastewater Treatment Plant	N	0.0010	0.0000	24.3401	4.4421	0.7302	0.9128	0.0204	0.0100	91.2754	3.3169	0.5453	0.6816	0.0144	0.0071	62.2918
MD0022454	UNION BRIDGE WWTP	001	MD-N24013PM1_3450_3400(CBWS)	Carroll, MD (CBWS Portion Only	Non-Federal	Municipal Wastewater Treatment Plant	N	0.1293	1554.1708	3156.0736	6618.7784	342.5110	258.9353	648.5850	66.0771	1151.6430	5256.1107	271.9952	205.6259	456.7233	46.5305	785.9497
	MD0022578 MDG766057 MD0766057 MD0766144 MDP121831 MD0001881 MD0024546 MDG492472 MDG490433 MD0021512 MD0344224 MD0024589 MDG912397 MD000779 MDG499852 MD0002527 MD0001884 MD001884 MD001884 MD001884 MD001884 MD001884 MD001884 MD001884 MD001884 MD001884 MD001884 MD001884 MD001884 MD001884 MD001884	MD0022578 MANCHESTER WWTP MD0766057 CARROLL COUNTY FAMILY YN MD0065927 CARROLL COUNTY FAMILY YN MD0766144 SOUTH CARROLL SWIM CLUB MDP121831 WATER DEPOT MD0001881 BTR HAMPSTEAD, INCBLACK MD0492472 S & G CONCRETE - FINKSBUR MDG492472 S & G CONCRETE - FINKSBUR MD0021512 FREEDOM DISTRICT WWTP MD344224 WALSH FUEL & SUPPLY CO,INI MD0024589 SOUTH CARROLL HIGH SCHO MDG912397 SHEETZ STORE # 132 MD0000779 LEHIGH CEMENT COMPANY LI MD6499852 C. J. 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Municipal Wastewater Treatment Plant N MD00656927 RUNNYMEADE WWTP MD-N24013WM0_3881_3880(CBWS) Carroll, MD (CBWS Portion Only) Non-Federal Municipal Wastewater Treatment Plant N MD0766144 SOUTH CARROLL SWIM CLUB 011 MD-N24013WM0_3881_3880(CBWS) Carroll, MD (CBWS Portion Only) Non-Federal Industrial Wastewater Treatment Plant N MD0001881 BTR HAMPSTEAD, INC-BLACK 001 MD-N24013WM0_3881_3880(CBWS) Carroll, MD (CBWS Portion Only) Non-Federal Industrial Wastewater Treatment Plant N MD00494464 PHEASANT RIDGE WWTP 001 MD-N24013WM0_3881_3880(CBWS Carroll, MD (CBWS Portion Only) Non-Federal Industrial Wastewater Treatment Plant N MD0492472 S & G CONCRETE - FINKSBUR 01 MD-N24013WM1_3882_3880(CBWS Carroll, MD (CBWS Portion Only) Non-Federal Industrial Wastewater Treatment Plant N MD0492472 S & G CONCRETE - FINKSBUR 01 MD-N24013WM1_3881_3880(CBWS Carroll, MD (CBWS Portion Only) Non-Federal Industrial Wastewater Treatment Plant N MD0490433 THOMAS, BENNETT & HUNTE 01 MD-N24013WM1_3882_3880(CBWS 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FAMILY N\D01 MD-N24013WM0_3881_3880(CBWS) Carroll, MD (CBWS Portion Only) Non-Federal Industrial Wastewater Treatment Plant N 0.0002 18.1820 3.0303 1.0303 MD-0766144 SOUTH CARROLL SWIM CLUB 01 MD-N24013PM1_3120_3400(CBWS) Carroll, MD (CBWS Portion Only) Non-Federal Industrial Wastewater Treatment Plant N 0.0002 18.1820 3.0303 1.0303 MD-0766144 SOUTH CARROLL SWIM CLUB 01 MD-N24013PM1_3450_3400(CBWS) Carroll, MD (CBWS Portion Only) Non-Federal Industrial Wastewater Treatment Plant N 0.0000 0.000	MD0022578 MANCHESTER WWTP CO2 MD-N24013WU0_3021_3020(CBWS) Carroll, MD (CBWS Portion Only) Non-Federal Municipal Wastewater Treatment Plant N 0.0002 18.1820 3.0303 1.0303 0.0848 MD-N24013WM0_3881_3880(CBWS Carroll, MD (CBWS Portion Only) Non-Federal MUnicipal Wastewater Treatment Plant N 0.0000	MD002578 MANCHESTER WWTP CO2 MD-N24013WU0_3021_3020(CBWS) Carroll, MD (CBWS Portion Only) Non-Federal Municipal Wastewater Treatment Plant N 0.0002 18.1820 3.0303 1.0303 0.0848 0.0970 MD0769507 RUNNYMEADE WWTP CO1 MD-N24013WM0_3881_3880(CBWS) Carroll, MD (CBWS Portion Only) Non-Federal Municipal Wastewater Treatment Plant N 0.0002 18.1820 3.0303 1.0303 0.0848 0.0970 MD0769507 MD-N24013PM1_3450_3400(CBWS) Carroll, MD (CBWS Portion Only) Non-Federal Municipal Wastewater Treatment Plant N 0.0002 18.1820 3.0303 1.0303 0.0848 0.0970 MD07696144 SOUTH CARROLL SWIM CLUB CO1 MD-N24013PM1_3450_3400(CBWS) Carroll, MD (CBWS Portion Only) Non-Federal Municipal Wastewater Treatment Plant N 0.0000 0.	MD0025278 MANCHESTER WWTP MD MD0726057 MD-N24013WU0_3021_3020(CBWS) Carroll, MD CBWS Portion Only Non-Federal Municipal Wastewater Treatment Plant N 0.0002 18.1820 3.0030 1.0303 0.0848 0.0970 0.0861 MD-N24013WM1_3820_3890(CBWS) Carroll, MD CBWS Portion Only Non-Federal Municipal Wastewater Treatment Plant N 0.0002 18.1820 3.0030 1.0303 0.0848 0.0970 0.0861 MD-N24013WM1_3820_3890(CBWS) Carroll, MD CBWS Portion Only Non-Federal Municipal Wastewater Treatment Plant N 0.0002 18.1820 3.0030 1.0303 0.0848 0.0970 0.0861 MD-N24013WM1_3820_3890(CBWS) Carroll, MD CBWS Portion Only Non-Federal Industrial Wastewater Treatment Plant N 0.0002 18.1820 3.0303 1.0303 0.0848 0.0970 0.0861 MD-N24013WM1_3881_3880(CBWS Carroll, MD CBWS Portion Only Non-Federal Industrial Wastewater Treatment Plant N 0.0002 18.1820 3.0303 1.0303 0.0848 0.0970 0.0861 MD-N24013WM1_3881_3880(CBWS Carroll, MD CBWS Portion Only Non-Federal Industrial Wastewater Treatment Plant N 0.0000	MDC025278 MANCHESTER WWTP 602 MD-N24013WU0 3021 3020(CBWS) Carroll, MD (CBWS Portion Only) Non-Federal Municipal Wastewater Treatment Plant N 0.0022 11674.7340 0.0000 13851.2592 0.0000 0.0	MD022578 MANCHESTER WWTP 602 MD-N24013WM0_3021_3020(CBWS) Carroll, MD (CBWS Portion Only) Non-Federal Municipal Wastewater Treatment Plant N 0.0022 11674,7340 0.0000 13851_2592 0.0000	MOD025278 MANC-HESTER WWTP To MD-N24013WIO 3021 3020(CBWS) Carroll, MD (CBWS Portion Only) Non-Federal Municipal Wastewater Treatment Plant N 0.0022 11674.7340 0.0000 13851.2592 0.0000 0.0	MOD025278 MANCHESTER WWTP 702 MD-N24013WID 3021 3020 (CBWS) Carroll, MD (CBWS Portion Only) Non-Federal Municipal Wastewater Treatment Plant N 0.0002 18.1820 3.0303 1.0303 0.0848 0.0970 0.0861 0.0000	MONOCESTR MANCHESTER WWTP 102 MD-N24013WU 3021 3020 (CBWS Carroll, MD (CBWS Portion Orly) Non-Federal Municipal Wastewater Treatment Plant N 0.3222 11674.740 0.0000 13851.2592 0.0000 0.0	MANCHESTER WWTP 102 MANCHESTER WWTP 103 MANCHESTER WWTP 104 MD-N24013WNIQ 3881 3880 (CBWS Carroll, MD (CBWS Portion Only) Non-Federal Municipal Wastewater Treatment Plant N 0.0002 18.1820 0.0000	MANCESTER MANC

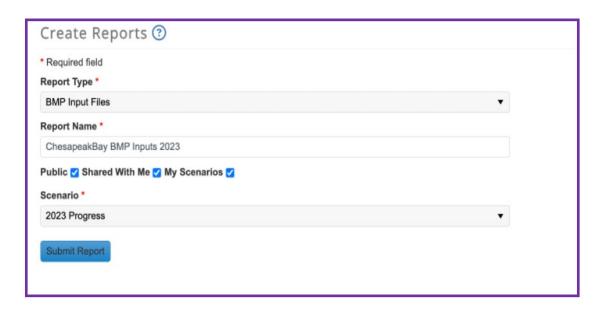
Base Progress Scenario Addition

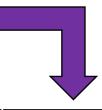
- We also have identified a way to add the base scenario BMP implementations to the process by using the Reports.
- We are also in the process of obtaining the Progress reports and integrating it to our web interface.



Adding this functionality; Need to optimize on top of this

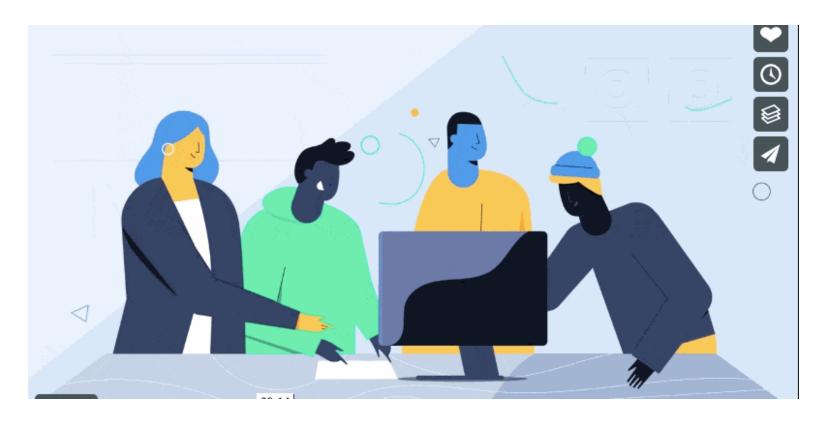
Base Progress Scenario Addition





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                                                                   GeographyName
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npsx2056x0x1
              nps dc bioretudab dc impervious 2.713406801223755
                                                                  acres
npsx3786x0x1
              nps dc bioretudab dc impervious 4.655004501342773
                                                                  acres
npsx3786x0x4
              nps dc bioretudab dc impervious 4.655004501342773
npsx5535x1x2
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                                                                      acres
six2100x0x1 si dc bioretudab dc impervious 0.04958677664399147 acres
six2100x0x2 si dc bioretudab dc impervious 0.04958677664399147 acres
arsx1155x0x2 ars dc bioretudab dc ms4cssnonregulated 0.5 acres
arsx1155x0x3 ars dc bioretudab dc ms4cssnonregulated 1 acres
usafx1070x0x1 dod dc bioretudab dc ms4cssnonregulated 0.6727272868156433 acres
usnx365x0x1 dod dc bioretudab dc ms4cssnonregulated 0.32001835107803345 acres
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usnx950x0x1 dod dc bioretudab dc ms4cssnonregulated 0.657805323600769
```

Live Demonstration



Link: https://coinlab.chesapeakebay.app/

Future Dashboard Improvements: Status Updates

Insert a status column

ID 🍦 Optimization Scenario Name	≜	Wastewater Data Set	*	Counties	A	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.		4

Status
Completed
Initializing
Optimizing
Completed
Completed
Optimizing

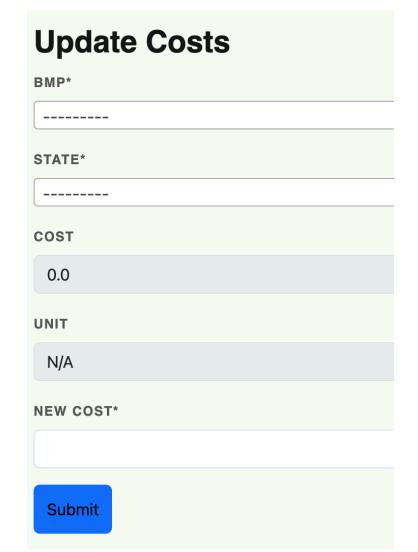
Will help the users keep track of what is going with each scenario: Optimizing/Fetching Base Scenario/Complete

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.

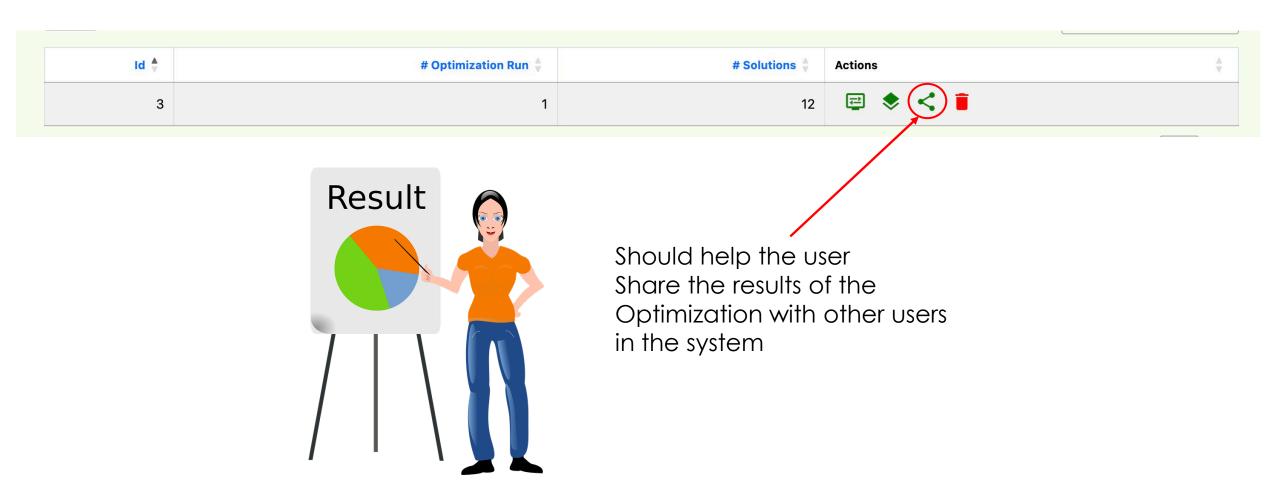


Future Dashboard Improvements: Cost Updates (Advanced Settings)



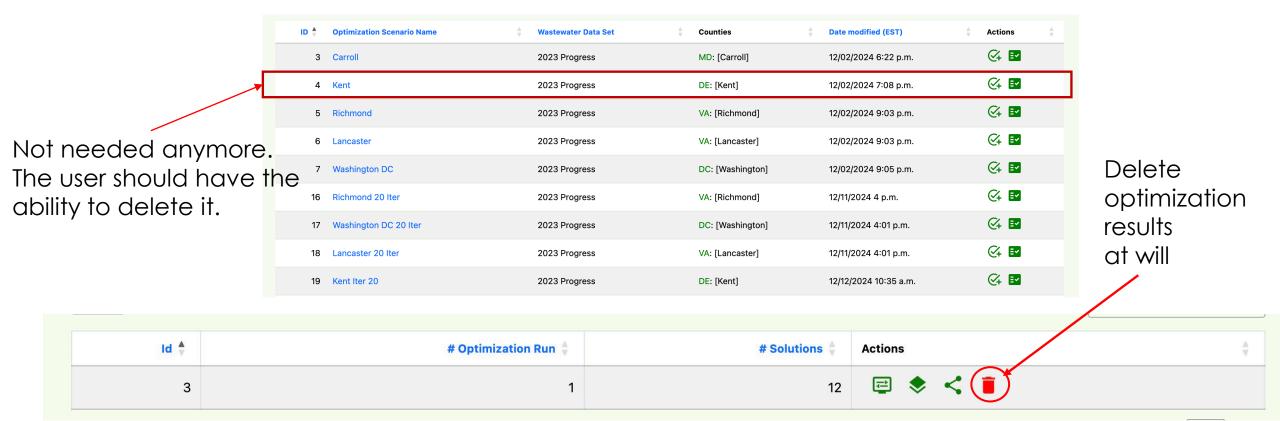
- Some of the cost information in the system might be old.
- If the user has updated cost information, the costs can be updated based on latest information

Future Improvements: Enable result sharing



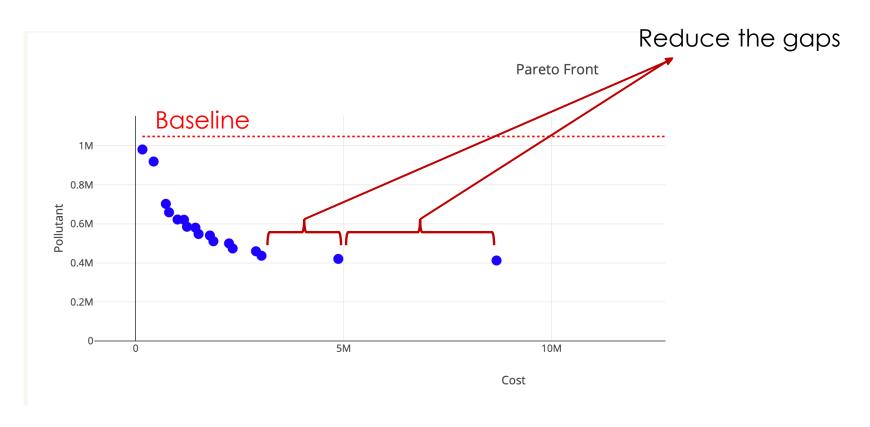
Future Improvements: Deleting Scenarios/Results

Right now, only the admins can delete scenarios



Future Improvements: Improvement in Optimization Algorithm

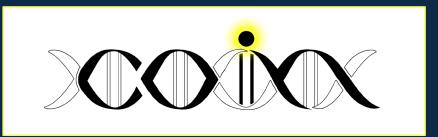
• Spread is not uniform, we are improving the algorithm to make the solution distribution more uniform.



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





Computational Optimization and Innovation

Thankyou



