Support Documents for the PSC Decisions and MB/WQGIT Activities

To facilitate discussions at the 10/19/22 meeting, below are the PSC decisions from the 9/15/22 meeting and some information that CBPO thought would be helpful for the working session. We have provided suggestions and some known information for each of the three decision items. Please reach out to Lee McDonnell, Branch Chief, Science, Analysis, and Implementation, at McDonnell.Lee@epa.gov or 410-267-5731 at any time with questions or if you would like further explanation of the material. CBPO staff will be on hand to answer questions at the 10/19/22 meeting.

PSC Decision 1

Over the next year, as a partnership we will figure out how the unaccounted additional loads are addressed post-2025 and on what timeframe as we work to 'recalibrate' the goal line.

Document 1 provides supporting material to help define the term "unaccounted load". The included table shows change in loads and reduction expectations since the 2018 planning targets were finalized. We offer some options to spur the group's development of an operational definition of "unaccounted loads."

PSC Decision 2

Convene a committee to develop short-term, interim resolutions to fertilizer data concerns (Check in at next PSC meeting) before moving forward with CAST 2021 as well as long-term resolutions for Phase 7 model.

Document 2 summarizes current AAPFCO and NASS data processing prior to be introduced to CAST.

Short Term Interim Resolution

Document 3 shows the incremental change in loads between the current version of CAST 2019 (no fertilizer correction) and CAST 2021 by applying 25%, 50% and 75% and 100% of the updated fertilizer amounts. This option is provided as a short-term solution to move forward with CAST 2021.

Document 4 provides the Urban Stormwater Workgroup's plans to address urban fertilizer concerns. The information shows the plan to address immediate concerns brought forward by West Virginia and the Workgroup's longer term plans for the urban fertilizer data concerns.

Long Term Resolution (Phase 7)

Document 5 and Document 6 provide information on an in-progress investigation of agricultural and urban fertilizer data sources. This effort involves working with jurisdictional representatives and fertilizer experts to evaluate current and new data sources that previously have not been directly utilized.

Document 7 provides information on the proposed PA-DEP alternate method to utilize National Agricultural Statistics Service (NASS) data for bringing the fertilizer data more up to date.

PSC Decision 3

Update process to include additional safeguards to prevent data analysis variations and to assess reasonability of modeling results after CBP protocols are applied.

Document 8 shows a flowchart of the steps currently in place for review of CAST-2019 and CAST-2021 modeled output by the partnership prior to the release of a new CAST version. A proposed schedule for future CAST versions is provided as an option for the group's discussion.

Document 9 provides a broad explanation of our modeling tools that reviews why and how we update CAST and the impact on planning goals and assessing progress toward the 2010 Chesapeake Bay TMDL.

Document 10 shows the Quality Assurance Project Plan (QAPP) for the review of the data that are processed prior to going into CAST. This QAPP is under review and will be revised to reflect current duties and procedures.

Principals Staff Committee (PSC) Decision: "Over the next year, as a partnership we will figure out how the unaccounted additional loads are addressed post-2025 and on what timeframe as we work to 'recalibrate' the goal line."

Defining Unaccounted Loads

The PSC was not specific about what was meant by "unaccounted loads". The discussions at the PSC and subsequent Management Board meetings centered around loads that were unexpected when the original Phase 3 WIPs were developed. Partners reported that they had gone back to their stakeholders several times over the past few years asking for additional reductions with each version of the Chesapeake Assessment Scenario Tool (CAST) and in response to climate change and Conowingo-related decisions. They were concerned that the process could lose credibility if implementation plans continue to be impacted by these changing conditions.

To illustrate, the exchange-adjusted planning targets Bay-wide were 199.3 million pounds of Total Nitrogen (TN). The original Phase 3 WIPs, using CAST-2017, approached that number at 203.5 million pounds of TN. However, the same Phase 3 WIPs run in CAST-2019 only reduced the load to 206.9 million pounds TN, a 3.35-million-pound increase in level of effort required by BMPs and other management actions. likewise, CAST-2021 would result in a Phase 3 WIP load of 212.8 million pounds TN, a 5.89-million-pound increase in level of effort.

Although not unexpected, partnership decisions on climate change and Conowingo call for further reductions. Climate change considerations agreed to by the PSC in December 2020 call for a 4.99-million-pound TN reduction and the Conowingo Watershed Implementation Plan agreed to by the PSC in 2022 calls for a 6.67-million-pound TN reduction. The changes in CAST and the additional reduction for climate and Conowingo are all products of partnership decisions and updated data, however the fact remains the total additional reduction effort is over 20 million pounds of TN and .40 million pounds of Total Phosphorus (TP).

Table 1

Unexpected Additional Loads		
Model version changes	TN	TP
Change in effort for moving to CAST-2019 from CAST-2017	3.35	0.18
Change in effort for moving to CAST-2021 from CAST-2019	5.89	-0.52
Total due to model version changes	9.24	-0.34
Known Additional Loads		
Planned increases in level of effort	TN	TP
Change in effort for climate change	4.99	0.60
Change in effort for Conowingo	6.67	0.14
Total due to planned increases	11.66	0.74

Suggested Path Forward

- The Phase 3 WIP planning targets would be unchanged in accordance with the July 2018 PSC decision, however the 2025 implementation deadline could be extended, pending future partnership discussions.
- Interim planning targets could be developed for 2025 that are higher (easier to reach) than the current planning targets by amounts selected from table 1.
- The CBP has the option to develop new planning targets using the Phase 7 model in 2027.
- CAST-2021 would be released pending resolutions of PSC decisions 2 and 3.

Calculating Farm Fertilizer Sales for the Region

Data Source: Association of American Plant Food Control Officials (AAPFCO)

Timeframe: Annual

1. Sum fertilizer sales (i.e., nitrogen and phosphorus) using AAPFCO designations (i.e., farm, non-farm, unknown).
2. These categorized data are then summed for each county.
3. Calculate the percent of farm fertilizer to total fertilizer sold.
4. Determine the three-year rolling average of farm fertilizer
5. Multiply fraction (Step 3) by the three-year rolling average (step 5) for each nutrient to get the final regional fertilizer sales available to farms.

Calculating Watershed Fertilizer Expenditures

Data Source: National Agricultural Statistics Service (NASS) Agriculture Census Data

Timeframe: Annual; interpolated for non-census years

1. Calculate county expenditures on fertilizer (i.e., nitrogen and phosphorus).
2. Sum expenditures on fertilizer.
3. NASS data are used to apportion a portion of fertilizer to counties that intersect the Chesapeake Bay watershed.

Change in Nutrient Loads to the Chesapeake Bay

Differences between CAST versions w/ increasing fertilizer levels by source for 2021 Progress scenario

Nitrogen Loads

		CAST19 to CAST21 Change w/ 25% Fertilizer Increase (M lbs)	CAST19 to CAST21 Change w/ 50% Fertilizer Increase (M lbs)	CAST19 to CAST21 Change w/ 75% Fertilizer Increase (M lbs)	CAST19 to CAST21 Total Change From Updates (M lbs)	CAST19 % Goal Achieved w/ Uncorrected Fertilizer (>= 80% is on track)	CAST21 % Goal Achieved w/ 25% Fertilizer Increase (>= 80% is on track)	CAST21 % Goal Achieved w/ 50% Fertilizer Increase (>= 80% is on track)	CAST21 % Goal Achieved w/ 75% Fertilizer Increase (>= 80% is on track)	CAST21 % Goal Achieved w/ Full Fertilizer Increase (>= 80% is on track)
CB Watershed	Agriculture	2.606	3.617	4.595	5.573	15%	5%	3%	0%	0%
CB Watershed	Developed	0.091	0.091	0.091	0.091	0%	0%	0%	0%	0%
CB Watershed	Wastewater	0	0	0	0	100%	100%	100%	100%	100%
CB Watershed	Septic	-0.053	-0.053	-0.053	-0.053	0%	0%	0%	0%	0%
CB Watershed	Natural	0.128	0.181	0.233	0.285	31%	26%	24%	22%	21%
CB Watershed	AllSources	2.771	3.835	4.865	5.896	42%	37%	36%	34%	33%

Phosphorus Loads

		CAST19 to CAST21 Change w/ 25% Fertilizer Increase (M lbs)	CAST19 to CAST21 Change w/ 50% Fertilizer Increase (M lbs)	CAST19 to CAST21 Change w/ 75% Fertilizer Increase (M lbs)	CAST19 to CAST21 Total Change From Updates (M lbs)	CAST19 % Goal Achieved w/ Uncorrected Fertilizer (>= 80% is on track)	CAST21 % Goal Achieved w/ 25% Fertilizer Increase (>= 80% is on track)	CAST21 % Goal Achieved w/ 50% Fertilizer Increase (>= 80% is on track)	CAST21 % Goal Achieved w/ 75% Fertilizer Increase (>= 80% is on track)	CAST21 % Goal Achieved w/ Full Fertilizer Increase (>= 80% is on track)
CB Watershed	Agriculture	-0.073	-0.060	-0.048	-0.035	22%	22%	22%	21%	20%
CB Watershed	Developed	-0.467	-0.467	-0.467	-0.467	0%	100%	100%	100%	100%
CB Watershed	Wastewater	0	0	0	0	96%	96%	96%	96%	96%
CB Watershed	Septic	0	0	0	0	0%	0%	0%	0%	0%
CB Watershed	Natural	-0.171	-0.167	-0.163	-0.160	36%	56%	55%	55%	55%
CB Watershed	AllSources	-0.711	-0.694	-0.678	-0.662	65%	83%	83%	82%	82%

Change in Nutrient Loads to the Chesapeake Bay

Differences between CAST versions w/ increasing fertilizer levels by jurisdiction for 2021 Progress scenario

Nitrogen Loads

		CAST19 to CAST21 Change w/ 25% Fertilizer Increase (M lbs)	CAST19 to CAST21 Change w/ 50% Fertilizer Increase (M lbs)	CAST19 to CAST21 Change w/ 75% Fertilizer Increase (M lbs)	CAST19 to CAST21 Total Change From Updates (M lbs)	CAST19 % Goal Achieved w/ Uncorrected Fertilizer (>= 80% is on track)	CAST21 % Goal Achieved w/ 25% Fertilizer Increase (>= 80% is on track)	CAST21 % Goal Achieved w/ 50% Fertilizer Increase (>= 80% is on track)	CAST21 % Goal Achieved w/ 75% Fertilizer Increase (>= 80% is on track)	CAST21 % Goal Achieved w/ Full Fertilizer Increase (>= 80% is on track)
New York	AllSources	0.571	0.631	0.690	0.750	69%	47%	45%	42%	40%
Pennsylvania	AllSources	1.426	1.939	2.418	2.898	22%	17%	15%	14%	13%
Maryland	AllSources	0.362	0.626	0.889	1.153	58%	53%	51%	48%	46%
Virginia	AllSources	0.140	0.275	0.410	0.540	75%	75%	74%	73%	72%
West Virginia	AllSources	-0.216	-0.201	-0.186	-0.172	100%	100%	100%	100%	100%
Delaware	AllSources	0.488	0.567	0.646	0.724	20%	0%	0%	0%	0%
District of Columbia	AllSources	-0.002	-0.002	-0.002	-0.002	100%	100%	100%	100%	100%
CB Watershed	AllSources	2.771	3.835	4.865	5.896	42%	37%	36%	34%	33%

Phosphorus Loads

		CAST19 to CAST21 Change w/ 25% Fertilizer Increase (M lbs)	CAST19 to CAST21 Change w/ 50% Fertilizer Increase (M lbs)	CAST19 to CAST21 Change w/ 75% Fertilizer Increase (M lbs)	CAST19 to CAST21 Total Change From Updates (M lbs)	CAST19 % Goal Achieved w/ Uncorrected Fertilizer (>= 80% is on track)	CAST21 % Goal Achieved w/ 25% Fertilizer Increase (>= 80% is on track)	CAST21 % Goal Achieved w/ 50% Fertilizer Increase (>= 80% is on track)	CAST21 % Goal Achieved w/ 75% Fertilizer Increase (>= 80% is on track)	CAST21 % Goal Achieved w/ Full Fertilizer Increase (>= 80% is on track)
New York	AllSources	-0.001	0.001	0.003	0.005	76%	77%	76%	75%	74%
Pennsylvania	AllSources	-0.054	-0.047	-0.041	-0.034	48%	51%	50%	50%	49%
Maryland	AllSources	-0.467	-0.464	-0.462	-0.459	74%	100%	100%	100%	100%
Virginia	AllSources	-0.270	-0.266	-0.262	-0.257	72%	91%	91%	90%	90%
West Virginia	AllSources	0.063	0.064	0.064	0.065	97%	65%	65%	65%	64%
Delaware	AllSources	0.022	0.022	0.022	0.023	52%	0%	0%	0%	0%
District of Columbia	AllSources	-0.003	-0.003	-0.003	-0.003	100%	100%	100%	100%	100%
CB Watershed	AllSources	-0.711	-0.694	-0.678	-0.662	65%	83%	83%	82%	82%

Urban Stormwater Workgroup (USWG) Effort to Revisit Urban Fertilizer Application

Two-phased approach:

Phase 1 –

- Short-term effort to revisit options to improve how urban fertilizer is applied to turfgrass in CAST.
- Kick-off in September 2022
- Small committee meets 2-3 times to develop and review short-term options for improving urban fertilizer application based on current data sources.
- USWG seeks to approve new method by May 2023.

Phase 2 –

- Longer-term effort to address Phase 7 improvements to both urban nutrient application/simulation and urban nutrient management BMPs
- Kick-off in Summer 2023 (likely 6-10 month effort, minimum)
- Refresh the committee, bring in academic and research partners as well as more local practitioners. Membership closer to 10-12, plus support staff.
- Key scope –
    - Evaluate findings from Tom Butler's work on new potential fertilizer data sources and make recommendations for improving tracking and reporting
    - Review scientific literature on urban nutrient sources and processing to determine if new approaches are needed in Phase 7
    - Evaluate options for improving UNM credit with a focus on addressing fertilizer legislation impacts and non-fertilized lands

PSC Fertilizer Support

Task

What?

- An evaluation of agricultural and urban fertilizer data sources.

Why?

- Multi jurisdictional and Principals' Staff Committee request

Deliverables?

- Inorganic fertilizer input
  - Status quo, supplemented with jurisdictional data, or something new.

1

Key Scoping Questions

- Are there other data sources that can inform nutrient application rates?
  - Specifically, are there any new sources of jurisdiction-generated data?
- At what scale are fertilizer sales and use data available?
- What is the feasibility of collecting more relevant jurisdictional level data?
- Are there streamlined methods of tracking and reporting without undue burden on the local and jurisdictional agencies?
- What improvements in nutrient data and application can we recommend for Phase 7

1

Bay Program Commitments

Role	POC
Lead	Tom Butler
Agriculture	Mark Dubin, Loretta Collins, Ruth Cassilly
CAST	Olivia Devereux, Jessica Rigelman
Watershed Technical Workgroup	Vanessa Van Note, Jeff Sweeney
Modeling Workgroup	Gary Shenk
Urban Stormwater Workgroup	David Wood

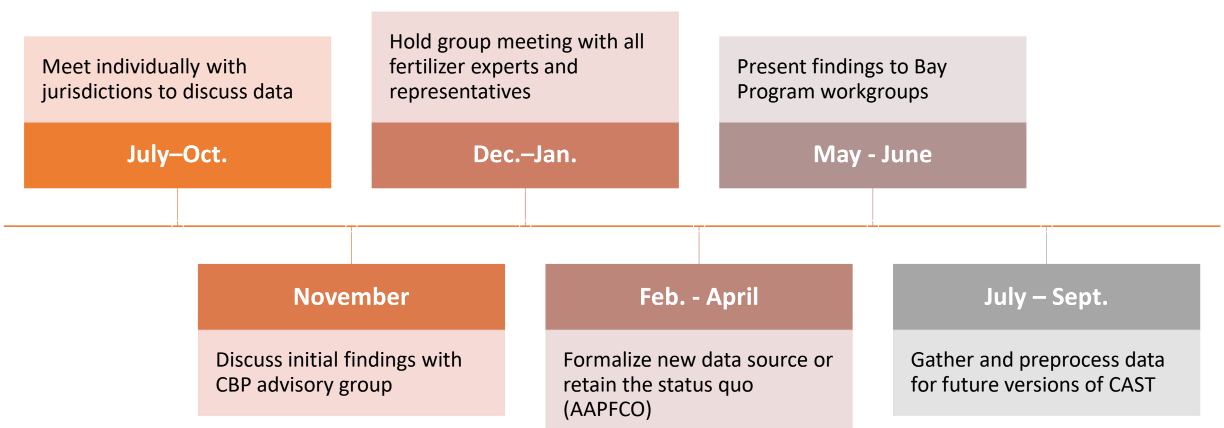
1

Jurisdiction Commitments

Jurisdiction	POC	Fertilizer Expert
MD	Elizabeth Hoffman	Tom Phillips
PA	Frank Schneider	David Dressler
NY	Greg Albrecht	Jan Morawski
VA	Seth Mullins	David Gianino
DE	Clint Gill	Justin Lontz
WVA	Dave Montali	Joshua Arbaugh
DC	Jonathan Champion	Cecilia Lane
NPS	Rene Senos	In progress
DOD	Kevin DuBois	Jessica Rodriguez

1

PROPOSED Timeline



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Current Progress

- Individual jurisdiction meetings
- Direct data collection
- Coordination with industry contacts
- Larger EPA conversations

How can we help inform fertilizer?

- Foundation for phase 7 investigations
- We have the correct experts from each jurisdiction who work with fertilizer data
- We have gathered several data sets which can potentially:
  - Help us verify our current data source
  - Improve the latency of fertilizer tonnage data
  - Update jurisdictional data sources-directly instead of through AAPFCO

Fertilizer data investigation short term fix PSC discussion

Background:

The Chesapeake Bay program partnership is concerned with the quality of fertilizer data used to run the Chesapeake Assessment Scenario Tool (CAST). And at the August 29th PSC meeting consensus was reached to examine a data source for the current version of CAST. But there is no formal group prepared to examine both the urban and agricultural fertilizer data. Therefore, we propose using an informally established team to support the PSC's request to examine the fertilizer inputs in the current CAST version.

Current informal teams' task:

- An evaluation of fertilizer sales data reported by state fertilizer experts.

Scoping questions that have driven the work:

- Are there other data sources that can inform nutrient application rates?
    - Specifically, are there any new sources of jurisdiction-generated data?
- At what scale are fertilizer sales and use data available?
- What is the feasibility of collecting more relevant jurisdictional level data?
- Are there streamlined methods of tracking and reporting without undue burden on the local and jurisdictional agencies?
- What improvements in nutrient data and application can we recommend for Phase 7

Current informal team participants:

The informal team currently has a group of Chesapeake Bay Program Office (CBPO) employees (Table 1.) who serve as expert advisors. These advisors work to ensure that the current fertilizer data needs of CAST will be met.

Role	POC
Lead	Tom Butler
Agriculture	Mark Dubin, Loretta Collins, Ruth Cassilly
CAST	Olivia Devereux, Jessica Rigelman
Watershed Technical Workgroup	Vanessa Van Note, Jeff Sweeney
Modeling workgroup	Gary Shenk
Urban Stormwater Workgroup	David Wood

Table 1. Current Chesapeake Bay Program Advisory members.

In addition to the CBPO advisors there are jurisdictional representatives and fertilizer experts from each of six states and Washington D.C. (Table 2.). These participants were provided by jurisdictions via the Agriculture Workgroup (AgWG) and Urban Stormwater Workgroup (USWG). Jurisdictional representatives act as a point of contact that ensures relevant information is disseminated to their jurisdictions. Fertilizer experts are the people who handle the states fertilizer tonnage collection as well as other sources of fertilizer data from within the state.

Jurisdiction	State POC	Fertilizer Expert
MD	Elizabeth Hoffman	Tom Phillips
PA	Frank Schneider	David Dressler
NY	Greg Albrecht	Jan Morawski
VA	Seth Mullins	David Gianino
DE	Clint Gill	Justin Lontz
WVA	Dave Montali	Joshua Arbaugh
DC	Jonathan Champion	Cecilia Lane

Table 2. Current Jurisdictional representatives and fertilizer experts.

Informal Team Workplan/timeline:

The informal team has been meeting with jurisdictional representatives and fertilizer experts since June 2022. Each meeting to date has been with an individual jurisdiction to establish a baseline for each jurisdiction's data reporting and management.

Upon the conclusion of these meetings there will be a discussion of the initial findings amongst the CBPO advisory group. This meeting will create the stage for how best to address data needs with jurisdictional data.

After determining the best way to proceed we plan to hold a large meeting with all the jurisdiction representatives and fertilizer experts. This meeting is designed to get each jurisdiction on the same page and examine the ability of each to provide updated fertilizer data directly to the CBPO. There are several concurrent efforts examining industry data which can be discussed at this meeting. If useful we can begin our own effort to examine industry data sources.

The next step is another CPBO advisory meeting to draft a presentation to and either propose a new data source or confirm the status quo as the best source of fertilizer data. This presentation would then be given to relevant workgroups within the CBPO. The proposed data source would then be collected and employed in the Phase 7 CAST.

A timeline of these proposed activities is presented in figure 1.

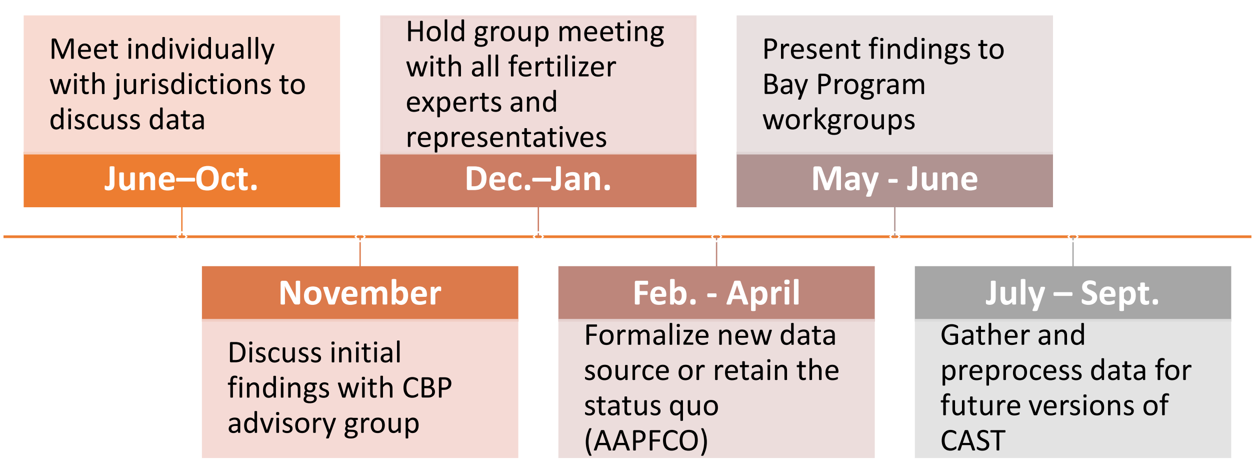


Figure 1. Outline for the examination of alternative fertilizer data sources.

Deliverables:

As a result of this investigation, we will provide phase 7 watershed model inorganic fertilizer input data. These input data have the potential to be the status quo, AAPFCO data, or a new source such as direct state reporting. It is important to note that AAPFCO data are state reported. If AAPFCO is reaffirmed as the best source of inorganic fertilizer data ,this will be confirmed with a comparison of AAPFCO reports with data that is reported directly from the jurisdictions.

How we can help inform phase 6:

- We have the correct experts from each jurisdiction who work with fertilizer data
- We have gathered several data sets which can potentially:
    - Help us verify our current data source
    - Improve the latency of fertilizer tonnage data
    - Update state data sources-directly from states instead of through AAPFCO

Fertilizer Data Sources

Jurisdictions expressed concern that the American Association of Plant Food Control Officials (AAPFCO) data are not more current. The most recent year that AAPFCO was able to provide to the Bay Program for CAST-21 was 2016. Jurisdictions expressed concern that the conditions in agriculture have changed since 2016, and these older data do not represent recent trends. In addition, New York ceased participating in reporting data to AAPFCO since 2016.

Jurisdictions also expressed concern about the data quality suggesting that it is not reflecting the fertilizer application to crops. Jurisdictions recommended that inflation and high costs of fertilizer should be accounted for in the model projections.

Review of the USDAs Natural Resource Conservation Service's (NRCS) Conservation Effects Assessment Program (CEAP) II Cropland Assessment for 2013 to 2016 show those data follow the same trends as the AAPFCO data. In addition, the AAPFCO data are processed by the Bay Program in a way that uses the USDA National Agricultural Statistics Service (NASS) fertilizer expense trends to further refine the data (described separately).

Ms. Jill Whitcomb, Director of the Chesapeake Bay Office of the Pennsylvania's Department of Environmental Protection, provided an alternative source of data to replace or augment the AAPFCO data. A summary of the datasets is below.

- AAPFCO data does not have the most recent data available, as it only goes through 2016. NASS has data available for major crops through 2021.
- AAPFCO data is available at the county scale, whereas annual NASS survey fertilizer data is available at the state level.
- AAPFCO accounts for all fertilizer sold, regardless of crop type. NASS survey data includes data for major crops, corn, and soybeans, which comprise 35% of all crops. NASS data, however, does not include sufficient data for wheat, which is another significant crop type in the Chesapeake Bay Watershed.

Table 1: Years, Scale, and Crops Available for AAPFCO and NASS Fertilizer Data

	AAPFCO	**NASS**
Years of Data	1985-2016	1990-2021
Scale	County	State
Crops	All agricultural fertilizer sold	Major Crops – Corn, Soybeans

Table 2: Years of NASS Survey Corn Fertilizer TN Application Rate Data Available by State. The X indicates the data is available in that year for that state.

	2016	2017	2018	2019	2020	2021	2022
Delaware							
Maryland							
New York	X		X			X	
Pennsylvania	X		X			X	
Virginia							

West Virginia							

Table 3: Years of NASS Survey Soybean Fertilizer Phosphate Application Rate Data Available by State. The X indicates the data is available in that year for that state.

	2016	2017	2018	2019	2020	2021	2022
Delaware							
Maryland							
New York							
Pennsylvania					X		
Virginia			X				
West Virginia							

Current Methods and Proposed Solutions

AAPFCO data are currently being used as a watershed-wide stock. Fertilizer sales data is reported by the states to AAPFCO at the county scale. The fertilizer data processing includes steps for removing outliers and smoothing the annual trends using NASS fertilizer expenses (described separately).

Pennsylvania proposed a new fertilizer data method to use application rates for the crops that NASS has in annual surveys, and create a fertilizer stock based on those data. The fertilizer can be distributed amongst the counties in each state based on the amount distributed in the 5-year NASS Censuses. The tables above show the availability of the data for each state for years after the most recent AAPFCO data. Note that these data are not available for MD in any year, and are only available for certain years in other states. The crops available comprise less than half of the crops planted in the watershed. Graphs of the data available upon request.

- Data are limited to certain years
- Some states do not have any data available outside of the Census (in years ending in 2 and 5)
- Less than half of the total area that is considered cropland is in corn and soybeans. There is less of wheat crop data available than even the corn or soybeans.

While the method is sound, the lack of data is a barrier.

Review of CAST Prior to Releasing an Updated Version

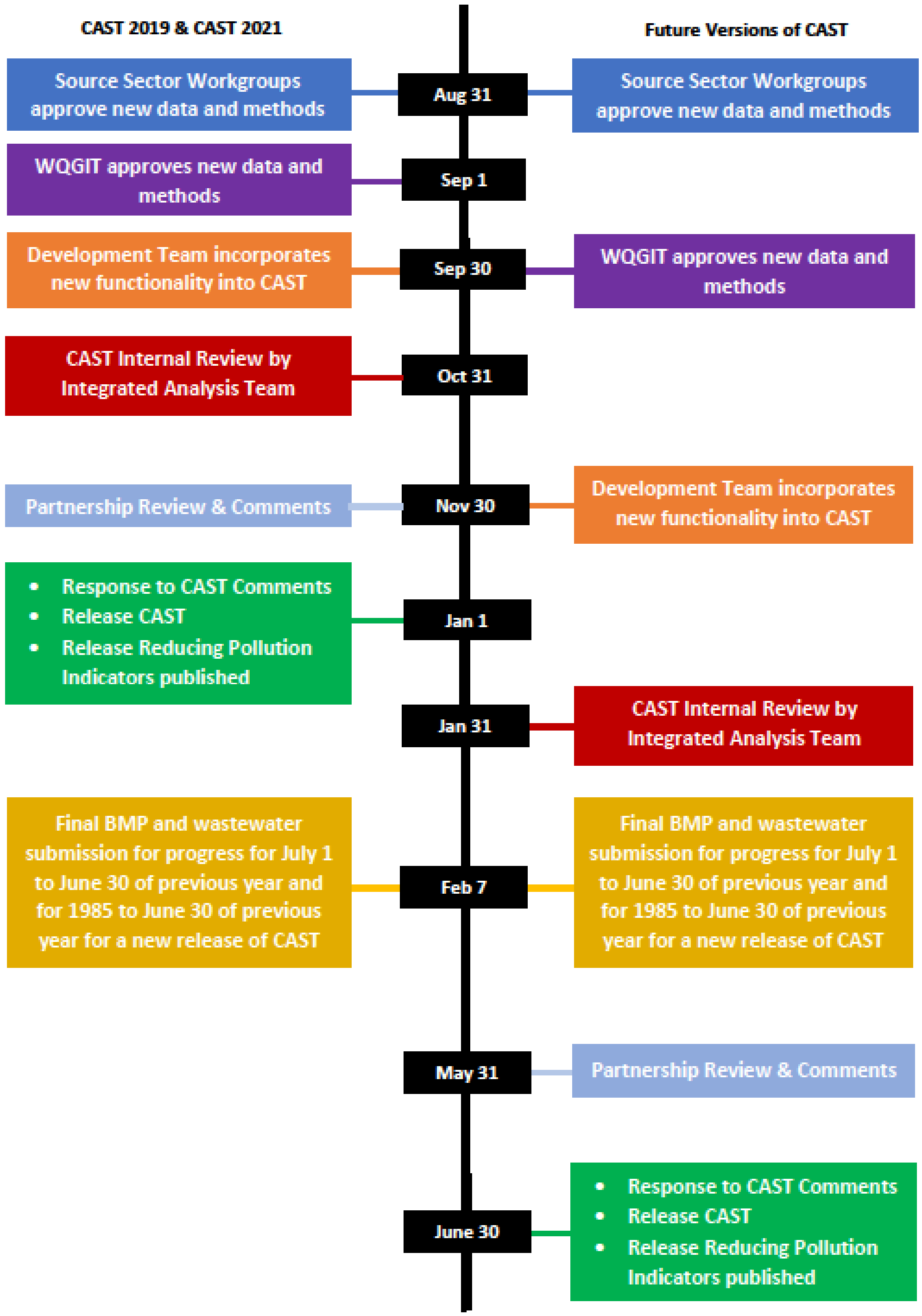
The flowchart schedule below shows the process steps and schedule for CAST releases. The left flowchart is the initial schedule developed for CAST-2019 and CAST-2021 updates. The right flowchart is one option for future CAST version updates.

For CAST-2021, we spent the month of September undertaking an internal review of the processed CAST nutrients applied and loads data. This included graphing those data and providing the data and graphs to the Integrated Analysis team members. The data review is an important step that allows us to be prepared for the questions and concerns that we anticipate the WQGIT and others to bring forward. This analysis focused on the following:

- Identifying shifts in overall loads
- Determining if some states are disproportionately affected or if loads shift in different directions for some states
- Assessing which load sources show the most change
- Determining how much of the changes are due to data updates and how much is due to the updated BMP history.
- All detailed updates are posted here: https://cast.chesapeakebay.net/About/UpgradeHistory

Improvements are necessary and welcome. The process outline below can serve as the basis of a framework for addressing data abnormalities evidenced in CAST going forward.

Other materials address the processing of source NASS and AAPFCO data prior to use in CAST or comparisons with monitored data. Addressing data abnormalities in those sources can be done separately.


CAST 2019 & CAST 2021
Future Versions of CAST
Source Sector Workgroups approve new data and methods
Aug 31
Source Sector Workgroups approve new data and methods
WQGIT approves new data and methods
Sep 1
Development Team incorporates new functionality into CAST
Sep 30
WQGIT approves new data and methods
CAST Internal Review by Integrated Analysis Team
Oct 31
Partnership Review & Comments
Nov 30
Development Team incorporates new functionality into CAST
• Response to CAST Comments
• Release CAST
• Release Reducing Pollution Indicators published
Jan 1
Jan 31
CAST Internal Review by Integrated Analysis Team
Final BMP and wastewater submission for progress for July 1 to June 30 of previous year and for 1985 to June 30 of previous year for a new release of CAST
Feb 7
Final BMP and wastewater submission for progress for July 1 to June 30 of previous year and for 1985 to June 30 of previous year for a new release of CAST
May 31
Partnership Review & Comments
June 30
• Response to CAST Comments
• Release CAST
• Release Reducing Pollution Indicators published

Chesapeake Bay Program Modeling Tools

The Chesapeake Bay Program uses state-of-the art science and monitoring data to replicate conditions of the Chesapeake Bay watershed. This information is then used by decision-makers at the federal, state and local levels to determine how best to restore and protect local waterways, and ultimately, the Chesapeake Bay. By combining advanced modeling tools and real-world monitoring data, we gain a comprehensive view of the Chesapeake ecosystem—from the depths of the Bay to the upper reaches of the watershed.

The suite of computer modeling tools developed by the Chesapeake Bay Program divides the 64,000-square-mile watershed into thousands of smaller segments and helps us predict the impacts of best management practices (BMPs) and policies at the regional and local level. The most significant value of the suite of modeling tools is the ability to predict how the Chesapeake Bay may respond to future conditions such as pollutant loads, land use changes and climate change.

Chesapeake Bay Total Maximum Daily Load

The Chesapeake Bay Total Maximum Daily Load (Bay TMDL) identifies the necessary pollution reductions from major sources of nitrogen, phosphorus and sediment across the seven watershed jurisdictions—Delaware, the District of Columbia, Maryland, New York, Pennsylvania, Virginia and West Virginia—and sets pollution limits necessary to meet water quality standards across the Chesapeake Bay. The Bay TMDL calls for all pollution control programs and practices to be in place by 2025 that will result in the eventual attainment of these water quality standards. Each jurisdiction prepares a Watershed Implementation Plan (WIP) to guide their efforts in reducing nitrogen, phosphorus and sediment pollution.

Extensive measures exist to ensure accountability for reducing pollution and meeting target dates for progress under the Bay TMDL. As part of this accountability framework, two-year milestones are in place to increase restoration work and ensure progress.

The Chesapeake Bay Program uses adaptive management in our decision-making framework, which allows us to learn while doing. Through adaptive management, we predict (plan) using the model, we implement BMPs and take management actions (act) to reduce nitrogen, phosphorus and sediment loading, we follow up by observing the response of the ecosystem (monitor) and then we adjust our approach and assumptions (adapt) based on what was predicted versus what actually happened. We make changes to our tools, update monitored and measured inputs, incorporate new science and revisit our predictions to formulate the next set of actions to take. This is how the partnership utilizes the principals of adaptive management.

Chesapeake Bay Watershed Model

The Chesapeake Bay Program has a suite of modeling tools that work together to determine how much nitrogen, phosphorus and sediment pollution is entering local waterways, where it is coming from, how local actions will help reduce it and much more. However, it is the Chesapeake Bay Watershed Model that estimates the amount of nitrogen, phosphorus and sediment pollution reaching the Chesapeake Bay.

The Chesapeake Bay Watershed Model is available as a free, web-based tool called the Chesapeake Assessment Scenario Tool (CAST), that helps users determine which BMPs may be the most cost-

effective and relevant to meeting nitrogen, phosphorus and sediment pollutant reduction goals for a given area.
To get started with CAST, users specify a region and then select BMPs to apply on that area. CAST then builds a scenario, which provides estimates of how much nitrogen, phosphorus and sediment pollution will be reduced. The estimated cost of this scenario is also provided so that users may select the practices that may be the most economical.

The tool is in use by counties, states, watershed groups and other units of local government across the Chesapeake Bay watershed for total maximum daily loads (TMDLs), nonpoint source pollutant management and municipal stormwater programs. It can help users better understand:

- Which BMPs could provide the greatest load reduction.
- The extent to which these BMPs could be implemented based on available resources and land availability, as well as the cost of implementation.
- How to refine the selected BMPs to meet planning needs.

CAST is one of four measures used by the Chesapeake Bay Program to assess progress toward meeting restoration goals. The other three measures look at tidal water quality trends, non-tidal loading trends (what and where conditions are improving, degrading or staying constant) and programmatic actions (such as policies, regulations and incentive programs) that the jurisdictions commit to implement through their WIPs and milestones.

Updating the Watershed Model

The Chesapeake Bay Program strives to use the best available science, data and information to inform and support our shared restoration efforts and collective decision-making processes. Given that scientific methods and data evolve over time, the partnership has discussed and debated how it can use and incorporate new methods and data into its modeling tools, while also retaining some amount of stability in the planning and implementation processes. In the past, updates to the model occurred whenever new data and information became available, without a defined schedule, causing logistical and communication challenges.

In 2014, the Modeling Workgroup under the Water Quality Goal Implementation Team (GIT) conducted a year-long investigation that deliberated how best to introduce new data and methods into the Chesapeake Bay Program modeling tools. The reason for this investigation was the 2012 U.S. Department of Agriculture (USDA) Census of Agriculture, 2011 National Land Cover Dataset and projections of human population growth from the jurisdictions. The impact of adding these new datasets was an increase in modeled nitrogen loads for Maryland, New York, Pennsylvania and West Virginia, and decreases in modeled nitrogen loads for Delaware, the District of Columbia and Virginia. Upon completing the investigation, the Milestone Workgroup made the recommendation to the Water Quality GIT that all jurisdictions should be evaluated with the same model that they used to develop their two-year milestones.

In December 2015 and January 2016, the Water Quality GIT and the Management Board, respectively, reached consensus on the recommendations from the Modeling Workgroup. It was decided that with the development of each jurisdiction's 2016-2017 milestones, the partnership would hold the assumptions set at the beginning of the milestone period constant over the following two years. Any changes to the decision to update the model every two years requires formal review and approval by the partnership.

Land uses would be predicted at the beginning of the milestone period and these projections would not be changed. At the end of the two years, Bay Program partners would factor in new information, BMP efficiencies and data previously approved by the partnership, into past and present progress runs, going back to 2009. With the introduction of new BMPs into the model, the jurisdictions then had the opportunity to go back and update their past reporting, using this new information.

The process for updating the model and transitioning to new versions is approved and directed by the partnership. By holding assumptions constant for the milestone period and updating with new data and information every two years, the model more accurately reflects what is happening on the ground. Changing conditions in the watershed can have as much, if not more, of an effect on nutrient and sediment pollutant loads, than BMP implementation.

Rationale

By consistently adding and refining new science, data, information and methods used in the model every two years, we get a better understanding of how our management actions and decisions may be impacting water quality and living resources across the Chesapeake Bay watershed. Some of these updates may include changes in livestock populations or land cover (e.g. forested land becoming urban). Accurately capturing these changes on a regular basis helps us understand if overall watershed health is improving or not, and why. These changes also measure historical progress and trends over time.

Updates to the model can change the amount of pollution estimated to enter the Bay from the rest of the watershed. For example, if there are more chickens in a given geographic area than previously reported and reflected in the model, this may show an increase in estimated nutrient loads because of additional manure. Subsequently, when new datasets are released, such as from the USDA Census of Agriculture, or high-resolution land cover, estimated pollutant loads may increase or decrease, particularly if future projections are being adjusted to account for the latest data. These adjustments, while having a potential impact on pollutant loads, are critical to the model as they show the most accurate representation of changes that have occurred over the last two years or more for a given geographic area.

These changes could mean that jurisdictions may have to adjust their implementation efforts to account for any increases in estimated pollutant loads. However, these potential changes in pollutant loads do not call for edits to a jurisdiction's WIP or local action plan. WIPs do not change unless a jurisdiction decides to do so, since they are official state documents.

There are technical and communication challenges with updating the model every two years. Although the 2025 Phase III WIP planning targets do not change, a given year's target and the level of effort needed to achieve the 2025 goal can modify, because historical progress runs will shift when they are re-calculated using new data and information.

New data means incorporating the effects of an ever-changing landscape (e.g., forest lands can become developed or turned into agricultural land). New data means a better estimate of animal populations and the amounts of crops grown. New data means updated science and our ability to incorporate information like high resolution land cover/land use. Finally, in this not all-inclusive list is updating BMP information to include new practices not previously included in the model, as well as updated efficiencies for existing BMPs.

These updates may impact a jurisdiction's level of effort in meeting their pollutant reduction goals. For example, if there was a huge increase in the acreage of soybeans being grown compared to what was previously reported, this will show as a rise in estimated pollutant loads as nitrogen from the roots, leaves and pods (that are not harvested) die and decompose, running off the land into the water. If previously reported lands used for agricultural production are taken out of use, there will be a decrease in estimated pollutant loads.

The differences show both greater improvements and degradations than were previously estimated – depending on the scale. This all leads to the Environmental Protection Agency (EPA) conducting two assessments of progress – one with the older version of the model and one with the updated version of the model. Each progress run will show different levels of achievement toward pollutant reduction goals. It can be difficult to explain to other partners and stakeholders the rationale behind these two assessments, and questions often arise about which version of the model should be and is available to use, for the next two-year milestone period.

If the model remains unchanged over time, no new BMPs will be added, no changes will be made to reflect BMP efficiencies, no updates will exist for land use/land cover data and there will be no realization of changes to livestock populations—just to name a few examples.

In making the decision to update the model every two years, the partnership evaluated the impact of allowing for changes versus locking the information down. It was known and understood that these updates would cause changes in pollutant loads for each jurisdiction.

The argument for model updates

TMDLs are plans put into place to restore impaired waterways by identifying the amount of pollution that a water body can receive while still meeting water quality standards. In particular, TMDLs address impairments to water quality that are not fully removed through point sources. In regard to the Bay TMDL, if new science, data and information are not incorporated into the model to reflect the best estimates of nutrient and sediment pollutant loads, then the model will not accurately predict how the actions taken today by each jurisdiction to reduce pollutant loads are helping to improve Bay water quality standards.

The partnership has invested millions of dollars into updating the Chesapeake Bay Program's suite of modeling tools in preparation for the Phase III WIPs and two-year milestones. The updates began in 2016 with the original high-resolution land cover analysis and continues to this day with the current six-year contract with the Chesapeake Conservancy.

Incorporating updated science, data and information, not only improves the accuracy of the model, but also helps restoration and conservation efforts from a variety of stakeholders. Additionally, it informs the ongoing collective efforts of Bay Program partners to better understand trends in water quality.

Updates are essential to maintaining public trust in the integrity of the restoration effort, particularly at the local level where people can easily verify whether our data reflects current conditions. Model updates are also essential for ensuring that our investments in restoration don't veer off course due to changing conditions in the watershed or scientific understanding.

How EPA uses the updated model

Before the model is updated, Chesapeake Bay Program partners can review any new data and information that is to be incorporated to ensure its accuracy. For the most recent round of updates (CAST-19), the Water Quality GIT began reviewing initial updated datasets in the summer of 2019. Once the updates are incorporated into the model, the partnership can run scenarios using the new version to see what changes have occurred for nutrient and sediment pollutant loads. For the newest version of the model, CAST-19, the Water Quality GIT has been reviewing the results of these scenario runs since fall 2019. The expectation is that this model will be used for the next two-year milestone period (2020-2021). The updated model will also be used for the annual BMP progress submissions and assessments over that same two-year period.

EPA uses the Chesapeake Bay Program approved suite of modeling tools – whether that be the current version, CAST-17, or the new version, CAST-19 – to assess progress for future milestone evaluations. EPA has also emphasized that its evaluations of progress are based on the partnership's decision that the Phase III WIP planning targets for 2025 will not change. If needed, it is the prerogative of each jurisdiction to revise their WIPs to adaptively manage their conservation efforts.

WIP targets and two-year milestones remain constant

In July 2018, the Principals' Staff Committee made the decision to approve the 2025 Phase III WIP planning targets for nutrient and sediment loads, using the Phase 6 Watershed Model, and stated that these targets would not change between that time and 2025, even with the addition of new science, data and information. Keeping the 2025 goals constant is intended to provide stability to state and local jurisdictions, while also allowing for the incorporation of the best available science, data and information into the model.

It is up to each jurisdiction to determine how they will reflect changes in pollutant loads into their WIPs and two-year milestones, as these are state-led efforts and official documents. It is not an EPA decision or expectation as to whether a jurisdiction should update its WIP or two-year milestones to reflect changes in pollutant loads. For example, it is the discretion of the Pennsylvania Department of Environmental Protection, in coordination with their local partners, to determine whether they want to update county targets to reflect the results from an updated version of the model or keep those targets the same. It is also a jurisdictional decision as to whether they should ask their counties for more reductions to account for any changes in pollutant loads. EPA's role in the partnership's accountability framework is to assess and report on the jurisdictions' progress toward for achieving the 2025 Phase III WIP planning targets, not each jurisdiction's localities (e.g. counties, townships), and to take appropriate federal actions, where warranted, at the jurisdiction level.

EPA and the Chesapeake Bay Program will continue to work closely with each jurisdiction on understanding and communicating shifts in pollutant loads due to model updates, and will continue to provide resources (e.g. staffing, financial) and technical assistance to support WIP and two-year milestone planning and implementation efforts.

Re-running old scenarios

When an updated version of the model is ready for use, EPA will use the new version to assess annual progress and evaluate future two-year milestones. It is recommended that users either re-run or create new scenarios in the updated version of the model to be consistent, but that is up to each user to determine. It is likely that re-running a scenario in an updated model could result in different numbers. A comparison tool between the older and newer version of the model will be available to help users understand any changes in the results between various scenarios. Chesapeake Bay Program management and staff continue to be available to provide technical assistance, including communications support, to help jurisdictions understand and apply any model updates to restoration planning and implementation.

Messaging challenges

Further discussions are needed by the partnership to determine options and approaches for how best to communicate this information to both targeted audiences and the general public. At a minimum, it is not just CAST users that should be aware of these updates but also program managers who are responsible for directing staff and resources toward providing and reviewing the information that informs these two-year model updates.

Chesapeake Bay Program

A Watershed Partnership

U.S. EPA Chesapeake Bay Program

University of Maryland Center for Environmental Science

Non-Point Source Data Analysis Quality Assurance Project Plan (QAPP)

Please proceed to the following page for the QAPP

Chesapeake Bay Program
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Non-Point Source Data Analysis Quality Assurance Project Plan

Jan 2022

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PROJECT MANAGEMENT

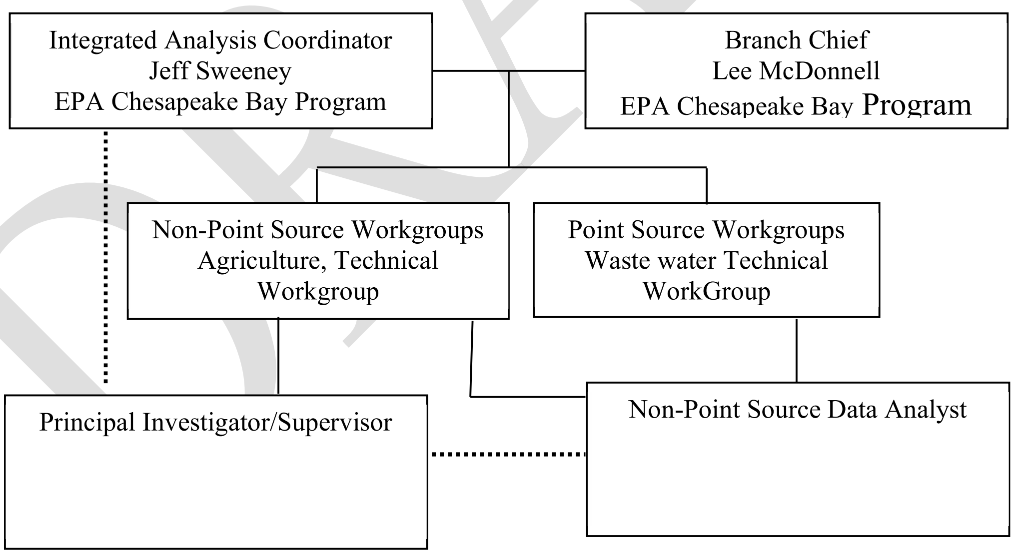
Project Staff and Organization

Key project staff responsible for project management, investigations, data processing and verification, and overall QA/QC are listed below. Although the Chesapeake Bay Program modeling team is not part of this specific project's organizational scheme, their names are also listed for their significant contributions to model design, coding, testing, and calibration; their understanding of non-point source input data requirements; and their overall involvement in achieving objectives of model output.

In addition, intended users of model output are not included in the listing or organization chart because of their high numbers. Users of model results are chiefly environmental management agencies in the Bay watershed jurisdictions (PA, MD, VA, DC, NY, WV, and DE), including members and participants of Chesapeake Bay Program Subcommittees and Workgroups, Federal agencies, state and Federal contractors, academic researchers, non-profit environmental organizations, and the press. The main user of the non-point source data project is the Chesapeake Bay Program Watershed Model (CBP WSM) itself.

Non-point source data project participants:

Figure 1. Organizational Chart



Project Objectives/Background

Managing non-point/point source pollutant information involves collection, analysis, and dissemination of Chesapeake Bay watershed data including land uses, animal and human populations, and point source and septic BMP implementation levels. The primary use of the information is to provide key input decks to the CBP Watershed Model used to guide environmental managers in their assessment of the impacts of nutrient and sediment control strategies on loads and, ultimately, water quality of the Chesapeake Bay and its tributaries.

The principal objective of the non-point/point source data project is to provide input files to the CBP Watershed Model for various scenarios ranging from historic and current watershed conditions to projected or future conditions. The level of confidence in historic or current data will be greater than that of projected conditions. A high level of confidence in the final point source data is achieved after each jurisdiction reviews and approves the compiled data. As databases used to formulate model input files are updated, their utilization will generally provide more accurate predictions for future watershed conditions. The project is considered on going since annually updated data continually become available and new facilities and better data are reported and employed.

This project is essential to a model application process and is separate from model development.The data quality issues addressed in the project plan are within a modeling application step and are specific to the tasks of data development. The project does not encompass a planning process to determine the need for a model or to decide whether or not a model currently exists that can be used to achieve these needs and requirements. The non-point source project plan assumes the application of an existing calibrated model that has undergone science peer review with considerations of the evolutionary nature of model development.

Project Description and Schedule

The non-point source data project is considered on-going with key milestones and associated dates identified previously in ***2014 Chesapeake Bay Watershed Agreement***. Interim deliverables would be the compilation and analysis of up-to-date information serving the CBP Watershed Model for its simulation of current nutrient and sediment loads to the Bay as well as determinations of additional affordable pollutant control measures necessary to meet water quality standards in the future. These control measures are eventually formalized into tributary strategies that achieve and maintain assigned loading caps to the nine major tributaries of the Chesapeake Bay as well as jurisdictional allocations within those tributaries.

The model simulation of nutrient and sediment loads and inputs to the model are continually refined as more accurate data becomes available and as computer power and understanding of pollutant cycling and transport improves. In other words, the model tool and its inputs are continually revised to better reflect the environmental processes taking place on the land and in river reaches so that pollutant management decisions are more informed and defensible. Through these refinements and the use of cross-media models, including both the Chesapeake Bay Program Watershed and Estuary Models, cap load allocations that are protective of the estuary's designated uses can be set, monitored, and reassessed as outlined in the ***2014 Chesapeake Bay Watershed Agreement***. The model simulations and inputs are used, in part, as the basis for planning purposes for removing the Chesapeake Bay and its tidal rivers from the Clean Water Act Section 303(d) list of impaired waters.

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Schedule:

Year 1:

1) Cooperate with agency and academic partners to develop, calibrate, and verify the watershed model.
2) Develop, adapt and maintain software systems to operate and calibrate the watershed model.
a) Development of Phase 6 Chesapeake Assessment Scenario tool(CAST)
b) Update Phase 5 Version of scenario builder and run scenarios to track progress of states in restoration of the Bay.
3) Collect feedback from panels on changes to Phase 6 model and incorporate the changes to address comments
4) Generate and analyze nutrient and sediment loads in the Chesapeake watershed, and interpret model results.
a) Complete 2016 Progress Scenario and other key scenarios and provide access to states through (Baytas.Chesapeakebay.net) and Chesapeake STAT portal
b) Provide Necessary inputs for the Phase 6 Watershed model
5) Ensure that data related to watershed modeling is accurately incorporated into the agricultural and nonpoint source databases and that the resultant information is properly communicated to the Chesapeake Bay Program Watershed Model.
a) Incorporate new Updates from AgCensus and State Non-Point Source databases into CAST tool.
b) Upload new Construction, Harvested forest and Land cover data for tracking yearly progress towards TMDL.
6) Assist states, the District of Columbia, and local jurisdictions with the development and assessment of implementation plans detailing practices necessary to meet TMDL allocations.
a) Run 2017 milestone implementation plans and provided necessary results to the states and local jurisdictions.
b) Make NEIEN error reports available through Baytas interface.
7) Develop data sharing agreements and partnerships required to support BMP data exchange across each of seven watershed jurisdictions' respective NEIEN nodes.
a) Update NEIEN look up tables in the database to incorporate and process new practices through Stored Procedures.
b) Collect requirements to add new schema elements in to NEIEN to track trading.

Year 2:

1) Assist the Chesapeake Bay Program and states with various tasks modeling the nutrient and sediment loads resulting from alternative management scenarios, such as developing, tracking, and, as necessary, adjusting two-year Chesapeake Bay restoration milestones.
a) Assist States and Local Jurisdictions in developing there 2019 Milestones and providing them necessary results.
b) Make necessary changes to the database to run 2017 Progress Scenarios and provide the nutrient and sediment load information to the states.

c) Assist states in Developing and running Draft and Final Phase III watershed Implementation plans.
d) Provides data management support for the CBP partners addressing wastewater discharged from facilities, combined sewer systems, on-site treatment systems, and regulated stormwater systems located across the entire Chesapeake Bay watershed.
2) Develop, adapt and maintain software systems to operate and calibrate the watershed model.
a) Continue development and Enhancing phase 6 version of the model (CAST).
b) Create new data visualization tools to interpret and analyze the results from Phase 6 model.
c) Update and enhance reports available in Baytas interface.
d) Develop application along with EPA consultant team to track yearly progress of Wastewater Treatment facilities.
3) Develop and operate the Chesapeake Bay Program agricultural and nonpoint source databases for watershed modeling.
4) Develop data sharing agreements and partnerships required to support BMP data exchange across each of seven watershed jurisdictions' respective NEIEN nodes.
a) Update NSPSBMP database to process trading information in NEIEN and make that data available to CAST tool.
5) Provide necessary technical support to build an optimization tool that can run simulations in parallel.
6) Provide Wastewater , On-site Treatment system, Spray Irrigation and other Point Source related data for Bay model scenarios in support of full range of analysis as needed by Bay program partners.

<u>Year 3:</u>

1) Develop, adapt and maintain software systems to operate and calibrate the watershed model.
a) Continue development of Watershed model and CAST tool and work on updating the database (SQL Server) to newer versions.
b) Update data visualization tools and create new reports to analyze and interpret watershed model results.
c) Incorporate new Updates from Agcensus, USDA census information for 2017 and State Non-Point Source databases and performance tune the existing stored procedures.
2) Provide support to the CBP partners through the preparation of reports, program materials, and scenario and model documentation
3) Assist States and Local Jurisdictions in developing and interpreting their Milestones and running their yearly progress towards the TMDL targets.
4) Work on building Geography codes in Point Source Application and provide necessary support to states for their 2019 Progress Submissions.
5) Assist the Nay program team in developing future enhancements to Point Source Application, like ability to submit WIP and Milestone information.

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<u>Years 4-6:</u>

1) Continued support of development of Scenario Builder and CAST tools
   https://sb.chesapeakebay.net/Login.aspx
   http://www.casttool.org/default.aspx?AcceptsCookies=yes
2) Add more reports to Baytas that can assist states in a better understating of the model results.
   https://baytas.chesapeakebay.net/Authenticate/Login?ReturnUrl=%2f

Semi-annual report

Throughout the project semi annual report on the progress made will be written by incumbent and submitted to EPA managers. The report will include details on the individual tasks completed, and in-progress. An annual review will be undertaken between the incumbent and Project officer to discuss achievements and progress towards the primary objectives of the project.

DATA ACQUISITION AND MANAGEMENT

Non-Direct Measurements (Data Acquisition Requirements)

Different types of data already existing within databases will be used as inputs to the model. The following are identifications of the project's data types, their non-direct measurement sources, general methodologies used in the conversion of source data to model input decks, and explanations about the use of the resulting input decks in the CBP Watershed Model. The four primary input decks that the non-point source data analyst is responsible for are discussed here– land uses, best management practices and their effectiveness, Crop Yields, Nutrient Inputs(Fertilizer and Manure), and also included are specific data acceptance criteria and any limitations on use of the data resulting from uncertainty in its quality.

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Crop Yields:

Phase 6 Model calculates yields for major crops according to yearly crop yield data provided by AgCensus, State submitted Max Yields and Yearly Yields data from NASS for Major crops listed below.

Crop Name
corn for grain
soybeans for beans
barley for grain
alfalfa hay
corn for silage or greenchop
wheat for grain
oats for grain

Yields are calculated for each crop in each county for each year. The step-by-step yield calculation procedure can be found below.

Datasets:

1) "Yearly NASS" yields for major crops
2) "Ag Census" yields
3) Scenario Builder "Max Yields"

Rule 1: Remove Outliers

1) Calculate Watershed-wide MEDIAN for crop for year for "Yearly NASS" data.
2) Calculate ABSOLUTE DEVIATION FROM MEDIAN as: Yearly County Crop Yield – Watershed-wide MEDIAN.
3) Calculate MEDIAN OF ABSOLUTE DEVIATIONS as: median of results from step 2.
4) Multiply result of step 3 by "4" to determine the MEDIAN OF ABSOLUTE DEVIATION OUTLIER CONSTANT
5) Add result of step 4 to result of step 1 to establish UPPER LIMIT.
6) Subtract result of step 4 from result of step 1 to establish LOWER LIMIT.
7) Remove all yields that do not fall within the range of UPPER LIMIT and LOWER LIMIT, making them NULL. Result becomes "Yearly NASS Revised."
8) Repeat process for "Ag Census" data. Result becomes "Ag Census Revised."

Rule 2: Populate with Yearly NASS yields

1) For each county, crop and year, calculate the average of the highest 3 out of the previous 5 values from "Yearly NASS Revised."
2) If NULL, make equal to most recent non-null value. For example, 1985 is NULL because there are not 3 previous values. Make 1985 equal 1988 where a non-NULL value exists.

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3) If NULL, make equal to the average yearly yield across Scenario Builder Growth Region. For example, 1990 is NULL for Somerset County, MD. Make 1990 equal average 1990 yield for Scenario Builder Growth Region MD_2.
4) If NULL, make equal to the average yield over all records for all years for the Scenario Builder Growth Region. For example, 1990 is NULL for ALL counties in Scenario Builder Growth Region MD_2, and no other data exists for Somerset County, so steps 1, 2 and 3 will not provide results. However, data exists for other counties within the Growth Region for other years. Make 1990 for Somerset County equal the average yield for all counties in the Growth Region over all years.
5) Result of above steps becomes "Yearly NASS Final."

Rule 3: Populate with Ag Census Yields

1) Repeat steps from Rule 2 above for "Ag Census Revised."
2) If NULL, make equal to the average of all available yields from "Ag Census Revised."
3) Result of steps becomes "Ag Census Final."

Rule 4: Combine Yearly NASS Final with Ag Census Final

1) If value exists in "Yearly NASS Final," use value.
2) If NULL, use existing values from "Ag Census Final."
3) Result of above steps becomes "USDA Combined Yields."

Rule 5: Calculate Ratio of USDA Combined Yields to Max Yields

1) For each county, crop and year, calculate the MAX YIELD RATIO from "USDA Combined Yields" to the value from "Max Yield."
2) Calculate a single COUNTY AVERAGE MAX YIELD RATIO over all crops for a single county from the results of step 1.
3) If NULL, make COUNTY AVERAGE MAX YIELD RATIO equal to most recent non-null value.
4) If NULL, make COUNTY AVERAGE MAX YIELD RATIO equal to the average of all COUNTY AVERAGE MAX YIELD RATIOS within Scenario Builder Growth Region for that year.
5) If NULL, make equal to the average of all COUNTY AVERAGE MAX YIELD RATIOS within Scenario Builder Growth Region for all years.
6) If NULL, make equal to 1.
7) Result of steps becomes MAX YIELD RATIO.

Rule 6: Calculate Revised Max Yields

1) Multiply Max Yield values by MAX YIELD RATIO for each county, crop and year.
2) Result of steps becomes "Revised Max Yields.

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Rule 7: Combine Revised Max Yields with USDA Combined Yields

1) If value exists in “USDA Combined Yields,” use value.
2) If NULL, use values from “Revised Max Yields.”
3) Result becomes “Combined Yields.”

Rule 8: Remove and Replace Outliers

1) Repeat steps from Rule 1 using “Combined Yields.”
2) If NULL, make equal to non-null value from “Combined Yields.”
3) If NULL, make equal to the average of yields for all counties within Scenario Builder Growth Region for that year.
4) If NULL, make equal to average of yields across all counties within Scenario Builder Growth Region for all years.
5) Result becomes “Final Yield”

Nutrient Inputs :

The major sources of nitrogen inputs into the watershed include legume fixation, manure/biosolids, commercial fertilizer, atmospheric deposition, point source discharges and septic runoff. The major sources of phosphorus into the watershed are commercial fertilizer, manure/biosolids, residual soil nutrients, point source discharges and rapid infiltration basins. Phase 6 model categorizes nutrient inputs to below categories.

- Organic sources (manure, biosolids, and spray irrigation) available for application to crops.
- Inorganic fertilizer available for application to crop

Manure Inputs (Animal Population):

The first step in estimating manure available in a county is to estimate the number of animals in existence on an average day in each county for the scenario year. The Phase 6 Model uses animal inventories for cattle, dairy, sheep, goats, swine, pullets, and layers that are provided every five years by the USDA-National Agricultural Statistics Service (NASS)’s Census of Agriculture. Five-year census of agriculture sales numbers are used for hogs for slaughter and pullets. Populations for broilers and turkeys are provided every year in USDA-NASS’s Poultry Production and Value surveys. Finally, populations for horses were provided by the states for the previous version of the modeling tools, and those populations were kept intact for the Phase 6 Model. The Census of Agriculture cannot release detailed sales or inventory data for an animal type if there are fewer than five operators raising that animal type within a county. When this occurs, the sales or inventory data are listed as non-disclosed. These non-disclosed values must be replaced with estimated sales or inventory values. The Algorithm to estimate these values can be found in section 3.2.1.1 of the model documentation.

Statewide populations for broilers, turkeys, Hogs and Pullets are provided every year in USDA-NASS’s Poultry Production and Value surveys and five year census. These statewide populations must be broken down into countywide populations for manure generation estimates. This is done

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by multiplying the annual, statewide value by the fraction of statewide Inventory of animals reported in the most recent Census of Agriculture.

Inorganic Fertilizer Inputs :

Crops in the Phase 6 Model also receive inorganic fertilizer inputs to meet nutrient application goals prescribed by states. The fertilizer data is provided by e Association of American Plant Food Control Officials (AAPFCO). AAPFCO provides County of fertilizer sale, Tons of fertilizer sold, Designated use of fertilizer (farm, non-farm or unknown), Concentration of nutrients within fertilizer sold. AAPFCO data cannot be directly used to estimate fertilizer use in a county because the data only reflects the county in which fertilizer was sold and not the counties where it is used. In order to address this Agricultural Modeling Subcommittee developed a unique fertilizer use estimation procedure which also relies upon AAPFCO fertilizer sales data. The steps the Phase 6 Model takes to estimate fertilizer use in each county are addressed briefly below.

Step 1: Sum Farm, Non-Farm, Unknown N and P205 individually by sales type, nutrient type and county for each county within NY, PA, MD, DE, VA and WV (both inside and outside the watershed counties) and by year:

The results become:

- Countywide Farm N and Farm P205 (individual numbers for each county and nutrient)
- Countywide Non-Farm N and Non-Farm P205 (individual numbers for each county and nutrient)
- Countywide Unknown N and Unknown P205 (individual numbers for each county and nutrient)
- Analyze the data for Outliers and Missing data. Establish rules to remove outlier data based on Standard deviation and median of historic data. Run a rolling Average to fill in missing values.

Step 2: Sum County Sales (by type and nutrient) across all counties by year. These totals become:

- Regionwide Farm N and Farm P205 (one number for each nutrient for each year)
- Regionwide Non-Farm N and Non-Farm P205 (one number for each nutrient for each year)
- Regionwide Unknown N and Unknown P205 (one number for each nutrient for each year)

Step 3: Sum Regionwide totals from step 2 to create the following:

- Regionwide N and Regionwide P2O5 (one number for each nutrient)

Step 4: Calculate fraction of regionwide sales made to farms by year dividing Regionwide Farm N by Regionwide N and Regionwide Farm P2O5 by Regionwide P2O5. Results become:

- Raw Fraction Farm N and Raw Fraction Farm P2O5 (one number for each nutrient for each year)

Step 5: Beginning in 1990, calculate a three-year rolling average fraction for farm sales by taking the average of the 1988, 1989 and 1990 Raw Fraction Farm N (or P2O5). Results become:

- Final Fraction Farm N and Final Fraction Farm P2O5 (one number for each nutrient for each year) – note, you will not have numbers for 1985 through 1989; set these values equal to 1990 Final Fraction Farm N and Final Fraction Farm P205.

Step 6: Calculate the final regionwide fertilizer sales available to farms each year by multiplying Regionwide N and Regionwide P2O5 by Final Fraction Farm N and Final Fraction Farm P2O5. Results become:

- Final Regionwide Farm N and Final Regionwide Farm P2O5 (one number for each nutrient)

Calculating Watershed Sales Bucket

Step 1: Calculate county expenditures on fertilizer by year using Ag Census data from 1997, 2002, 2007 and 2012 for each county within NY, PA, MD, DE, VA and WV (both inside and outside the watershed counties). Data for years between Ag Census years should be interpolated for each county. Data prior to 1997 should be equal to 1997. Data past 2012 should be equal to 2012. Results become:

- County Fertilizer Expenditures (individual numbers for each county and year)

Step 2: Calculate the total regional expenditures on fertilizer by year for all counties inside and outside the watershed. Results become:

- Regionwide Fertilizer Expenditures (one number per year)

Step 3: Calculate the total watershed expenditures on fertilizer by year for all counties INSIDE the watershed. Results become:

- Watershed Fertilizer Expenditures (one number per year)

Step 4: Calculate the fraction of regional expenditures that occurred within the watershed counties for each year. Results become:

- Fraction Watershed Fertilizer Expenditures (one number per year)

Step 5: Calculate the final watershed-wide fertilizer sales bucket by year by multiplying Regionwide Farm N and Regionwide Farm P2O5 by Fraction Watershed Fertilizer Expenditures. Results become:

- Watershed N Sales and Watershed P2O5 Sales (one number per nutrient per year)

Land Uses

To calibrate the Watershed Model, annual land use data are required for every land-river segment spanning the period 1985 – 2013. These data are combined with the **USDA** Census of Agriculture, NASS Annual surveys and other data sources to generate tabular land-use estimates that are read directly into the Watershed Model (Table 1 provides a list of the Phase 6 land uses). This data is termed as Base conditions data which is primarily used to run scenarios in the model.

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Apart from being used as base data to run calibration scenarios, this data is also used to run yearly progress scenarios, which gives a good measure in Tracking TMDL goals of Jurisdictions. The data is updated at regular intervals and frequency of these updates in model are listed in Table below(Table No 7). Land uses are grouped into agricultural, developed and natural categories. Details about how the acres of each land use are generated and how various datasets are integrated and reconciled are included within this section.

The final tabular Phase 6 land use database is the most accurate and detailed land use dataset that has ever been created for the Chesapeake Bay watershed. It is largely consistent across the region, enabling a fair assessment of the relative differences in nutrient and sediment sources throughout the watershed.

Developing this dataset required the generation of 1m-resolution land cover data, translation of these data into 1m-resolution land uses, aggregation of 1m-resolution land uses to 10m resolution, aggregation of 10m-resolution land uses to land-river segments, and integration of these data with the USDA Census of Agriculture and state-provided estimates of construction acres at the county scale. Different products are associated with each of these steps and all of them serve as valuable tools for guiding implementation actions and local-scale pollution reduction assignments.

The base year for the land use dataset is 2013, which is the year represented by most of the aerial imagery informing the 1-meter resolution land cover data. All other years are based on estimates of trends from 2013 back through 1985 as described below. Future land uses (2013 – 2025) for use in Phase III Watershed Implementation Plans will be simulated using the Chesapeake Bay Land Change Model v3a (CBLCM) and the Maryland Department of Planning's Growth Model (for Maryland only). These models and results will be discussed in forthcoming documentation.

Table 1: List of Phase 6 Land uses

Sector	Land use
Agriculture	Ag Open Space
Agriculture	Full Season Soybeans
Agriculture	Grain with Manure
Agriculture	Grain without Manure
Agriculture	Legume Hay
Agriculture	Silage with Manure
Agriculture	Silage without Manure
Agriculture	Small Grains and Grains
Agriculture	Double Cropped Land

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Agriculture	Specialty Crop High
Agriculture	Specialty Crop Low
Agriculture	Other Agronomic Crops
Agriculture	Other Hay
Agriculture	Pasture
Agriculture	Riparian Pasture Deposition
Agriculture	Permitted Feeding Space
Agriculture	Non-Permitted Feeding Space
Developed	Non-Regulated Roads
Developed	Non-Regulated Buildings and Other
Developed	Non-Regulated Tree Canopy over Impervious
Developed	Non-Regulated Tree Canopy over Turf Grass
Developed	Non-Regulated Turf Grass
Developed	MS4 Roads
Developed	MS4 Buildings and Other
Developed	MS4 Tree Canopy over Impervious
Developed	MS4 Tree Canopy over Turf Grass
Developed	MS4 Turf Grass
Developed	Regulated Construction
Developed	CSS Roads
Developed	CSS Buildings and Other
Developed	CSS Tree Canopy over Impervious
Developed	CSS Tree Canopy over Turf Grass
Developed	CSS Turf Grass
Developed	CSS Construction
Natural	CSS Mixed Open

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Natural	CSS Forest
Natural	Harvested Forest
Natural	True Forest
Natural	Non-tidal Floodplain Wetland
Natural	Headwater or Isolated Wetland
Natural	Mixed Open
Natural	Water
Natural	Stream Bed and Bank
Natural	Shoreline

High-Resolution Land Cover

"Land cover" represents observable characteristics of the land surface. For example, land may appear covered by impervious surfaces, herbaceous vegetation, or tree canopy. High-resolution (1m x 1m pixels) land cover data provided the basis for developing the Phase 6 land uses. These data were produced for 206 counties within, intersecting, and adjacent to the Chesapeake Bay watershed. The data were derived from 2013 or 2014 leaf-on aerial imagery from the USDA's National Agricultural Imagery Program, available leaf-off imagery produced by state and county agencies (variable vintages), and the latest LiDAR imagery available for approximately 75% of the watershed counties as of May 2016. Three contractors developed these data with the overall effort divided by states. Detailed information on how these data were produced and their classification schema are available from: http://chesapeakeconservancy.org/conservation-innovation-center/high-resolution-data/land-coverdata-project/

https://www.vita.virginia.gov/uploadedFiles/VITA_Main_Public/ISP/VGIN/Land_Cover/LandCover_Tech nicalPlanOfOperations_v7_20160506.pdf

Because the classification schema used in Virginia differed from the schema used in other states, a generalized cross-walk was developed to relate these land cover products to the Phase 6 land cover classes used to inform the Phase 6 land use.

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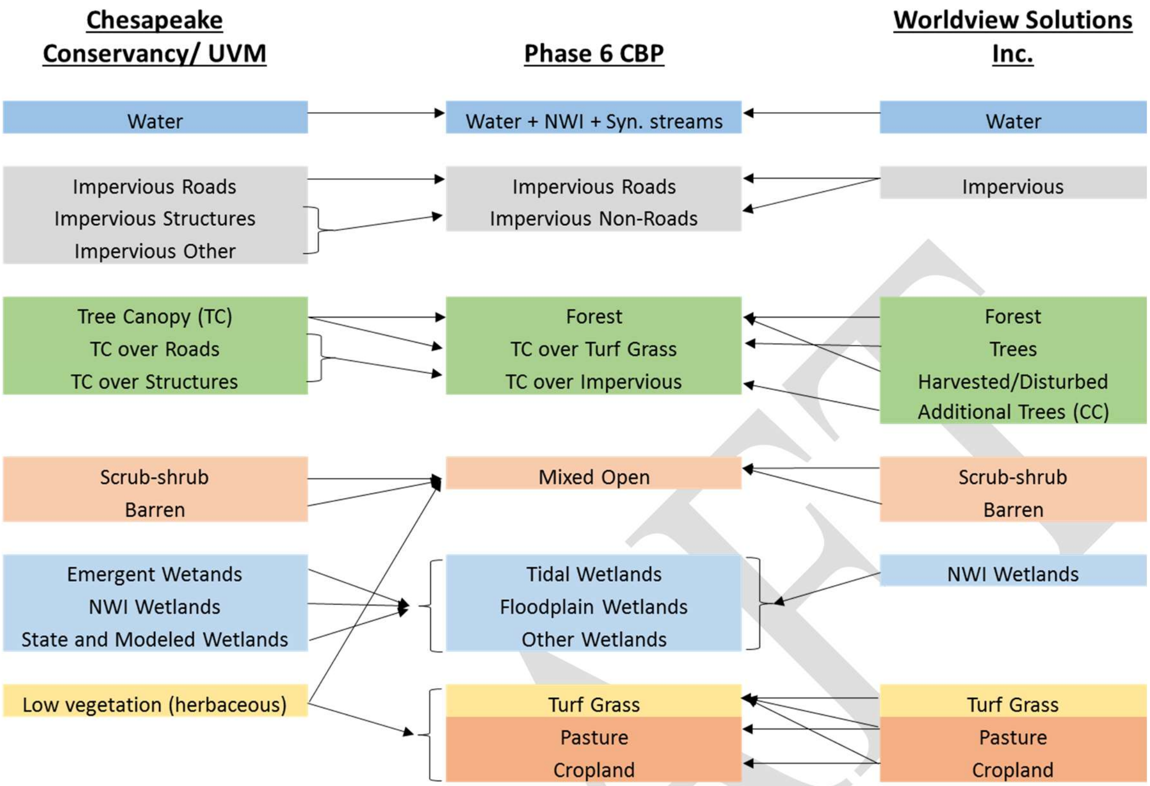
Figure 2: Land Cover Classification Schema



High-resolution Land Use

In contrast to land cover, "land use" represents how humans use the land (e.g., residential, commercial, agriculture, mining). Nutrient and sediment sources are related to land cover, land use, and land management. The CBP's land use classification schema was developed to represent a hybrid of both surface characteristics and use (land management is represented through reported Best Management Practices). The CBP Land Use Workgroup (LUWG) led this effort, working closely with the Forestry Workgroup, Urban Storm water Workgroup, Agriculture Workgroup, Watershed Technical Workgroup, Wastewater Workgroup, Federal Facilities Workgroup, Wetlands Workgroup, and Water Quality Goal Implementation Team to develop a set of classes that both represent unique sources of nutrients and/or sediments and could be mapped with available information. The LUWG also worked with these groups to develop the class definitions and decision rules required to map each class. Note that the WQGIT approved the proposal to not include an explicit extractive land use in the Phase 6 Watershed Model. Areas known to be extractive are simulated as "mixed open" and excluded from areas classed as agriculture or turf grass.

Categories of Mapped Land Use Classes

1) Impervious Non-Roads = buildings, driveways, sidewalks, parking lots, runways, some private roads, most railyards, and barren lands within industrial.

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2) Tree Canopy over Impervious Surfaces = trees over roads and non-road impervious surfaces.

3) Water = streams, ponds, canals, ditches, detention basins, reservoirs.

4) Floodplain Wetlands = National Wetlands Inventory (NWI) and state designated wetlands located within the FEMA designated 100-year floodplain or on soils with flooding characteristics.

5) Other Wetlands = National Wetlands Inventory (NWI) non-pond, non-lake wetlands, emergent wetlands mapped from high-resolution imagery outside Virginia.

6) Tidal Wetlands = National Wetlands Inventory (NWI) and state designated wetlands classified as marine and estuarine wetland systems, palustrine wetlands.

7) Forest = all standing trees and areas of tree harvest farther than 30’ to 80’ from non-road impervious surfaces and forming contiguous patches >=1-acre in extent.

8) Mixed Open = Small patches of trees (< 1 acre) outside developed areas, and all scrub-shrub, herbaceous, and barren lands that have been minimally disturbed.

9) Turf Grass = These include all herbaceous and barren lands within road rights of-way and residential, commercial, recreational, and other turf-dominated land uses (e.g., cemeteries, shopping centers) and a portion of herbaceous and barren lands within federal facilities, parks, institutional campuses, and large developed parcels.

10) Cropland = Herbaceous and barren lands that are not classed as turf grass or mixed open. The portion of such lands that are crops is determined by the frequency at which the lands are classified as crops in the NASS Cropland Data Layers (2008 through 2015)

11) Pasture/Hay = Herbaceous and barren lands that are not classed as turf grass or mixed open. The portion of such lands that are pasture/hay is determined by the frequency at which the lands are classified as pasture/hay in the NASS Cropland Data Layers (2008 through 2015).

12) Federal Agencies – For the purposes of accurately attributing land use management responsibilities to federal agencies, federal lands were mapped and grouped into nine federal agency categories

1) Agricultural Research Service,
2) Department of Defense,
3) Other Federal Land,
4) US Forest Service,
5) US Fish and Wildlife Service,
6) General Services Administration,
7) National Aeronautics and Space Administration,
8) National Park Service,
9) Smithsonian Institution and Other Federal.

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While land uses on federal lands were mapped, federal agencies were offered the opportunity to designate the condition of their herbaceous lands using an online Federal Facilities Editor Tool developed by the USGS. Agencies were asked to designate the proportion of cropland, pasture, mixed open, and turf grass composing all herbaceous lands within their properties. These estimates were explicitly accounted for in the Phase 6 mapping process. For agencies and federal lands that did not report these data to the CBPO, default rules were established based on the size of the federal properties.

Estimating Agricultural Acres

Acres of each agricultural land use which includes crops are estimated based upon acres of crops reported by the Census of Agriculture. Most Nutrient calculations are done on the crop level, the crops are eventually aggregated up to land uses containing crops with similar management. Table 2 lists the land use category for each crop.

Table 2: Land use category for Crops

Crop Name	Land Use
Alfalfa hay	Legume Hay
Alfalfa seed	Legume Hay
Aquatic plants	Specialty Crop Low
Asparagus	Specialty Crop Low
Barley for grain	Small Grains and Grains
Bedding/garden plants	Specialty Crop High
Beets	Specialty Crop High
Berries - all	Specialty Crop Low
Birdsfoot trefoil seed	Legume Hay
Broccoli	Specialty Crop High
Bromegrass seed	Other Hay
Brussels sprouts	Specialty Crop High
Buckwheat	Small Grains and Grains
Bulbs; corms; rhizomes; and tubers – dry	Specialty Crop High
Canola	Small Grains and Grains
Cantaloupe	Specialty Crop High
Carrots	Specialty Crop High

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Cauliflower	Specialty Crop High
Celery	Specialty Crop High
Chinese cabbage	Specialty Crop High
Collards	Specialty Crop High
Corn for grain	Grain with Manure
Corn for silage or greenchop	Silage with Manure
Cotton	Other Agronomic Crops
Cropland idle or used for cover crops or soil improvement but not harvested and not pastured or grazed	Other Agronomic Crops
Cropland in cultivated summer fallow	Other Agronomic Crops
Cropland on which all crops failed or were abandoned	Other Hay
Cropland used only for pasture or grazing	Pasture
Cucumbers and pickles	Specialty Crop High
Cut Christmas trees production	Specialty Crop Low
Cut flowers and cut florist greens	Specialty Crop High
Dry edible beans excluding limas	Other Agronomic Crops
Dry onions	Specialty Crop High
Eggplant	Specialty Crop High
Emmer and spelt	Small Grains and Grains
Escarole and endive	Specialty Crop High
Fescue seed	Other Hay
Foliage plants	Specialty Crop High
Garlic	Specialty Crop High
Green lima beans	Specialty Crop Low
Green onions	Specialty Crop High
Greenhouse vegetables	Specialty Crop High
Haylage or greenchop from alfalfa or alfalfa mixtures	Legume Hay
Head cabbage	Specialty Crop High
Herbs - fresh cut	Specialty Crop High

Honeydew melons	Specialty Crop High
Kale	Specialty Crop High
Land in orchards	Specialty Crop Low
Lettuce	Specialty Crop High
Mushrooms	Specialty Crop High
Mustard greens	Specialty Crop High
Nursery stock	Specialty Crop Low
Oats for grain	Small Grains and Grains
Okra	Specialty Crop High
Orchardgrass seed	Other Hay
Other field and grass seed crops	Other Hay
Other haylage; grass silage and greenchop	Other Hay
Other managed hay	Other Hay
Other nursery and greenhouse crops	Specialty Crop High
Parsley	Specialty Crop High
Pastureland and rangeland other than cropland and woodland pastured	Pasture
Peanuts for nuts	Other Agronomic Crops
Peas - Chinese (sugar and Snow)	Specialty Crop Low
Peas - green (excluding southern)	Specialty Crop Low
Peas - green southern (cowpeas)	Specialty Crop Low
Peppers - bell	Specialty Crop High
Peppers - chile (all peppers – excluding bell)	Specialty Crop High
Popcorn	Specialty Crop High
Potatoes	Specialty Crop High
Potted flowering plants	Specialty Crop High
Pumpkins	Specialty Crop High
Radishes	Specialty Crop High
Red clover seed	Legume Hay

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Rhubarb	Specialty Crop High
Rye for grain	Small Grains and Grains
Ryegrass seed	Other Hay
short-rotation woody crops	Specialty Crop Low
Small grain hay	Other Hay
Snap beans	Specialty Crop Low
Sod	Other Agronomic Crops
Sorghum for grain	Grain with Manure
Sorghum for silage or greenchop	Silage with Manure
Soybeans for beans	Full Season Soybeans
Spinach	Specialty Crop High
Squash	Specialty Crop High
Sunflower seed - non-oil varieties	Specialty Crop Low
Sunflower seed - oil varieties	Specialty Crop Low
Sweet corn	Other Agronomic Crops
Sweet potatoes	Specialty Crop High
Timothy seed	Other Hay
Tobacco	Other Agronomic Crops
Tomatoes	Specialty Crop High
Triticale	Small Grains and Grains
Turnip greens	Specialty Crop High
Turnips	Specialty Crop High
Vegetable & flower seeds	Specialty Crop High
Vegetables - mixed	Specialty Crop High
Vetch seed	Legume Hay
Watermelons	Specialty Crop High
Wheat for grain	Small Grains and Grains
Wild hay	Ag Open Space

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Table 3: Data Updates Frequency

Data Type	Data Description	Data Source	Data Update Frequency	Tentative Release Date	Recent Data Point	Data Quality Checks
Crop Yields	yields of crops by crop type	AgCensus	Once every 5 Years	2024	2017	1) Missing Values 2) Remove Outliers
		Nass Annual Survey-Major Crops	Annually	August of each year	2020	
Animal Population	Pullets- Sales	Agcensus	Once every 5 Years	August of each year	2017	1) Missing Values 2) D filling Procedure 3) County data from State wide Reported Numbers 4) Sum of All counties <= Statewide Numbers
	Turkeys-Production Numbers	Nass Annual Survey	Annually	August of each year	2020	
	Hogs and pigs breeding -Sales	AgCensus	Once every 5 Years	2024	2017	
	beef- Inventory	Agcensus	Once every 5 Years	2024	2017	
	broilers - Production Numbers	Nass Annual Survey	Annually	August of each year	2020	
	Dairy -Inventory	Agcensus	Once every 5 Years	2024	2017	
	Hogs for Slaughter - Sales	Agcensus	Once every 5 Years	2024	2017	
	Horses -Inventory	Jurisdictions	Historic Data	Unknown	2007	
	Layers- Inventory	Agcensus	Once every 5 Years	2024	2017	
	Other Cattle- Inventory	Agcensus	Once every 5 Years	2024	2017	
	Sheep and Lambs - Inventory	Agcensus	Once every 5 Years	2024	2017	
	Goats - Inventory	Agcensus	Once every 5 Years	2024	2017	
Fertilizer	Sales of Fertilizer by county	AAPFCO	Annually	Unknown	2016	1) Missing Values 2) Remove Outliers
	Expenditure	Agcensus	Once every 5 Years	Agcensus	2012	
Crop Acres	Total acres of crops by crop type,Total Harvested cropland, Total Agriculture Land	AgCensus	Once every 5 Years	2024	2017	1) Missing Values 2) True up Procedure
Confined Animal Feeding Operations	Splits between afo and cafo animals	Jurisdictions	Annually	2023	Phase 5 (PA Updated 2020 data)	1) Ratio of Afo+CAF0 =1

*Release date for some of the data sources are tentative, so Data analyst will look for the data manually every month for five year census data, and every bi-weekly for yearly Nass surveys beginning the tentative date.

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Forecasting Agricultural Acres

Agricultural land use acres for any year after the last available census year, 2017, for the Phase 6 calibration, are projected for each county using a double-exponential smoothing projection method approved by the Agriculture Workgroup. Double-exponential smoothing (NIST/SEMATECH 2016) is a short-term data forecasting method that is most often used when future values are believed to be related to both long-term and short-term trends in historic values. The method allows users to combine predictions of long-term and short-term trends by placing different weights or emphasis on each type of trend. The Agriculture Workgroup was asked to determine the weights of the alpha and beta values. The choices of the alpha and beta weighting factors, of 0.8 and 0.2 respectively, were chosen based upon an analysis of which factors best predicted both poultry and cattle populations reported in the 2007 Census of Agriculture. A formula, explanation of terms, and example projections are provided below.

Equation 1: double exponential smoothing

y_t = Actual county value as reported by Census of Agriculture at time t

S_t = Smoothed value for time t

b_t = Estimated trend for time t

AF_t = Trend-adjusted forecast for time t

a = Alpha value is the weight placed upon the most recent Census of Agriculture value

Beta = Beta value is the weight placed upon the long-term trend in Census of Agriculture values

$$S_t = a * y_t + (1-a) * (S_{t-1} + b_{t-1})$$

$$S_1 = y_1$$

$$b_t = Beta * (S_t - S_{t-1}) + (1 - Beta) * b_{t-1}$$

$$b_1 = average((y_2 - y_1), (y_3 - y_2), (y_4 - y_3))$$

$$AF_t = S_{t-1} + b_{t-1}$$

Non Point Source Data Quality Checks

1) Missing Data Check:

Most of the inputs for model are at a county scale, the data from various sources like Agcensus, NASS surveys are checked to make sure a data point exists for each year and for every county in watershed. Any missing data will be flagged and a correction for it will be calculated based on workgroup approved methods, which vary from using an Average between known data points or estimating a value based on growth region of the county etc. The Census of Agriculture cannot release detailed sales or inventory data for an animal type if there are fewer than five operators raising that animal type within a county. When this occurs, the sales or inventory data are listed as non-disclosed. These non-disclosed values are replaced with estimated sales or inventory values based on D filling procedure, for more details on this procedure please refer to section 3.2.1.1 of model documentation.

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2) *Outliers:*

Fertilizer and Yield data go through a process of identifying outliers based on the median and standard deviation of the historic values. An upper and lower bound for the data is established and the values that are not in this range are flagged as outliers. These values will be removed from further calculations and an estimated value is calculated based on the procedure explained in crop yields and Fertilizer inputs section of the document.

Combining Agricultural Land Uses with Mapped Land Uses (True up Procedure)

The estimated annual extent of agricultural land uses were apportioned from the county level to landriver segments based on the relative proportion of land-river segment acres to county acres of total agriculture, pasture, or cropland. Relative proportions of total agriculture were used to allocate: Permitted Feeding Space and Non-Permitted Feeding Space. Relative proportions of pasture were used to allocate: Ag Open Space, Legume Hay, Other Hay, and Pasture. Relative proportions of cropland were used for all other agricultural land uses. Once apportioned to land-river segments, the annualized Census of Agriculture agricultural land use acreages are combined with the mapped land use acres for each year from 1985 – 2013. If the apportioned amount of agricultural land use acres in a land-river segment differed from the mapped amount, the extent of all mapped land uses in the land-river segment were adjusted according to their state-wide mapping accuracies and the extent of Census of Agriculture acreages were adjusted based on their county-level reporting standard error rates. The mapped land use accuracies apply to 2013 conditions and not necessarily to historic conditions because the backcast process introduces additional errors. For more details on true up process please refer to URL below and Database User Stored Procedure

SP_CreatePreBMPLanduse

(ftp://ftp.chesapeakebay.net/Modeling/Phase6/Draft_Phase_6/Documentation/05%20Land%20Use.pdf)

Post True UP Process:
Harvested Forest and Construction Acres

Following the true-up process, annual harvested forest acres were estimated based on state-reported acreages. The area of harvest forest was subtracted from the estimated area of forest land use.

Land under construction for any given year was estimated based on the state-reported Erosion and Sediment Control permitted acres apportioned to land-river segments based on the relative amount of a county's development falling within each land-river segment. "Developed" acres include all regulated and non-regulated impervious roads, impervious non-roads, tree canopy over turf, and impervious surfaces, and turf grass. The construction acres were subtracted from each of the developed land uses classes based on their relative proportions to the overall amount of development.

Table 4: Final Land use Summary for 2013 (in acres)

Sector	Landuse	DC	DE	MD	NY	PA	VA	WV
Agriculture	All Landuses	0	183548	1467004	946529	3092785	2466250	399174
Developed	All Landuses	32,549	60,713	1,280,255	354,267	1,658,583	1,782,601	179,633
Natural	All Landuses	6,437	202,251	2,696,721	2,627,308	9,446,421	9,246,780	1,683,374
Water	All Landuses	731	5,775	158,664	81,888	272,600	213,495	26,715

For more details on Landuse, Animal Numbers and Nutrient Information please login to CAST tool (URL Below) and navigate to reports section to create reports for 1985-2013.

CAST Scenario tool: **https://cast.chesapeakebay.net/**

Best Management Practices

Introduction

The major use of the Watershed Model within the Chesapeake Bay Program Partnership is the prediction of change in load due to management actions. Best Management Practice (BMP) efficiency factors are one of the main ways to represent the effect of management actions. Figure 3 shows the overall structure of the phase 6 watershed model. Some types of BMPs reduce loads by a given mass rather than a percentage. Other BMPs may change load source acreages. BMPs that change input loads are discussed in section 3 and below.

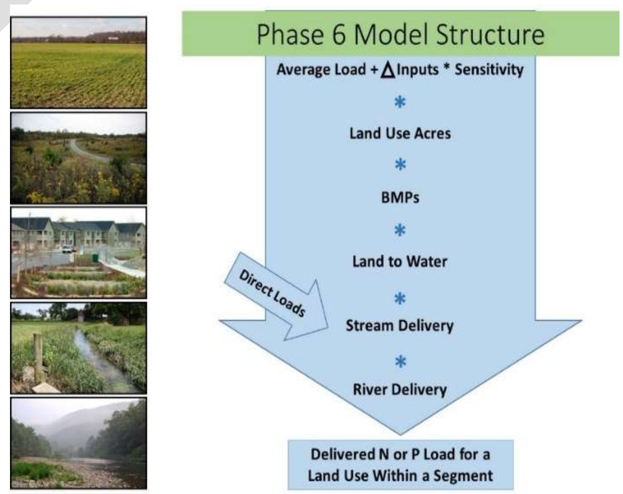

Figure 3: Phase 6 Model Structure

Protocol for adding or modifying BMPs

The BMPs that are available for credit in the Phase 6 watershed model have been approved by the Partnership according to the Chesapeake Bay Program's BMP protocol (Chesapeake Bay Program 2015a), Please refer to BMP Appendix A, B on CAST Documentation at URL below for more information. The Water Quality Goal Implementation Team (WQGIT) is responsible

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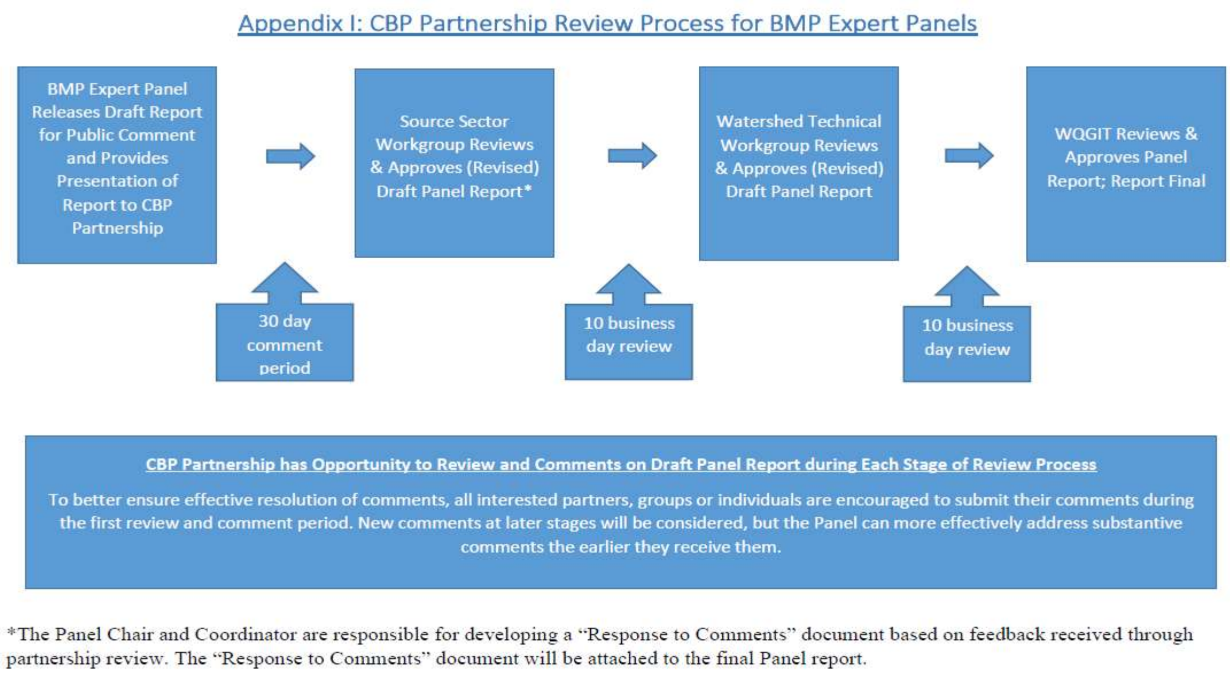
for approving the loading rate reductions and percentage adjustments to these rates used in Phase 6. Since the definitions and values used for both loading and efficiency estimates have important implications for the Chesapeake Bay Program and the various partners, it is critical that they be developed in a process that is consistent, transparent, and scientifically defensible.

CAST URL (*https://cast.chesapeakebay.net/Documentation/ModelDocumentation*)

Figure 4 below shows the partnership review process for BMP Expert Panels. The panel report approval process includes public comment and reviews from the relevant source sector workgroup or workgroups, the Watershed Technical Workgroup, and the Water Quality Goal Implementation Team.

Figure 4: BMP Approval Process



Types of BMPs

BMPs may be classified into types based on how they are calculated. Six types are described. There are many exceptions that are addressed at the end of this section.

1. **Land Use Change BMPs**

Load source change practices simply alter a previously projected Land use acre to a different Land use. For example, Tree Planting can alter an acre of pasture to an acre of forest. Below are some examples of Load Source Change BMP's.

2. **Efficiency BMPs**

   An efficiency value is a percentage of a pollutant that is removed when the BMP is applied. For example, Dry Extended Detention Ponds remove 20% of nitrogen that would have been delivered without the Detention Ponds.

3. **Land Use Change with efficiency BMPs**

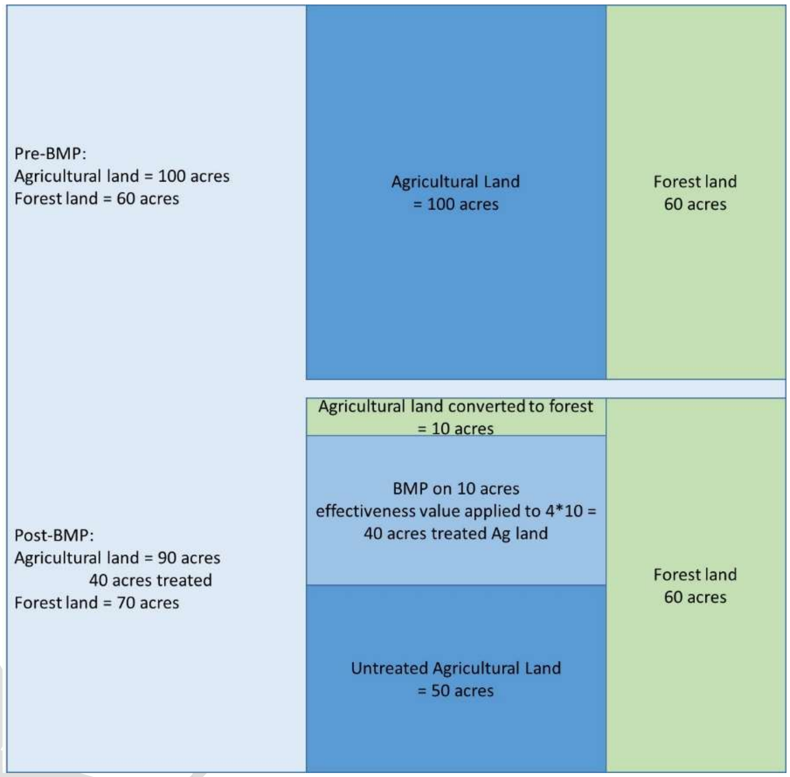


Figure 5 Load Source Change with Efficiency example

   Some BMPs work as both a load source change and an efficiency BMP. In these cases, the load source change is calculated first, and then an efficiency is applied to an additional number of acres of the original load source. The load source change BMPs that also have an efficiency value are: grass buffers, grass buffer-streamside with exclusion fencing, forest buffers, forest buffer-streamside with exclusion fencing, wetland creation for floodplain and headwater and wetland restoration for floodplain and headwater. It is assumed that the presence of these BMPs reduces the amount of nutrients delivered from upland acres as water and nutrients move through the soil matrix. **Figure 5** illustrates an example of a forest buffer applied to agricultural land. When a BMP is put on a specific load source, the benefit of the efficiency BMP is applied to all load sources within that group. For example, if put on pasture, then the efficiency is applied to all agricultural load sources.

4. **Animal BMPs**

   These BMPs are applied to the animal manure for specific animal types. These BMPs can act in several ways. Some animal BMPs, like Dairy Precision Feeding, reduce the concentration of nitrogen or phosphorus in a ton of manure. Other animal BMPs relocate the manure from one load source to another, such as with Animal Waste Management Systems. Some animal BMPs reduce the amount of nitrogen deposited on the feeding space, such as Animal Waste Management Systems.

   Figure 6 below shows the impact of animal BMPs on the loads in the model. When load input reduction, like manure transport, or feed additive BMPs are used, the manure load decreases in that geography. However, the crop need is not changed so other sources of nutrients will make up the difference in the crop need where they are available. Nutrients are applied to meet the nitrogen crop need. This typically results in an over application of phosphorus where manure is the nutrient source.

5. Manure Transport BMPs

Some BMPs directly reduce the amount of nutrients applied to each acre of land. The total application of manure to the load source could be reduced in a county if a jurisdiction indicated that manure was transported out of that county.

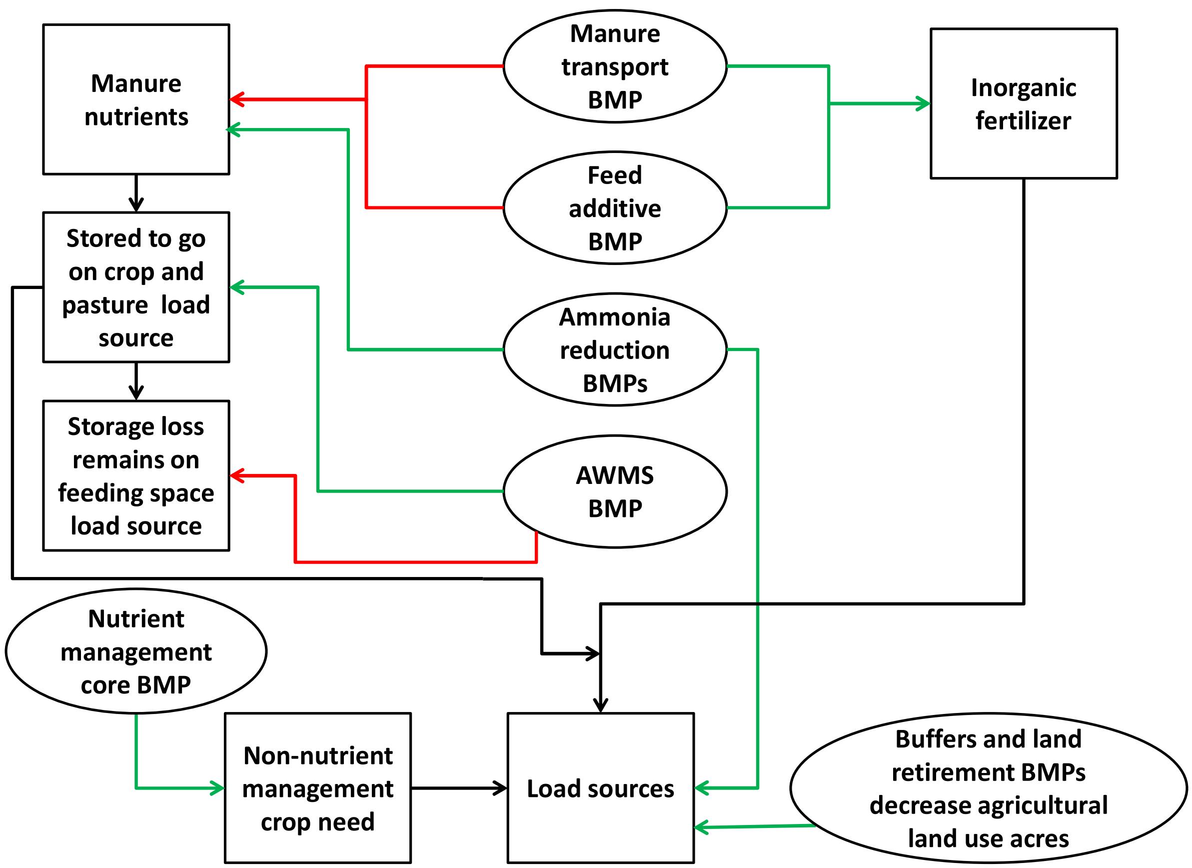


Figure 6: Impact of Animal BMPs on Loads

6. Load reduction BMPs

The load reduction BMPs include algal flow-way, oyster aquaculture, stream restoration, shoreline management, dirt and gravel roads, street sweeping, and storm drain cleaning. These are modeled as a simple removal of pounds of nitrogen, phosphorus and/or sediment from the edge-of-stream, edge-of-river or edge-of-tide load. For every unit of BMP (such as feet) submitted, an amount of nitrogen, phosphorus or sediment is removed.

Application methods

BMPs are compiled for each scenario. These may be available on a spatial scale different from the load source and land-river segment scale of the Watershed Model. There may be conflicts for the maximum available load source to apply the BMPs for both load source change BMPs and efficiency BMPs. The following rules are applied to arrive at the final BMP data set for each scenario.

Spatial distribution

BMPs are always applied to the model at the smallest spatial scale – a single Land use in a single land-river segment for an agency. The Land uses include classifications of land with area as well as sources that are direct loads to a stream that do not have an area attributed to the source. States can submit BMPs through the **National Environmental Information Exchange Network (NEIEN)** at a variety of scales. When BMPs are submitted at a level coarser than land-river segment, they are disaggregated proportionately based on the acres of the receiving Land use in each land-river segment that comprises the aggregation.

Annual implementation of BMPs is submitted to **NEIEN**, which is used for tracking annual progress of implementation, by latitude and longitude, county, state, or hydrologic unit code (HUC). HUC scales are available on even numbers from four to 12. For geographic areas that cross the Chesapeake Bay Watershed boundary, data can be submitted either by the entire county or for just the portion that is inside the watershed. For details about the NEIEN Schema and instructions on how to submit and validate these BMPs please refer to URL below. Figure 7 gives a relational Database representation of NEIEN Database. For planning scenarios, such as Milestones and WIPs, more general data are needed; however, the same geographic designations can be used. In addition, BMPs can be submitted on the geographies in the Source Data. Chesapeake Bay segments refer to the segments in the tidal estuary used for the 2010 Chesapeake Bay TMDL.

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NEIEN Schema URL (http://webservices.chesapeakebay.net/schemas/)

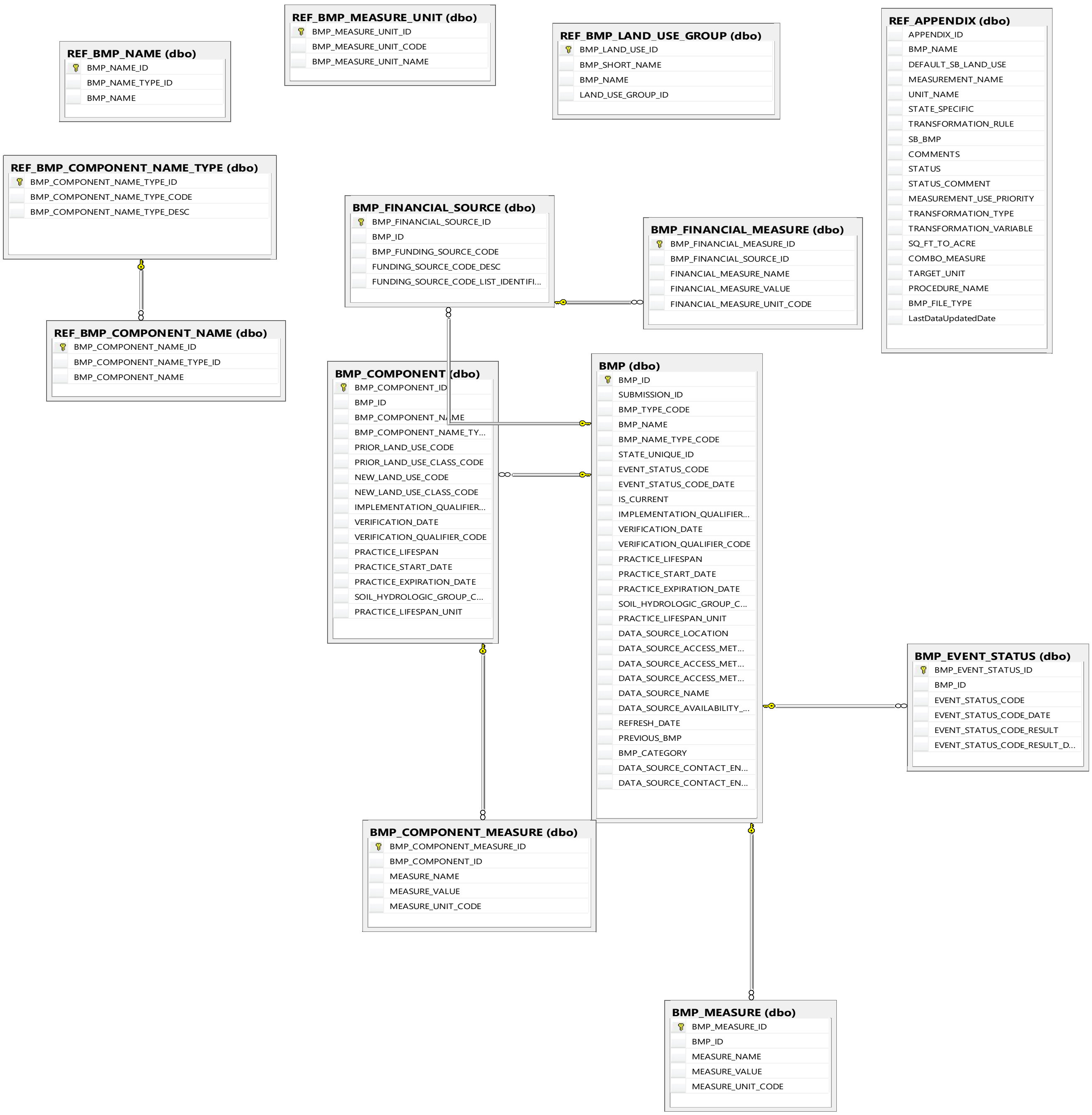

Figure 7: Non-Point Source BMP Database Diagram

Land use groups

BMPs can be submitted on defined Land use groups. When submitted as a group, BMPs are divided according to the fraction of each area or load that comprises the group. The Land use groups are provided in the spreadsheet under 'source data,' and are updated to reflect Phase 6 changes (see [http://cast.chesapeakebay.net/)](http://cast.chesapeakebay.net/). The tab is named "Land use Group Components".

Order of Land use change BMPs

Land use change BMPs that are applied to the same Land use may be limited by the amount of Land use available in that land-river segment for that agency. They are applied in an order such that BMPs higher on the list will be preferentially credited. Table 4 below shows the order and database code that gets executed to process the BMP. Names of ruleset are modified for security purposes. This information is also available in the Source Data table on the CAST website. Animal and load input BMPs are credited prior to the efficiency BMPs. The load reduction BMPs are credited last.

Table 5: Land Use change BMP order

BmpGroupName	RuleSet	BmpGroupOrder
Impervious Surface Reduction	spBmpRuleSet_LanduseChange……..	2
Forest Conservation	spBmpRuleSet_LanduseChange………..	3
Urban Forest Buffers	spBmpRuleSet_LanduseChange………………	4
Urban Grass Buffers	spBmpRuleSet_LanduseChange……………..	5
Urban Tree Planting	spBmpRuleSet_LanduseChange…………	6
Urban Forest Planting	spBmpRuleSet_LanduseChange……….	7
Abandoned Mine Reclamation	spBmpRuleSet_LanduseChange……………	8
Forest Buffers Access Area	spBmpRuleSet_LanduseChange………………	10
Grass Buffers on Access Area	spBmpRuleSet_LanduseChange……………….	11
Narrow Forest Buffer Access Area	spBmpRuleSet_LanduseChange…………………	12
Narrow Grass Buffer Access Area	spBmpRuleSet_LanduseChange……………….	13
Forest Buffers	spBmpRuleSet_LanduseChange……………….	14

Narrow Forest Buffer	spBmpRuleSet_LanduseChange……………….	15
Wetland Restoration Floodplain	spBmpRuleSet_LanduseChange……………..	16
Wetland Restoration Headwater	spBmpRuleSet_LanduseChange……….	17
Wetland Creation Floodplain	spBmpRuleSet_LanduseChange……………..	18
Wetland Creation Headwater	spBmpRuleSet_LanduseChange……………..	19
Land Retirement to Pasture	spBmpRuleSet_LanduseChange………………	20
Land Retirement to Ag Open Space	spBmpRuleSet_LanduseChange………………….	21
Grass Buffers	spBmpRuleSet_LanduseChange………….	22
Narrow Grass Buffer	spBmpRuleSet_LanduseChange…………..	23
Tree Planting	spBmpRuleSet_LanduseChange…………..	24
Carbon Sequestration/Alternative Crops	spBmpRuleSet_LanduseChange…………..	25
Wetland Enhance/Rehabilitate	spBmpRuleSet_LanduseChange………	26
Septic Connections	spBmpRuleSet_Septic………..	30
Load Reduction Bmps	spBmpRuleSet_Load………..	90
Stream and Shore Bmps	spBmpRuleSet_StreamShore…………	91
Dirt and Gravel Roads	spBmpRuleSet_DirtAndGravelRoad……………	92

Point Source Data

Point source data acquisition and management involve data collection, QA/QC, verification, assumption, compilation, analysis, and dissemination of the point sources within the Chesapeake Bay watershed. The data acquisition procedures and data acceptance criteria are described in detail below.

Data in the Database

The point source data including the facility data and nutrient load data are processed and stored in Microsoft SQL Server and will be part of the Point Source Application. The work databases that process the raw data and compile the final data are being developed in house. Until the Application is developed the same data can be found in point source data manager's PC with backups on a CIMS network drive as an access database. The final compiled data are loaded into the point source database on the CBPO SQL server

Parameters

Monthly data for the parameters listed in following Table are contained in a Microsoft Access database on CIMS network.

Table 6. Parameters Included in the Point Source Database

PARAMETER	UNITS	PARAMETER	UNITS
Flow	10^6 gal/day (MGD)	Total Phosphorus (TP)	mg/L
Total Nitrogen (TN)	mg/L	Phosphate (PO_4)	mg/L
Ammonia Nitrogen (NH_3)	mg/L	Total Organic Phosphorus (TOP)	mg/L
Nitrate-Nitrite Nitrogen (NO_{23})	mg/L	Biochemical Oxygen Demand (BOD)	mg/L
Total Organic Nitrogen (TON)	mg/L	Dissolved Oxygen (DO)	mg/L
Total Kjeldahl Nitrogen (TKN)	mg/L		

Facility Profile

The Chesapeake Bay Program Point Source Database includes information for approximately 5000 (the exact number varying depending on the year) industrial, municipal, and federal facilities discharging directly to surface waters within the Chesapeake Bay watershed from all surrounding jurisdictions: New York, Pennsylvania, Maryland, Delaware, District of Columbia, Virginia and West Virginia. Information for both online and off-line facilities is stored in the database for modeling purpose. Table 6 is a summary of the number of current active significant facilities in each jurisdiction as of 2016. There are currently 465 significant facilities Active in Bay Watershed.

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Table 7: Significant Facilities

State	No of Significant Facilities
DC	1
DE	4
MD	83
NY	30
PA	215
VA	118
WV	14

A significant discharger is a facility that meets one of the following criteria:

• In West Virginia, Delaware and New York - Facility treating domestic wastewater and the design flow is greater than or equal to 0.4 million gallons per day (MGD).

• In Pennsylvania - Facility treating domestic wastewater and discharging greater than or equal to 0.4 MGD.

• In Maryland - Facility treating domestic wastewater and the design flow is greater than or equal to 0.5 MGD.

• In Virginia - Facility treating domestic wastewater and the existing design flow is greater than or equal to 0.5 MGD west of the fall line or 0.1 MGD east of the fall line. If adopted, the draft point source permitting regulations in Virginia would redefine all new facilities greater than 40,000 gallons per day (GPD) or facilities expanding by greater than 40,000 GPD as significant.

• Industrial facilities with a nutrient load equivalent to 3,800 total phosphorus (TP) lbs./year or 27,000 total nitrogen (TN) lbs/year.

Jurisdictions are encouraged, but not required, to track "non-significant" facilities not meeting the above definition and provide their flow and concentration data on an annual basis to EPA CBPO. For the purpose of consistency, jurisdictions are strongly encouraged to include flow and concentrations for all facilities with a design flow greater than 0.40 MGD.

Data Sources

The sources of point source information, listed below, are described in more detail in the section appropriate to each jurisdiction:

- EPA's Permit Compliance System (PCS) and Integrated Compliance Information System based on State National Pollutant Discharge Elimination System (NPDES) Discharge Monitoring Reports;

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- Data files from the Virginia Department of Environmental Quality based on PCS, Discharge Monitoring Reports (DMR's), and the Virginia Voluntary Nutrient Monitoring Program;
- Data files from the Washington Metropolitan Council of Governments;
- Combined sewer overflow flow and concentration estimates from the District of Columbia Department of Consumer and Regulatory Affairs;
- The completed 1996 version tributary strategies from Pennsylvania, Maryland, the District of Columbia, and Virginia;
- Data from the Maryland Department of the Environment;
- Data from Delaware Department of Natural Resources and Environmental Control;
- Data from West Virginia Department of Environmental Protection;
- Data from New York Department of Environmental Conservation

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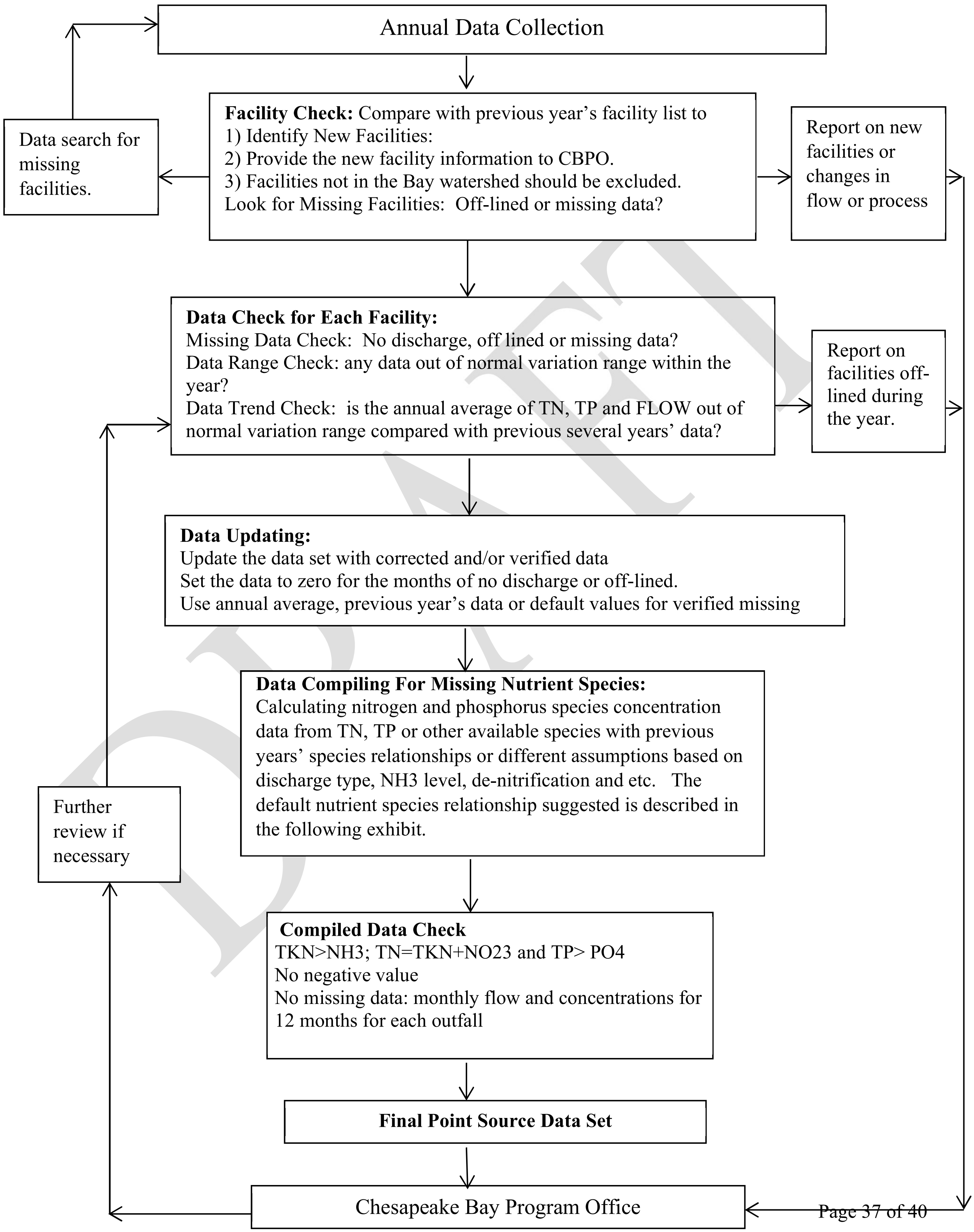
Figure 8: Jurisdiction Data Processing Flow Diagram



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Point Source Data Check

1) Missing Data Check:
Normally, a discharge point is supposed to have 12 monthly data records. Each data record contains the parameters described above. If a discharge point has missing data records for certain months, these missing data records need to be sent back to the state agency to verify if it is due to no discharge, facility off-lined, missing data, or no data available. After the state agency returns the verified information, the data set needs to be updated accordingly.

2) Data Range Check:

Two data range checks need to be performed on the data set after all missing data are verified and updated. The first one is to check the normal data range of all parameters. Any data value out of the normal range of the parameter needs to be checked. The other is to check the data range of one parameter among the 12 monthly data records. Any data value far away from the annual average needs to be checked. All of these suspected data need to be sent back to the state agency for verification and correction.

3) Data Trend Check:
Any dramatic data trend change should be viewed with skepticism. This check is done by comparing the annual average flow or concentration of a facility with its historic data trend. The suspicious data trend change needs to be verified with the data source to make sure this change has a reason such as treatment technology change or operation change. If a dramatic TN concentration drop is due to a Biological Nutrient Removal (BNR) technology implementation, this facility needs to be updated with BNR status.

Verification and Correction of Suspected Data

QA/QC results from the above steps are sent back to each jurisdiction for verification and correction. For NY, WV and DE data, the QA/QC results need to be verified by direct contact with the facility. The state agency or the facility will check with their DMR reports and the lab reports to either confirm or correct the suspicious data.

Nutrient Species Data Compiling

Nitrogen and phosphorus species concentration data were calculated from TN, TP or other available species with different assumptions based on discharge type, NH3 level, de-nitrification, etc. The detailed descriptions can be found Figure 9 below.

QA/QC on Compiled Data

Due to different assumptions and methodologies used to calculate the species for different facilities, some calculated results may not be reasonable. The following rules need to be enforced to keep the calculated data correct. Any calculated numbers that violate these rules need to be adjusted.

1. TN=NH3+TON+NO23
2. TP=TOP + PO4
3. No negative value

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Figure 9: Species Relationship for pollutants

Type of Point Source		NH3/NO3/OrgN (w/o Nitrification)	NH3/NO3/OrgN (w/ Nitrification)++	NH3/NO3/OrgN (w/Denitrification)
Municipalities (phase IV)		80/5/15[1]	7/85/8	12/73/15
Municipalities (phase V)		80/3/17**	7/80/13**	12/73/15[2]
Industries	Chemical	7/85/8+		
	Pulp & Paper	1/0/99**		
	Poultry Facilities w/BNR			8/75/17**
	Nonchemical (includes seafood, poultry, & food processors w/out BNR)	80/3/17**	7/85/8+	/75/17**

(1) Stearns and Wheler recommended 80/0/20; however, the PSWG felt that there would often be minimal (5%) NOx present.
(2) Unchanged from the ratio recommended by Stearns and Wheler in Phase IV.
++Apply this relationship wherever NH3 limits apply
+Assumed by performing an analysis of MD chemical industry wastewater effluents which showed it is very close to the relationship for nitrifying sewage. This would apply to all chemical discharges and assumes that wastewaters are treated chemically and thus would not vary as for sewage relationships
** Updated, as based on an analysis of actual data from plants operating in Virginia.

Type of Point Source	Facilities w/out TP Reduction OP/TP ratio	Facilities With TP Reduction OP/TP Ratio
All	71/29[a]	67/33[a]

[a] determined by averaging the actual data from MD and VA plants (including Blue Plains for "with TP Reduction".
Facility with TP Reduction is defined as a facility having a permit limit for total phosphorus.

Period	TSS Default (All jurisdictions)	TSS Default w/out NRT	TSS Default w/ NRT
1985-1990[b]	45		
1990-2000	25		
2000-2010		15	8

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Type of Point Source	DO concentration 1985-1990	DO Concentration 1990-2010
All	4.5 mg/l [(b)]	5.0 mg/l

(b) takes into account a number of NMP facilities operating across the watershed

Model Outputs

A Relational Database is developed in Microsoft SQL Server that can be accessed through Applications like **Baytas (**Chesapeake Bay Tracking Accountability System**)** and **Chesapeake Stat**. Users can download reports for on outputs to the model by changing the scenario names from the drop down in reports tab. Any users who register to these applications can access official progress, Milestones and Phase 1, 2 Watershed Implementation Plans. Data for more scenarios can be provided based on further requests.

Chesapeake Assessment Scenario tool (**CAST**) also provides reports for Animal, Land Use, and Nutrient Information that are part of Bay watershed model. Users can navigate to Public reports from the CAST URL to create their own reports. Adhoc validation reports for NEIEN data are also provided on request to the users.

Baytas URL: (https://baytas.chesapeakebay.net/Authenticate/Login?ReturnUrl=%2f)

Chesapeake Stat: (http://www.chesapeakeprogress.com/)

CAST URL: (https://cast.chesapeakebay.net/)

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Chesapeake Bay Program, Annapolis, MD. Chesapeake Bay Program. 2013. Estimates of County-Level Nitrogen and Phosphorus Data for Use in Modeling Pollutant Reduction: Documentation for Scenario Builder Version 2.4. Chesapeake Bay Program Office. Annapolis, MD. January, 2013.

Ning Zhou, Chesapeake Bay Point Source Annual Data Report 2000- Model 4.2 and 4.3 Data Compiling Description: 1998, 2000, Tributary Strategy, 2005, 2010, and 2005 LOT.

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Chesapeake Bay Program, Chesapeake Assessment Scenario Tool-Model Documentation, Retrieved from (https://cast.chesapeakebay.net/Documentation/ModelDocumentation)

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