



Chesapeake Bay Program
A Watershed Partnership

USEPA Chesapeake Bay Program

**Non-Point Source Data Analysis
Quality Assurance Project Plan**

Prepared by

University of Maryland Center for Environmental Science

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Approval

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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.

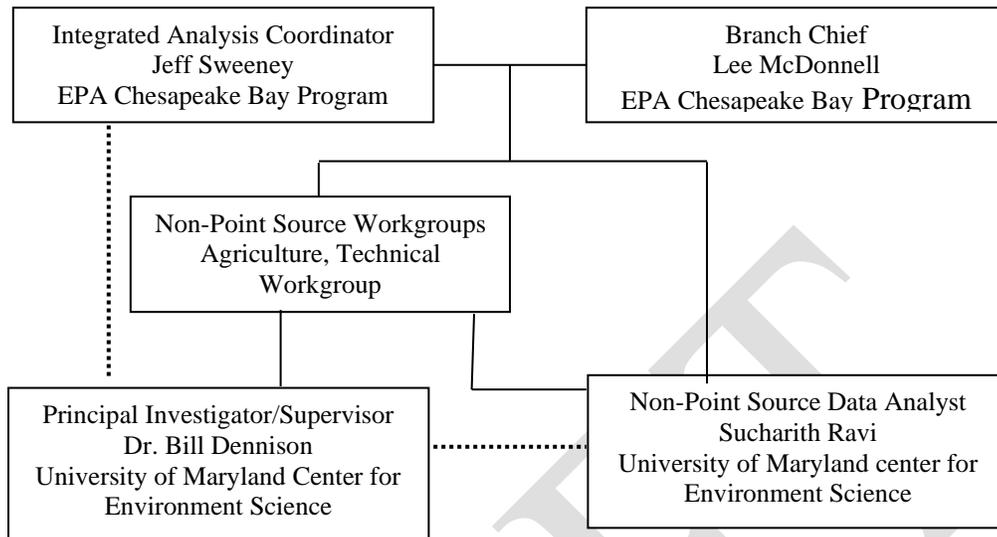
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Figure 1. Organizational Chart



Project Objectives/Background

Managing non-point source pollutant information involves collection, analysis, and dissemination of Chesapeake Bay watershed data including land uses, animal and human populations, 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 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 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 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.

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 Ag Census 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.

Year 3:

- 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 Ag Census, 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 Bay program team in developing future enhancements to Point Source Application, like ability to submit WIP and Milestone information.

Years 4-6:

- 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 semiannual report on the progress made will be written by incumbent and submitted to UMCES and 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.

Crop Yields:

Phase 6 Model calculates yields for major crops according to yearly crop yield data provided by Ag Census, 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.

- 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.”

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 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 the 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 P205 (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 P205 by Regionwide P205. 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 P2O5.

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. 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
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
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

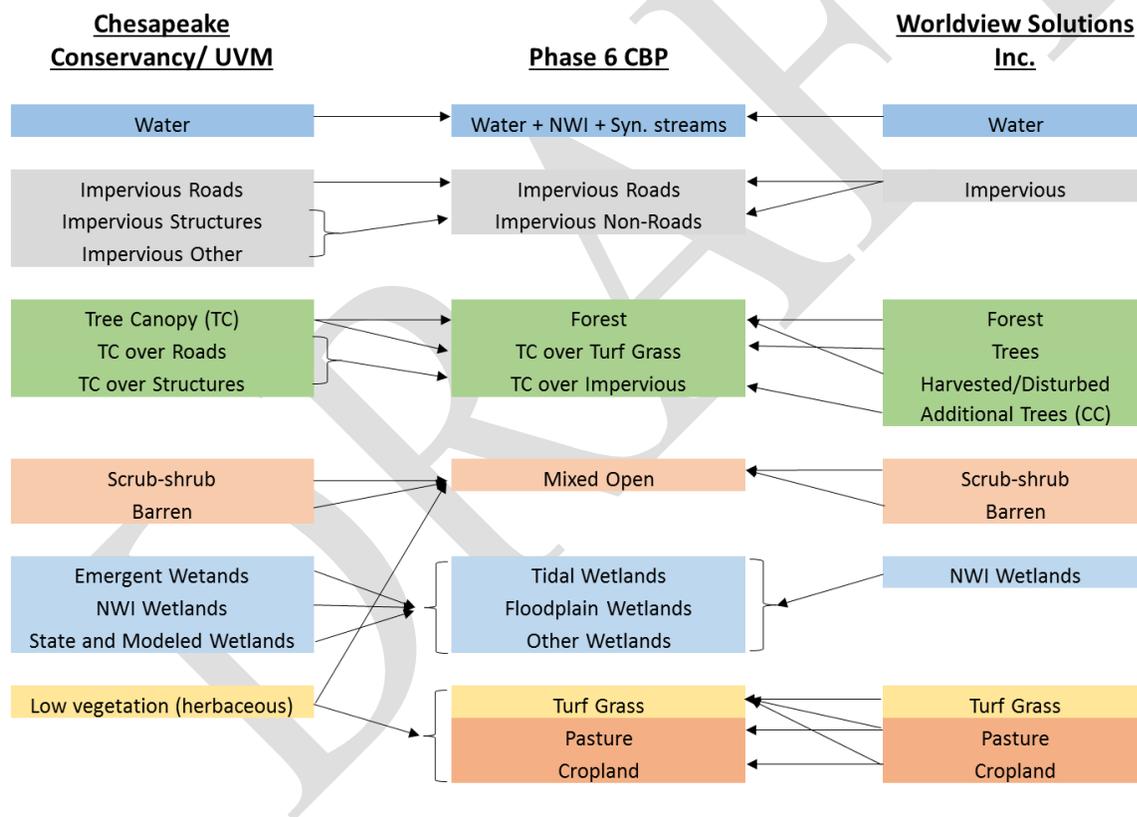
“Land cover” represents observable characteristics of the land surface. For example, land may appear covered by impervious surfaces, herbaceous vegetation, or tree canopy. High-resolution (1m x 1m pixels) land cover data provided the basis for developing the Phase 6 land uses. These data were produced 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_TechnicalPlanOfOperations_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.

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.
- 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.

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
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
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

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	Ag Census	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	Ag census	Once every 5 Years	August of each year	2017	1) Missing Values
	Turkeys-Production Numbers	Nass Annual Survey	Annually	August of each year	2020	2) D filling Procedure
	Hogs and pigs breeding -Sales	Ag Census	Once every 5 Years	2024	2017	3) County data from Statewide Reported Numbers
	beef-Inventory	Ag Census	Once every 5 Years	2024	2017	4) Sum of All counties <= Statewide Numbers
	broilers -Production Numbers	Nass Annual Survey	Annually	August of each year	2020	
	Dairy -Inventory	Ag Census	Once every 5 Years	2024	2017	
	Hogs for Slaughter -Sales	Ag Census	Once every 5 Years	2024	2017	
	Horses -Inventory	Jurisdictions	Historic Data	Unknown	2007	
	Layers-Inventory	Ag Census	Once every 5 Years	2024	2017	
	Other Cattle-Inventory	Ag Census	Once every 5 Years	2024	2017	

	Sheep and Lambs - Inventory	Ag Census	Once every 5 Years	2024	2017	
	Goats - Inventory	Ag Census	Once every 5 Years	2024	2017	
Fertilizer	Sales of Fertilizer by county	AAPFCO	Annually	Unknown	2016	1) Missing Values 2) Remove Outliers
	Expenditure	Ag Census	Once every 5 Years	Agcensus	2012	
Crop Acres	Total acres of crops by crop type, Total Harvested cropland, Total Agriculture Land	Ag Census	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+CAF O=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.

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

$$St = a * yt + (1-a) * (St-1 + bt-1)$$

$$S1 = y1$$

$$bt = Beta * (St - St-1) + (1 - Beta) * bt-1$$

$$b1 = \text{average} ((y2 - y1), (y3 - y2), (y4 - y3))$$

$$AFt = St-1 + bt-1$$

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 Ag census, 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.

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.

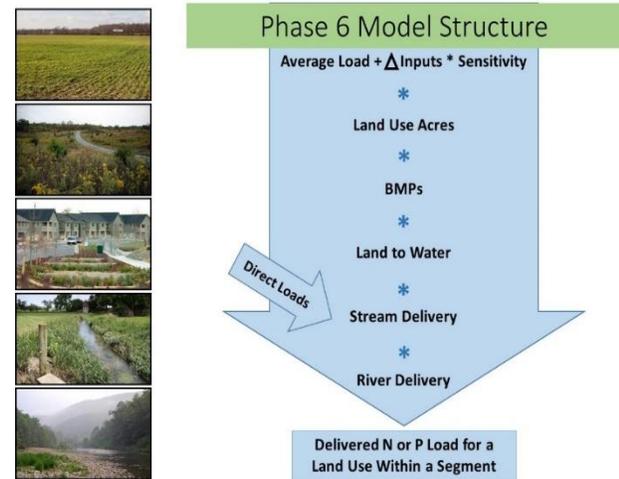


Figure 3: Phase 6 Model

Structure

Protocol for adding or modifying BMPs

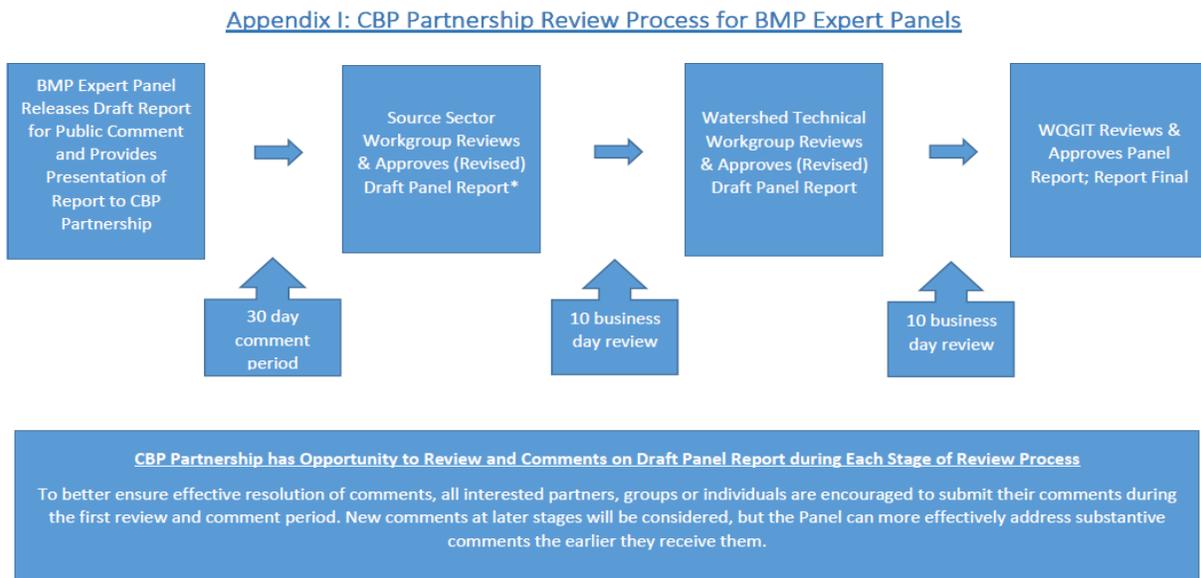
The BMPs that are available for credit in the Phase 6 watershed model have been approved by the Partnership according to the Chesapeake Bay Program’s BMP protocol (Chesapeake Bay

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 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



*The Panel Chair and Coordinator are responsible for developing a “Response to Comments” document based on feedback received through partnership review. The “Response to Comments” document will be attached to the final Panel report.

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

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.



Figure 5 Load Source Change with Efficiency example

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.

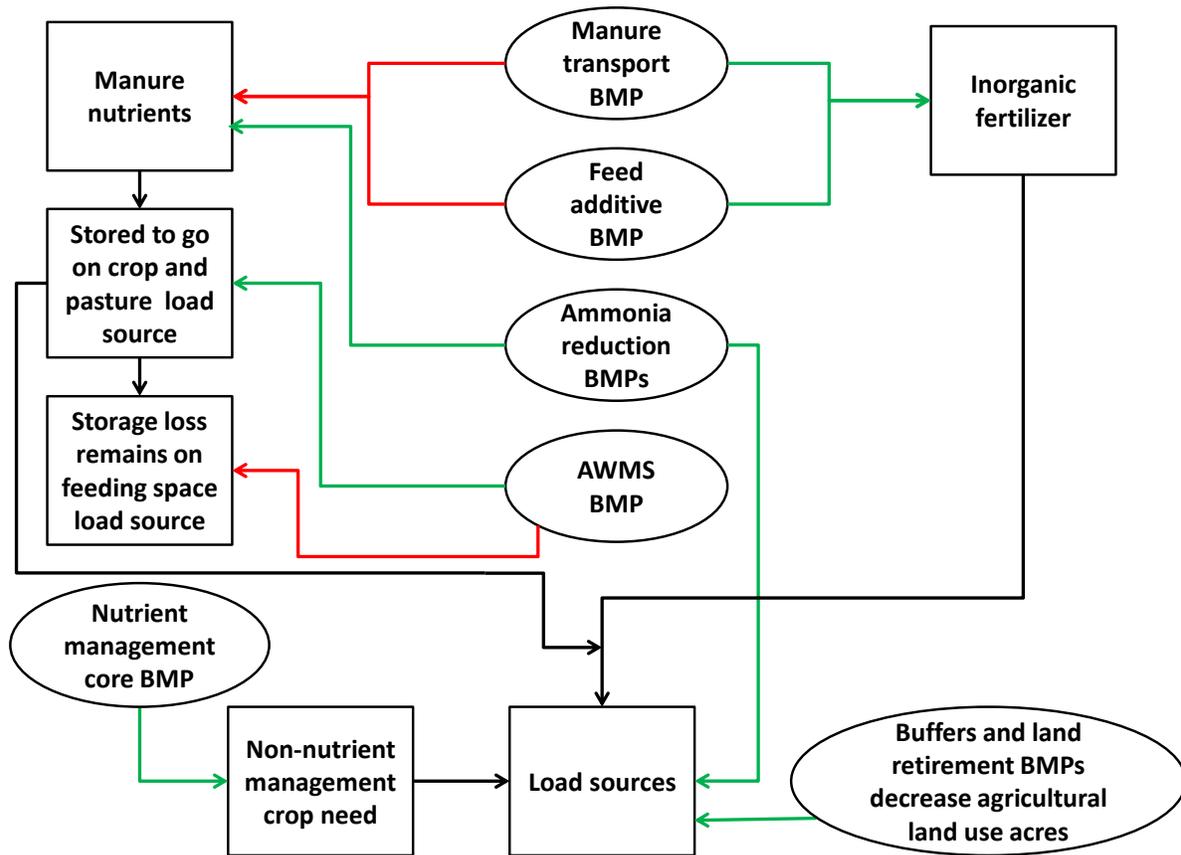


Figure 6: Impact of Animal BMPs on Loads

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.

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

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

Model Outputs

Chesapeake Assessment Scenario tool (**CAST**) 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. Ad hoc validation reports for NEIEN data are also provided on request to the users.

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

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